TGD INSPIRED THEORY OF CONSCIOUSNESS: PART I

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0.1 PREFACE

Brief summary of TGD

Towards the end of the year 2023 I became convinced that it would be appropriate to prepare collections about books related to TGD and its applications. The finiteness of human lifetime was my first motivation. My second motivation was the deep conviction that TGD will mean a revolution of the scientific world view and I must do my best to make it easier.

The first collection would relate to the TGD proper and its applications to physics. Second collection would relate to TGD inspired theory of consciousness and the third collection to TGD based quantum biology. The books in these collections would focus on much more precise topics than the earlier books and would be shorter. This would make it much easier for the reader to understand what TGD is, when the time is finally mature for the TGD to be taken seriously. This particular book belongs to a collection of books about TGD proper.

The basic ideas of TGD

TGD can be regarded as a unified theory of fundamental interactions but is not the kind of unified theory as so called GUTs constructed by graduate students in the seventies and eighties using detailed recipes for how to reduce everything to group theory. Nowadays this activity has been completely computerized and it probably takes only a few hours to print out the predictions of this kind of unified theory as an article in the desired format. TGD is something different and I am not ashamed to confess that I have devoted the last 45 years of my life to this enterprise and am still unable to write The Rules.

If I remember correctly, I got the basic idea of Topological Geometrodynamics (TGD) during autumn 1977, perhaps it was October. What I realized was that the representability of physical space-times as 4-dimensional surfaces of some higher-dimensional space-time obtained by replacing the points of Minkowski space with some very small compact internal space could resolve the conceptual difficulties of general relativity related to the definition of the notion of energy. This belief was too optimistic and only with the advent of what I call zero energy ontology the understanding of the notion of Poincare invariance has become satisfactory. This required also the understanding of the relationship to General Relativity.

It soon became clear that the approach leads to a generalization of the notion of space-time with particles being represented by space-time surfaces with finite size so that TGD could be also seen as a generalization of the string model. Much later it became clear that this generalization is consistent with conformal invariance only if space-time is 4-dimensional and the Minkowski space factor of the embedding space is 4-dimensional. During last year it became clear that 4-D Minkowski space and 4-D complex projective space CP_2 are completely unique in the sense that they allow twistor space with Kähler structure.

It took some time to discover that also the geometrization of also gauge interactions and elementary particle quantum numbers could be possible in this framework: it took two years to find the unique internal space (CP_2) providing this geometrization involving also the realization that family replication phenomenon for fermions has a natural topological explanation in TGD framework and that the symmetries of the standard model symmetries are much more profound than pragmatic TOE builders have believed them to be. If TGD is correct, the mainstream particle physics chose the wrong track leading to the recent deep crisis when people decided that quarks and leptons belong to the same multiplet of the gauge group implying instability of the proton.

Instead of trying to describe in detail the path, which led to TGD as it is now with all its side tracks, it is better to summarize the recent view which of course need not be final.

TGD can be said to be a fusion of special and general relativities. The Relativity Principle (Poincare Invariance) of Special Relativity is combined with the General Coordinate Invariance and Equivalence Principle of General Relativity. TGD involves 3 views of physics: physics geometry, physics as number theory and physics as topological physics in some sense.

Physics as geometry

"Geometro-" in TGD refers to the idea about the geometrization of physics. The geometrization program of Einstein is extended to gauge fields allowing realization in terms of the geometry of surfaces so that Einsteinian space-time as abstract Riemann geometry is replaced with sub-manifold geometry. The basic motivation is the loss of classical conservation laws in General Relativity Theory (GRT)(see **Fig. 16.1**). Also the interpretation as a generalization of string models by replacing string with 3-D surface is natural.

- Standard model symmetries uniquely fix the choice of 8-D space in which space-time surfaces live to $H = M^4 \times CP_2$ [L181]. Also the notion of twistor is geometrized in terms of surface geometry and the existence of twistor lift fixes the choice of H completely so that TGD is unique [L71, L88](see **Fig. 16.6**). The geometrization applies even to the quantum theory itself and the space of space-time surfaces - "world of classical worlds" (WCW) - becomes the basic object endowed with Kähler geometry (see **Fig. 16.8**). The mere mathematical existence of WCW geometry requires that it has maximal isometries, which together twistor lift and number theoretic vision fixes it uniquely [L182].

- General Coordinate Invariance (GCI) for space-time surfaces has dramatic implications. A given 3-surface fixes the space-time surface almost completely as analog of Bohr orbit (preferred extremal). This implies holography and leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K143, L108].

- From the beginning it was clear that the theory predicts the presence of long ranged classical electro-weak and color gauge fields and that these fields necessarily accompany classical electromagnetic fields in all scales. It took about 26 years to gain the maturity to admit the obvious: these fields are classical correlates for long range color and weak interactions assignable to the phases of ordinary matter predicted by the number theoretic vision and behaving like dark matter but identifiable as matter explaining the missing baryon problem whereas the galactic dark matter would correspond to the dark energy assignable monopole flux tubes as deformations of cosmic strings. The only possible conclusion is that TGD physics is a fractal consisting of an entire hierarchy of fractal copies of standard model physics. Also the understanding of electro-weak massivation and screening of weak charges has been a long standing problem and p-adic physics solved this problem in terms of p-adic thermodynamics [K27, K66] [L172].

- One of the most recent discoveries of classical TGD is exact general solution of the field equations. Holography can be realized as a generalized holomorphy realized in terms of what I call Hamilton-Jacobi structure [L177]. Space-time surfaces correspond to holomorphic imbeddings of the space-time surface to H with a generalized complex structure defined by the vanishing of 2 analytic functions of 4 generalized complex coordinates of H. These surfaces are automatically minimal surfaces. This is true for any geneneral coordinate invariant action constructed in terms of the induced geometric structures so that the dynamics is universal. Different actions differ only in the sense that singularities at which the minimal surface property fails depend on the action. This affects the scattering amplitudes, which can be constructed in terms of the data related to the singularities [L190].

- Generalized conformal symmetries define an extension of conformal symmetries and one can assign to them Noether charges. Besides this the so called super-symplectic symmetries associated with $\delta M^4_+ \times CP_2$ define isometries of the "world of classical worlds" (WCW), which by holography is essentially the space of Bohr orbits of 3-surfaces as particles so that quantum TGD is expected to reduce to a generalization of wave mechanics.

Physics as number theory

During these years TGD led to a rather profound generalization of the space-time concept. Quite general properties of the theory led to the notion of many-sheeted space-time with sheets representing physical subsystems of various sizes. At the beginning of 90s I became dimly aware of the

importance of p-adic number fields and soon ended up with the idea that p-adic thermodynamics for a conformally invariant system allows to understand elementary particle massivation with amazingly few input assumptions. The attempts to understand p-adicity from basic principles led gradually to the vision about physics as a generalized number theory as an approach complementary to the physics as an infinite-dimensional spinor geometry of WCW approach. One of its elements was a generalization of the number concept obtained by fusing real numbers and various p-adic numbers along common rationals. The number theoretical trinity involves besides p-adic number fields also quaternions and octonions and the notion of infinite prime.

Adelic physics [L69, L70] fusing real and various p-adic physics is part of the number theoretic vision, which provides a kind of dual description for the description based on space-time geometry and the geometry of "world of classical words". Adelic physics predicts two fractal length scale hierarchies: p-adic length scale hierarchy and the hierarchy of dark length scales labelled by $h_{eff} = nh_0$, where n is the dimension of extension of rational. The interpretation of the latter hierarchy is as phases of ordinary matter behaving like dark matter. Quantum coherence is possible in arbitarily long scales. These two hierarchies are closely related. p-Adic primes correspond to ramified primes for a polynomial, whose roots define the extension of rationals: for a given extension this polynomial is not unique.

$M^8 - H$ duality

The concrete realization of the number theoretic vision is based on $M^8 - H$ duality (see **Fig. 16.7**). What the precise form is this duality is, has been far from clear but the recent form is the simplest one and corresponds to the original view [L183]. M^8 corresponds to octonions O but with the number theoretic metric defined by $Re(o^2)$ rather than the standard norm and giving Minkowskian signature.

The physics in M^8 can be said to be algebraic whereas in H field equations are partial differential equations. The dark matter hierarchy corresponds to a hierarchy of algebraic extensions of rationals inducing that for adeles and has interpretation as an evolutionary hierarchy (see **Fig. 16.9**). p-Adic physics is an essential part of number theoretic vision and the space-time surfaces are such that at least their M^8 counterparts exists also in p-adic sense. This requires that the analytic function defining the space-time surfaces are polynomials with rational coefficients.

$M^8 - H$ duality relates two complementary visions about physics (see **Fig. 16.2**), and can be seen as a generalization of the momentum-position duality of wave mechanics, which fails to generalize to quantum field theories (QFTs). $M^8 - H$ duality applies to particles which are 3-surfaces instead of point-like particles.

p-Adic physics

The idea about p-adic physics as physics of cognition and intentionality emerged also rather naturally and implies perhaps the most dramatic generalization of the space-time concept in which most points of p-adic space-time sheets are infinite in real sense and the projection to the real imbedding space consists of discrete set of points. One of the most fascinating outcomes was the observation that the entropy based on p-adic norm can be negative. This observation led to the vision that life can be regarded as something in the intersection of real and p-adic worlds. Negentropic entanglement has interpretation as a correlate for various positively colored aspects of conscious experience and means also the possibility of strongly correlated states stable under state function reduction and different from the conventional bound states and perhaps playing key role in the energy metabolism of living matter.

If one requires consistency of Negentropy Mazimization Principle with standard measurement theory, negentropic entanglement defined in terms of number theoretic negentropy is necessarily associated with a density matrix proportional to unit matrix and is maximal and is characterized by the dimension n of the unit matrix. Negentropy is positive and maximal for a p-adic unique prime dividing n.

Hierarchy of Planck constants labelling phases ordinary matter dark matter behaving like dark matter

One of the latest threads in the evolution of ideas is not more than nine years old. Learning about the paper of Laurent Nottale about the possibility to identify planetary orbits as Bohr orbits with a gigantic value of gravitational Planck constant made once again possible to see the obvious. Dynamical quantized Planck constant is strongly suggested by quantum classical correspondence and the fact that space-time sheets identifiable as quantum coherence regions can have arbitrarily large sizes. Second motivation for the hierarchy of Planck constants comes from bio-electromagnetism suggesting that in living systems Planck constant could have large values making macroscopic quantum coherence possible. The interpretation of dark matter as a hierarchy of phases of ordinary matter characterized by the value of Planck constant is very natural.

During summer 2010 several new insights about the mathematical structure and interpretation of TGD emerged. One of these insights was the realization that the postulated hierarchy of Planck constants might follow from the basic structure of quantum TGD. The point is that due to the extreme non-linearity of the classical action principle the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is one-to-many and the natural description of the situation is in terms of local singular covering spaces of the imbedding space. One could speak about effective value of Planck constant $h_{eff} = n \times h$ coming as a multiple of minimal value of Planck constant. Quite recently it became clear that the non-determinism of Kähler action is indeed the fundamental justification for the hierarchy: the integer n can be also interpreted as the integer characterizing the dimension of unit matrix characterizing negentropic entanglement made possible by the many-sheeted character of the space-time surface.

Due to conformal invariance acting as gauge symmetry the n degenerate space-time sheets must be replaced with conformal equivalence classes of space-time sheets and conformal transformations correspond to quantum critical deformations leaving the ends of space-time surfaces invariant. Conformal invariance would be broken: only the sub-algebra for which conformal weights are divisible by n act as gauge symmetries. Thus deep connections between conformal invariance related to quantum criticality, hierarchy of Planck constants, negentropic entanglement, effective p-adic topology, and non-determinism of Kähler action perhaps reflecting p-adic non-determinism emerges.

The implications of the hierarchy of Planck constants are extremely far reaching so that the significance of the reduction of this hierarchy to the basic mathematical structure distinguishing between TGD and competing theories cannot be under-estimated.

TGD as an analog of topological QFT

Consider next the attribute "Topological". In condensed matter physical topological physics has become a standard topic. Typically one has fields having values in compact spaces, which are topologically non-trivial. In the TGD framework space-time topology itself is non-trivial as also the topology of $H = M^4 \times CP_2$. Since induced metric is involved with TGD, it is too much to say that TGD is topological QFT but one can for instance say, that space-time surfaces as preferred extremals define representatives for 4-D homological equivalence classes.

The space-time as 4-surface $X^4 \subset H$ has a non-trivial topology in all scales and this together with the notion of many-sheeted space-time brings in something completely new. Topologically trivial Einsteinian space-time emerges only at the QFT limit in which all information about topology is lost (see **Fig. 16.3**).

Any GCI action satisfying holography=holomorphy principle has the same universal basic extremals: CP_2 type extremals serving basic building bricks of elementary particles, cosmic strings and their thickenings to flux tubes defining a fractal hierarchy of structure extending from CP_2 scale to cosmic scales, and massless extremals (MEs) define space-time correletes for massless particles. World as a set or particles is replaced with a network having particles as nodes and flux tubes as bonds between them serving as correlates of quantum entanglement.

"Topological" could refer also to p-adic number fields obeying p-adic local topology differing radically from the real topology (see **Fig. 30**).

Zero energy ontology

TGD inspired theory of consciousness entered the scheme after 1995 as I started to write a book about consciousness. Gradually it became difficult to say where physics ends and consciousness theory begins since consciousness theory could be seen as a generalization of quantum measurement theory by identifying quantum jump as a moment of consciousness and by replacing the observer with the notion of self identified as a system which is conscious as long as it can avoid entanglement with environment. The somewhat cryptic statement "Everything is conscious and consciousness can be only lost" summarizes the basic philosophy neatly.

General coordinate invariance leads to the identification of space-time surfaces are analogous to Bohr orbits inside causal diamond (CD). CD obtained as intersection of future and past directed light-cones (with CP_2 factor included). By the already described hologamphy, 3-dimensional data replaces the boundary conditions at single 3-surface involving also normal derivatives with conditions involving no derivates.

In zero energy ontology (ZEO), the superpositions of space-time surfaces inside causal diamond (CD) having their ends at the opposite light-like boundaries of CD, define quantum states. CDs form a scale hierarchy (see **Fig. 16.11** and **Fig. 16.12**). Quantum states are modes of WCW spinor fields, essentially wave functions in the space WCW consisting of Bohr orbit-like 4-surfaces.

Quantum jumps occur between these and the basic problem of standard quantum measurement theory disappears. Ordinary state function reductions (SFRs) correspond to "big" SFRs (BSFRs) in which the arrow of time changes (see **Fig. 16.13**). This has profound thermodynamic implications and the question about the scale in which the transition from classical to quantum takes place becomes obsolete. BSFRs can occur in all scales but from the point of view of an observer with an opposite arrow of time they look like smooth time evolutions.

In "small" SFRs (SSFRs) as counterparts of "weak measurements" the arrow of time does not change and the passive boundary of CD and states at it remain unchanged (Zeno effect).

Equivalence Principle in TGD framework

There have been also longstanding problems related to the relationship between inertial mass and gravitational mass, whose identification has been far from obvious.

- Gravitational energy is well-defined in cosmological models but is not conserved. Hence the conservation of the inertial energy does not seem to be consistent with the Equivalence Principle. In this framework the quantum numbers are assigned with zero energy states located at the boundaries of CDs defined as intersections of future and past directed light-cones. The notion of energy-momentum becomes length scale dependent since one has a scale hierarchy for causal diamonds. This allows to understand the non-conservation of energy as apparent.

  Equivalence Principle in the form expressed by Einstein's equations follows from Poincare invariance once it is realized that GRT space-time is obtained from the many-sheeted space-time of TGD by lumping together the space-time sheets to a regionof Minkowski space and endowing it with an effective metric given as a sum of Minkowski metric and deviations of the metrices of space-time sheets from Minkowski metric. Similar description relates classical gauge potentials identified as components of induced spinor connection to Yang-Mills gauge potentials in GRT space-time. Various topological inhomogenities below resolution scale identified as particles are described using energy momentum tensor and gauge currents.

  At quantum level, the Equivalence Principle has a surprisingly strong content. In linear Minkowski coordinates, space-time projection of the M^4 spinor connection representing gravitational gauge potentials the coupling to induced spinor fields vanishes. Also the modified Dirac action for the solutions of the modified Dirac equation seems to vanish identically and in TGD perturbative approach separating interaction terms is not possible.

  The modified Dirac equation however fails at the singularities of the minimal surface representing space-time surface and Dirac action reduces to an integral over singularities for the trace of the second fundamental form slashed between the induced spinor field and its conjugate. Also the M^4 part of the trace is non-vanishing and gives rise to the gravitational coupling. The trace gives both standard model vertices and graviton emission vertices. One

could say that at the quantum level gravitational and gauge interactions are eliminated everywhere except at the singularities identifiable as defects of the ordinary smooth structure. The exotic smooth structures [L169], possible only in dimension 4, are ordinary smooth structures apart from these defects serving as vertex representing a creation of a fermion-antifermion pair in the induced gauge potentials. The vertex is universal and essentially the trace of the second fundamental form as an analog of the Higgs field and the gravitational constant is proportional to the square of CP_2 radius.

- There is a delicate difference between inertial and gravitational masses. One can assume that the modes of the imbedding space spinor fields are solutions of massles Dirac equation in either $M^4 \times CP_2$ and therefore eigenstates of inertial momentum or in $CD = cd \times CP_2$: in this case they are only mass eigenstates. The mass spectra are identical for these options. Inertial momenta correspond naturally to the Poincare charges in the space of CDs. For the CD option the spinor modes correspond to mass squared eigenstates for which the mode for H^3 with a given value of light-proper time is a unitary irreducible $SO(1,3)$ representation rather than a representation of translation group. These two eigenmode basis correspond to gravitational basis for spinor modes.

Quantum TGD as a generalization of Einstein's geometrization program

I started the serious attempts to construct quantum TGD after my thesis around 1982. The original optimistic hope was that path integral formalism or canonical quantization might be enough to construct the quantum theory but it turned that this approach fails due to the extreme non-linearity of the theory.

It took some years to discover that the only working approach is based on the generalization of Einstein's program. Quantum physics involves the geometrization of the infinite-dimensional "world of classical worlds" (WCW) identified as the space of 3-dimensional surfaces. Later 3-surfaces where replaced with 4-surfaces satifying holography and therefore as analogs of Bohr orbits.

- If one assumes Bohr orbitology, then strong correlations between the 3-surfaces at the ends of CD follow and mean holography. It is natural to identify the quantum states of the Universe (and sub-Univeverses) as modes of a formally classical spinor field in WCW. WCW gamma matrices are expressible in terms of oscillator operators of free second quantized spinor fields of H. The induced spinor fields identified projections of H spinor fields to the space-time surfaces satisfy modified Dirac equation for the modified Dirac equation. Only quantum jump remains the genuinely quantal aspect of quantum physics.

- Quantum TGD can be seen as a theory for free spinor fields in WCW having maximal isometries and the generalization of the Super Virasoro conditions gives rise to the analog massless Dirac equation at the level of WCW.

The world of classical worlds and its symmetries

The notion of "World of Classical Worlds" (WCW) emerged around 1985 but found its basic form around 1990. Holography forced by the realization of General Coordinate Invariance forced/allowed to give up the attempts to make sense of the path integral.

A more concrete way to express this view is that WCW does not consist of 3-surfaces as particle-like entities but almost deterministic Bohr orbits assignable to them as preferred extremals of Kähler action so that quantum TGD becomes wave mechanics in WCW combined with Bohr orbitology. This view has profound implications, which can be formulated in terms of zero energy ontology (ZEO), solving among other things the basic paradox of quantum measurement theory. ZEO forms also the backbone of TGD inspired theory of consciousness and quantum biology.

WCW geometry exists only if it has maximal isometries: this statement is a generalization of the discovery of Freed for loop space geometries [A19]. I have proposed [K55, K30, K139, K104, L182] that WCW could be regarded as a union of generalized symmetric spaces labelled by zero modes which do not contribute to the metric. The induced Kähler field is invariant under symplectic transformations of CP_2 and would therefore define zero mode degrees of freedom if one assumes

that WCW metric has symplectic transformations as isometries. In particular, Kähler magnetic fluxes would define zero modes and are quantized closed 2-surfaces. The induced metric appearing in Kähler action is however not zero mode degree of freedom. If the action contains volume term, the assumption about union of symmetric spaces is not well-motivated.

Symplectic transformations are not the only candidates for the isometries of WCW. The basic picture about what these maximal isometries could be, is partially inspired by string models.

- A weaker proposal is that the symplectomorphisms of H define only symplectomorphisms of WCW. Extended conformal symmetries define also a candidate for isometry group. Remarkably, light-like boundary has an infinite-dimensional group of isometries which are in 1-1 correspondence with conformal symmetries of $S^2 \subset S^2 \times R_+ = \delta M^4_+$.

- Extended Kac Moody symmetries induced by isometries of δM^4_+ are also natural candidates for isometries. The motivation for the proposal comes from physical intuition deriving from string models. Note they do not include Poincare symmetries, which act naturally as isometries in the moduli space of causal diamonds (CDs) forming the "spine" of WCW.

- The light-like orbits of partonic 2-surfaces might allow separate symmetry algebras. One must however notice that there is exchange of charges between interior degrees of freedom and partonic 2-surfaces. The essential point is that one can assign to these surface conserved charges when the dual light-like coordinate defines time coordinate. This picture also assumes a slicing of space-time surface by by the partonic orbits for which partonic orbits associated with wormrhole throats and boundaries of the space-time surface would be special. This slicing would correspond to Hamilton-Jacobi structure.

- Fractal hierarchy of symmetry algebras with conformal weights, which are non-negative integer multiples of fundamental conformal weights, is essential and distinguishes TGD from string models. Gauge conditions are true only the isomorphic subalgebra and its commutator with the entire algebra and the maximal gauge symmetry to a dynamical symmetry with generators having conformal weights below maximal value. This view also conforms with p-adic mass calculations.

- The realization of the symmetries for 3-surfaces at the boundaries of CD and for light-like orbits of partonic 2-surfaces is known. The problem is how to extend the symmetries to the interior of the space-time surface. It is natural to expect that the symmetries at partonic orbits and light-cone boundary extend to the same symmetries.

After the developments towards the end of 2023, it seems that the extension of conformal and Kac-Moody symmetries of string models to the TGD framework is understood. What about symplectic symmetries, which were originally proposed as isometries of WCW? In this article this question is discussed in detail and it will be found that these symmetries act naturally on 3-D holographic data and one can identify conserved charges. By holography this is in principle enough and might imply that the actions of holomorphic and symplectic symmetry algebras are dual. Holography=holomorphy hypothesis is discussed also in the case of the modified Dirac equation.

About the construction of scattering amplitudes

From the point of view of particle physics the ultimate goal is of course a practical construction recipe for the S-matrix of the theory. I have myself regarded this dream as quite too ambitious taking into account how far-reaching re-structuring and generalization of the basic mathematical structure of quantum physics is required. After having made several guesses for what the counterpart of S-matrix could be, it became clear that the dream about explicit formulas is unrealistic before one has understood what happens in quantum jump.

- In ZEO [K143, L108] one must distinguish between "small" state function reductions (SSFRs) and "big" SFRs (BSFRs). BSFR is the TGD counterpart of the ordinary SFRs and the arrow of the geometric time changes in it. SSFR follows the counterpart of a unitary time evolution and the arrow of the geometric time is preserved in SSFR. The sequence of SSFRs is the TGD

counterpart for the sequence of repeated quantum measurements of the same observables in which nothing happens to the state. In TGD something happens in SSFRs and this gives rise to the flow of consciousness. When the set of the observables measured in SSFR does not commute with the previous set of measured observables, BSFR occurs.

The evolution by SSFRs means that also the causal diamond changes. At quantum level one has a wave function in the finite-dimensional moduli space of CDs which can be said to form a spine of WCW [L180]. CDs form a scale hierarchy. SSFRs are preceded by a dispersion in the moduli space of CDs and SSFR means localization in this space.

- There are several S-matrix like entities. One can assign an analog of the S-matrix to each analog of unitary time evolution preceding a given SSFR. One can also assign an analog S-matrix between the eigenstate basis of the previous set of observables and the eigenstate basis of new observers: this S-matrix characterizes BSFR. One can also assign to zero energy states an S-matrix like entity between the states assignable to the two boundaries of CD. These S-matrix like objects can be interpreted as a complex square root of the density matrix representable as a diagonal and positive square root of density matrix and unitary S-matrix so that quantum theory in ZEO can be said to define a square root of thermodynamics at least formally.

In standard QFTs Feynman diagrams provide the description of scattering amplitudes. The beauty of Feynman diagrams is that they realize unitarity automatically via the so-called Cutkosky rules. In contrast to Feynman's original beliefs, Feynman diagrams and virtual particles are taken only as a convenient mathematical tool in quantum field theories. The QFT approach is however plagued by UV and IR divergences and one must keep mind open for the possibility that a genuine progress might mean opening of the black box of the virtual particle.

In the TGD framework this generalization of Feynman diagrams indeed emerges unavoidably.

- The counterparts of elementary particles can be identified as closed monopole flux tubes connecting two parallel Minkowskian space-time sheets and have effective ends which are Euclidean wormhole contacts. The 3-D light-like boundaries of wormhole contacts as orbits of partonic 2-surfaces.

  The intuitive picture is that the 3-D light-like partonic orbits replace the lines of Feynman diagrams and vertices are replaced by 2-D partonic 2-surfaces. A stronger condition is that fermion number is carried by light-like fermion lines at the partonic orbits, which can be identified as boundaries string world sheets.

- The localization of the nodes of induced spinor fields to 2-D string world sheets (and possibly also to partonic 2-surfaces) implies a stringy formulation of the theory analogous to stringy variant of twistor formalism with string world sheets having interpretation as 2-braids. In the TGD framework, the fermionic variant of twistor Grassmann formalism combined with the number theoretic vision [L163, L164] led to a stringy variant of the twistor diagrammatics.

- Fundamental fermions are off-mass-shell in the sense that their momentum components are real algebraic integers in an extension of rationals associated with the space-time surfaces inside CD with a momentum unit determined by the CD size scale. Galois confinement states that the momentum components are integer valued for the physical states.

- The twistorial approach suggests also the generalization of the Yangian symmetry to infinite-dimensional super-conformal algebras, which would determine the vertices and scattering amplitudes in terms of poly-local symmetries.

The twistorial approach is however extremely abstract and lacks a concrete physical interpretation. The holography=holomorphy vision led to a breakthough in the construction of the scattering amplitudes by solving the problem of identifying interaction vertices [L190].

1. The basic prediction is that space-time surfaces as analogs of Bohr orbits are holomorphic in a generalized sense and are therefore minimal surfaces. The minimal surface property fails at lower-dimensional singularities and the trace of the second fundamental form (SFF) analogous to acceleration associated with the Bohr orbit of the particle as 3-surface has a delta function like singularity but vanishes elsewhere.

2. The minimal surface property expressess masslessness for both fields and particles as 3-surfaces. At singularities masslessness property fails and singularities can be said to serve as sources which also in QFT define scattering amplitudes.

3. The singularities are analogs of poles and cuts for the 4-D generalization of the ordinary holomorphic functions. Also for the ordinary holomorphic functions the Laplace equation as analog massless field equation and expressing analyticity fails. Complex analysis generalizes to dimension 4.

4. The conditions at the singularity give a generalization of Newton's "F=ma"! I ended up where I started more than 50 years ago!

5. In dimension 4, and only there, there is an infinite number of exotic diff structures [**?**], which differ from ordinary ones at singularities of measure zero analogous to defects. These defects correspond naturally to the singularities of minimal surfaces. One can say that for the exotic diff structure there is no singularity.

6. Group theoretically the trace of the SFF can be regarded as a generalization of the Higgs field, which is non-vanishing only at the vertices and this is enough. Singularities take the role of generalized particle vertices and determine the scattering amplitudes. The second fundamental form contracted with the embedding space gamma matrices and slashed between the second quantized induced spinor field and its conjugate gives the universal vertex involving only fermions (bosons are bound states of fermions in TGD). It contains both gauge and gravitational contributions to the scattering amplitudes and there is a complete symmetry between gravitational and gauge interactions. Gravitational couplings come out correctly as the radius squared of CP_2 as also in the classical picture.

7. The study of the modified Dirac equation leads to the conclusion that vertices as singularities and defects contain the standard electroweak gauge contribution coming from the induced spinor connection and a contribution from the M^4 spinor connection. M^4 part of the generalized Higgs can give rise to a graviton as an $L = 1$ rotational state of the flux tube representing the graviton. It is not clear whether M^4 Kähler gauge potential can give rise to a spin 1 particle. The vielbein part of M^4 spinor connection is pure gauge and could give rise to gravitational topological field theory.

Figures

Basic ideas of TGD inspired quantum biology

The following list gives the basic elements of TGD inspired quantum biology.

- Many-sheeted space-time allows the interpretation of the structures of macroscopic world around us in terms of space-time topology. Magnetic/field body acts as intentional agent using biological body as a sensory receptor and motor instrument and controlling biological body and inheriting its hierarchical fractal structure. Fractal hierarchy of EEGs and its variants can be seen as communication and control tools of magnetic body. Also collective levels of consciousness have a natural interpretation in terms of magnetic body. Magnetic body makes also possible entanglement in macroscopic length scales. The braiding of magnetic flux tubes makes possible topological quantum computations and provides a universal mechanism of memory. One can also undersand the real function of various information molecules and corresponding receptors by interpreting the receptors as addresses in quantum computer memory and information molecules as ends of flux tubes which attach to these receptors to form a connection in quantum web.

  Note that also the notion of electric body makes sense [L175]. Quite generally, long range classical gravitational, electric and magnetic fields give rise to very large values of effective Planckl constants. The Nottale's hypothesis of gravitational Planck constant generalizes to electric interactions.

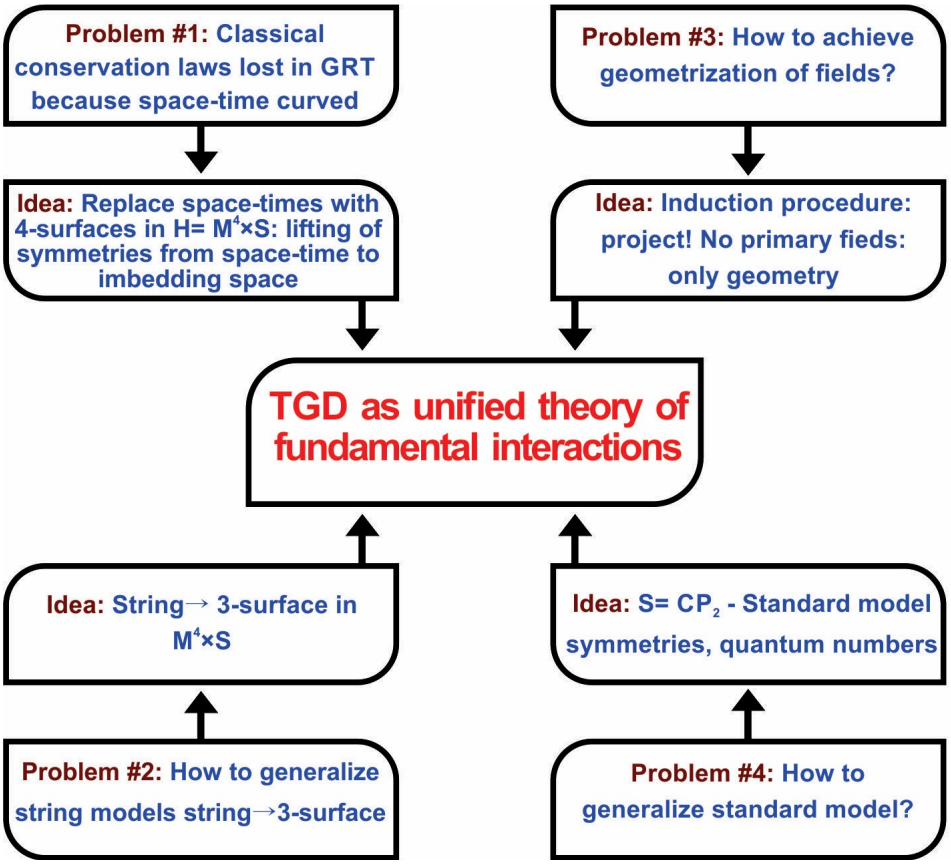

Figure 1: The problems leading to TGD as their solution.

- Magnetic body carrying dark matter and forming an onion-like structure with layers characterized by large values of Planck constant is the key concept of TGD inspired view about Quantum Mind to biology.. Magnetic body is identified as intentional agent using biological body as sensory receptor and motor instrument. EEG and its fractal variants are identified as a communication and control tool of the magnetic body and a fractal hierarchy of analogs of EEG is predicted. Living system is identified as a kind of Indra's net with biomolecules representing the nodes of the net and magnetic flux tubes connections between then.

  The reconnection of magnetic flux tubes and phase transitions changing Planck constant and therefore the lengths of the magnetic flux tubes are identified as basic mechanisms behind DNA replication and analogous processes and also behind the phase transitions associated with the gel phase in cell interior. The braiding of magnetic flux makes possible universal memory representation recording the motions of the basic units connected by flux tubes. Braiding also defines topological quantum computer programs updated continually by the flows of the basic units. The model of DNA as topological quantum computer is discussed as an application. In zero energy ontology the braiding actually generalize to 2-braiding for string world sheets in 4-D space-time and brings in new elements.

- Zero energy ontology (ZEO) makes possible the proposed p-adic description of intentions and cognitions and their transformations to action. Time mirror mechanism based on sending of negative energy signal to geometric past would apply to both long term memory recall, remote metabolism, and realization of intentional acting as an activity beginning in the geometric past in accordance with the findings of Libet. ZEO gives a precise content to the notion of negative energy signal in terms of zero energy state for which the arrow of geometric time is opposite to the standard one.

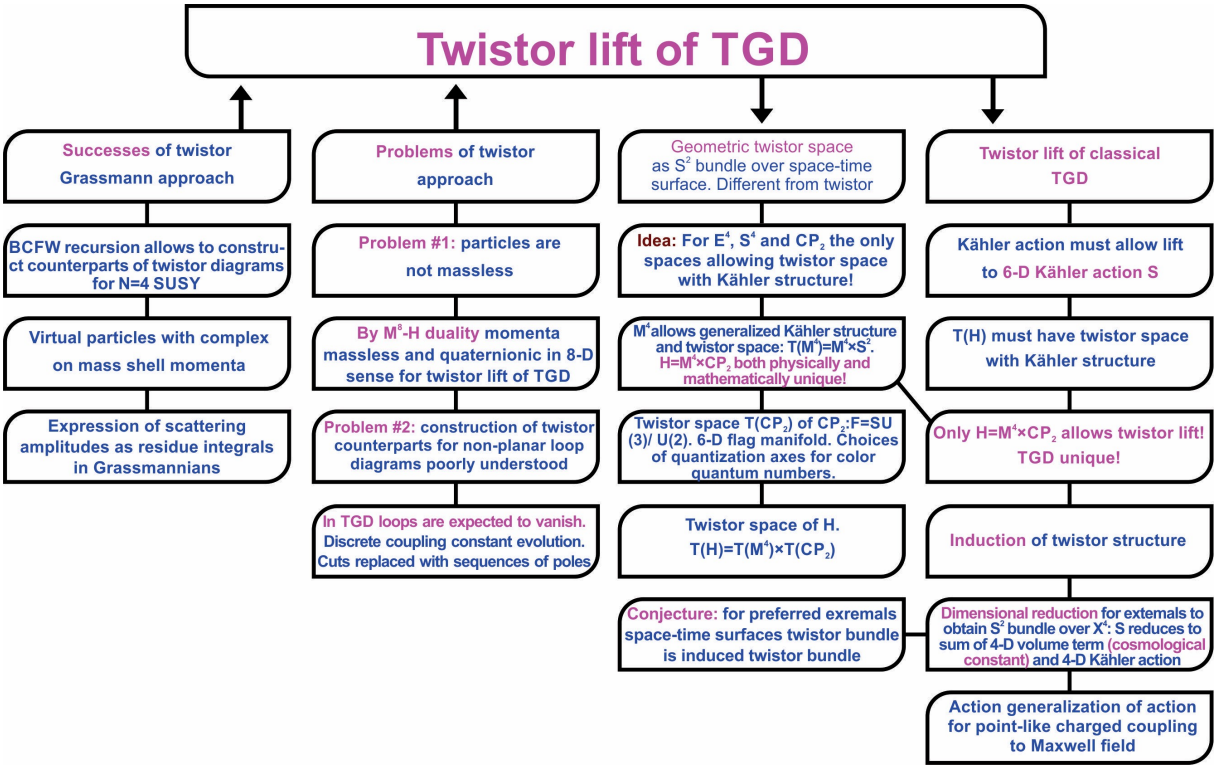

Figure 2: Twistor lift

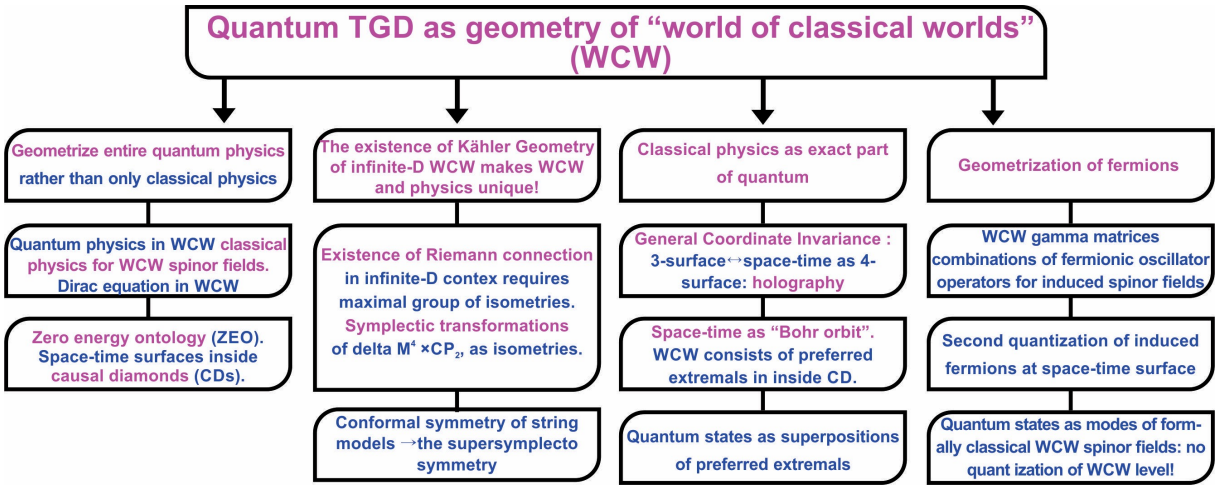

Figure 3: Geometrization of quantum physics in terms of WCW

The associated notion of causal diamond (CD) is essential element and assigns to elementary particles new fundamental time scales which are macroscopic: for electron the time scale is .1 seconds, the fundamental biorhythm. An essentially new element is time-like entanglement which allows to understand among other things the quantum counterparts of Boolean functions in terms of time-like entanglement in fermionic degrees of freedom.

- The assignment of dark matter with a hierarchy of Planck constants gives rise to a hierarchy of macroscopic quantum phases making possible macroscopic and macrotemporal quantum coherence and allowing to understand evolution as a gradual increase of Planck constant. The model for dark nucleons leads to a surprising conclusion: the states of nucleons correspond to DNA, RNA, tRNA, and amino-acids in a natural manner and vertebrate genetic code as correspondence between DNA and amino-acids emerges naturally. This suggests that genetic code is realized at the level of dark hadron physics and living matter in the usual sense provides a secondary representation for it. The hierarchy of Planck constants emerges from basic TGD under rather general assumptions.

- p-Adic physics can be identified as physics of cognition and intentionality. Negentropic entanglement possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds. NMP respects negentropic entanglement and the attractive idea is that the experience of understanding and positively colored emotions relate to negentropic entanglement.

- Living matter as conscious hologram is one of the basic ideas of TGD inspired biology and consciousness theory. The basic objection against TGD is that the interference of classical

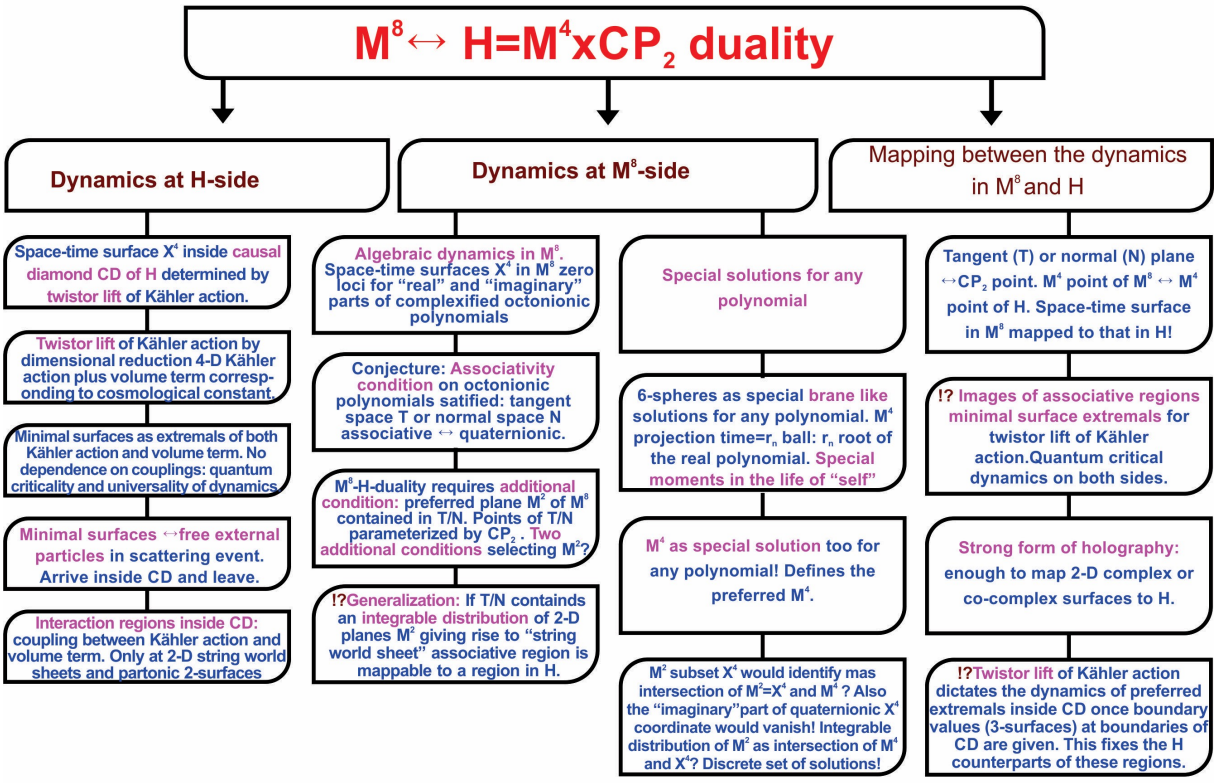

Figure 4: $M^8 - H$ duality

fields is impossible in the standard sense for the reason that that classical fields are not primary dynamical variables in TGD Universe. The resolution is based on the observation that only the interference of the effects caused by these fields can be observed experimentally and that many-sheeted space-time allows to realized the summation of effects in terms of multiple topological condensations of particles to several parallel space-time sheets. One concrete implication is fractality of qualia. Qualia appear in very wide range of scales: our qualia could in fact be those of magnetic body. The proposed mechanism for the generation of qualia realizes the fractality idea.

Various anomalies of living matter have been in vital role in the development of not only TGD view about living matter but also TGD itself.

- TGD approach to living matter was strongly motivated by the findings about the strange behavior of cell membrane and of cellular water, and gel behavior of cytoplasm. Also the findings about effects of ELF em fields on vertebrate brain were decisive and led to the proposal of the hierarchy of Planck constants found later to emerge naturally from the non-determinism of Kähler action. Rather satisfactorily, the other manner to introduce the hierarchy of Planck constants is in terms of gravitational Planck constant: at least in microscopic scales the equivalence of these approaches makes sense and leads to highly non-trivial predictions. The basic testable prediction is that dark photons have cyclotron frequencies inversely proportional to their masses but universal energy spectrum in visible and UV range which corresponds to the transition energies for biomolecules so that they are ideal for biocontrol at the level of both magnetic bodies and at the level of biochemistry.

- Water is in key role in living matter and also in TGD inspired view about living matter. The

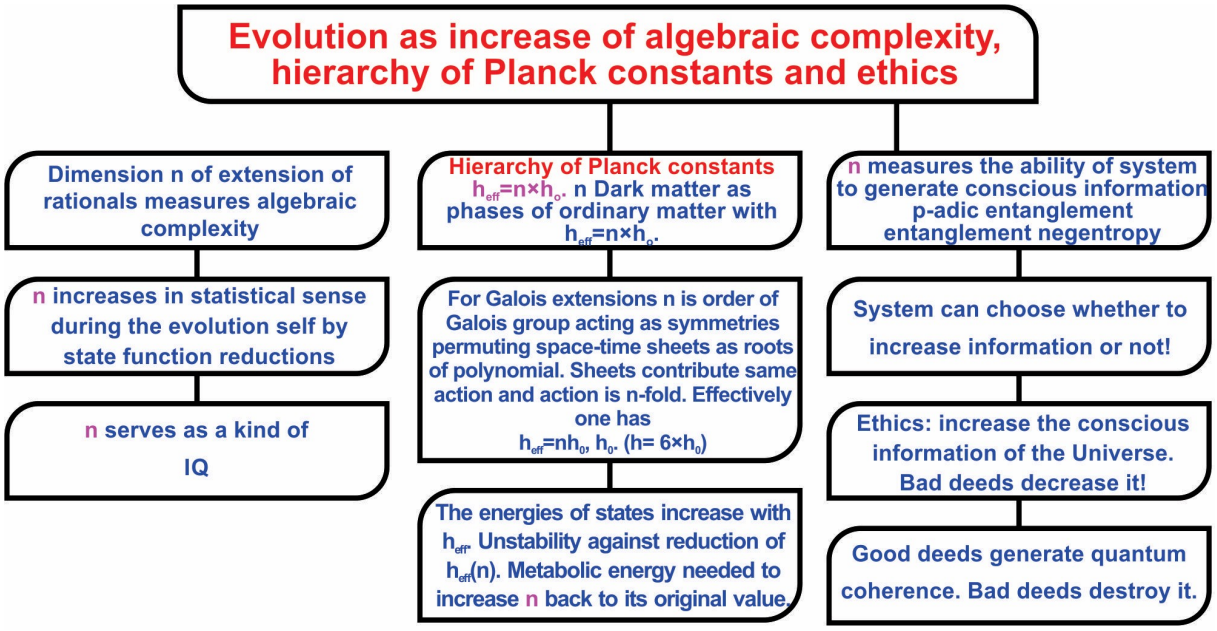

Figure 5: Number theoretic view of evolution

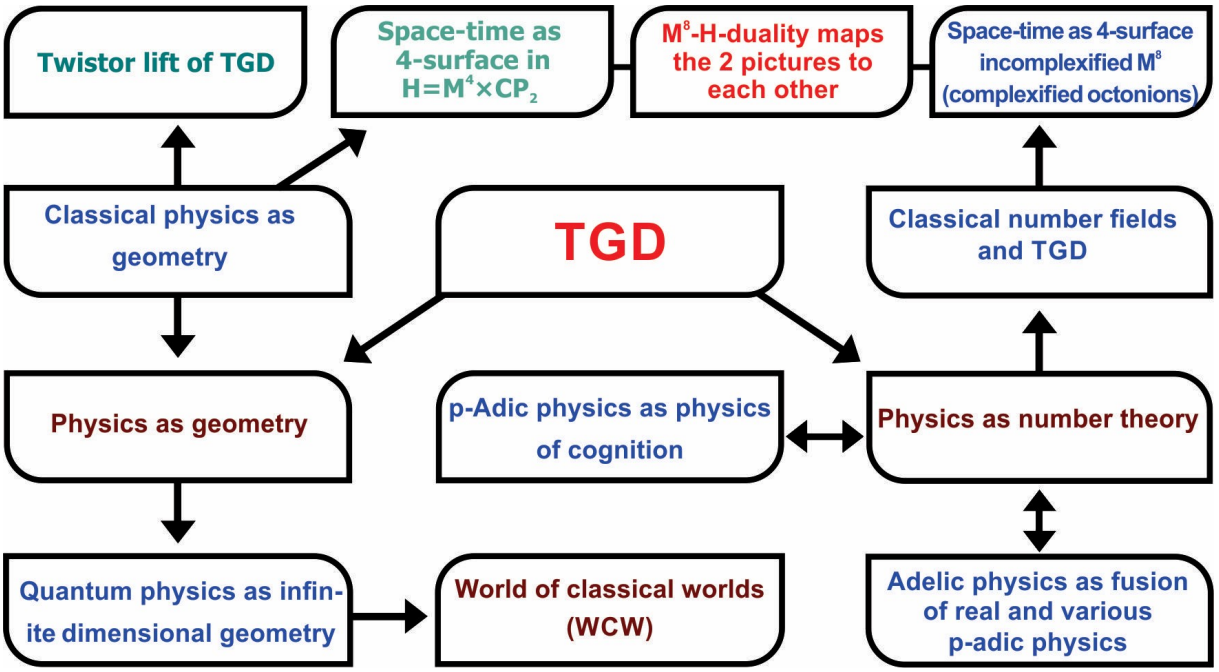

Figure 6: TGD is based on two complementary visions: physics as geometry and physics as number theory.

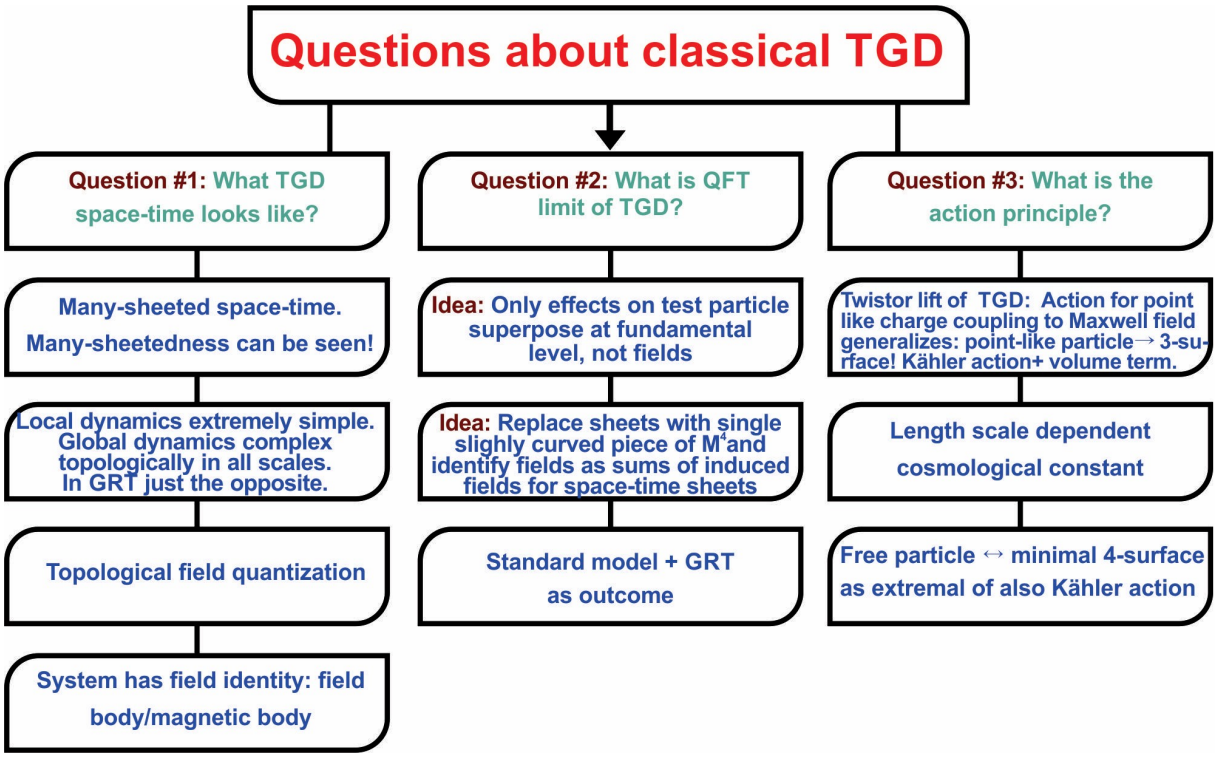

Figure 7: Questions about classical TGD.

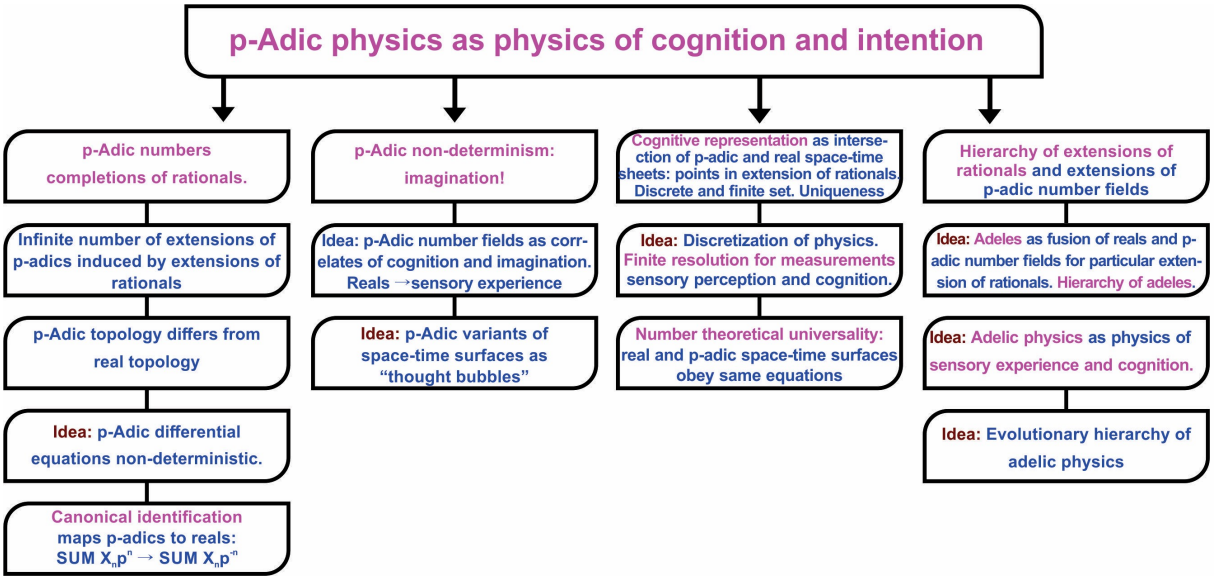

Figure 8: p-Adic physics as physics of cognition and imagination.

anomalies of water lead to a model for dark nuclei as dark proton strings with the surprising prediction that DNA, RNA, aninoacids and even tRNA are in one-one correspondence with the resulting 3-quark states and that vertebrate genetic code emerges naturally. This leads to a vision about water as primordial lifeform still playing a vital role in living organisms. The model of water memory and homeopathy in turn generalizes to a vision about how immune system might have evolved.

- Metabolic energy is necessary for conscious information processing in living matter. This suggests that metabolism should be basically tranfer of negentropic entanglement from nutrients to the organism. ATP could be seen as a molecule of consciousness in this picture and high energy phosphate bond would make possible the transfer of negentropy.

- Pollack effect and its generalizations are in a central role in the TGD inspire quantum biology. In the Pollack effect, the feed of energy allows to increase the value of effective Planck constant so that an ordinary charged particle transforms to its dark variant, being kicked to, say, the gravitational magnetic body of the system itself or some other system such as the Earth or Sun. Charge separation takes place between ordinary biomatter and its magnetic body. Dissipation is extremely small at the magnetic /field body so that Pollack effect makes it possible to realize various biological functions at the magnetic/field body. Photons, in particular solar photons, can provide the energy needed to increase the value of h_{eff} but there are many other possibilities. For instance, the formation of molecular bound states of atoms liberates energy which can be used in the Pollack effect and this process could generate dark matter at the magnetic and more general field bodies.

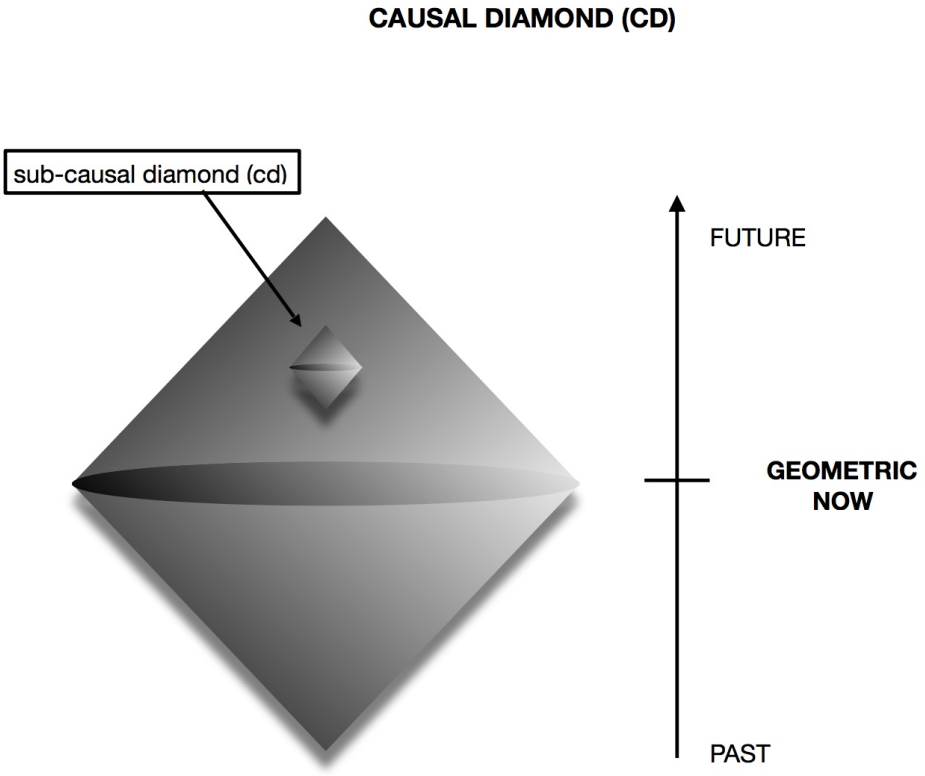

Figure 9: Causal diamond

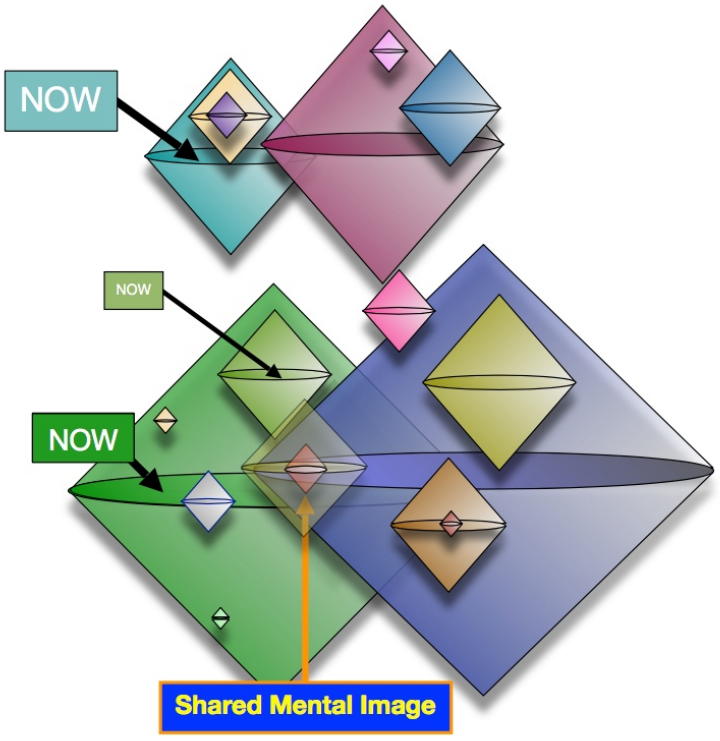

Figure 10: CDs define a fractal "conscious atlas"

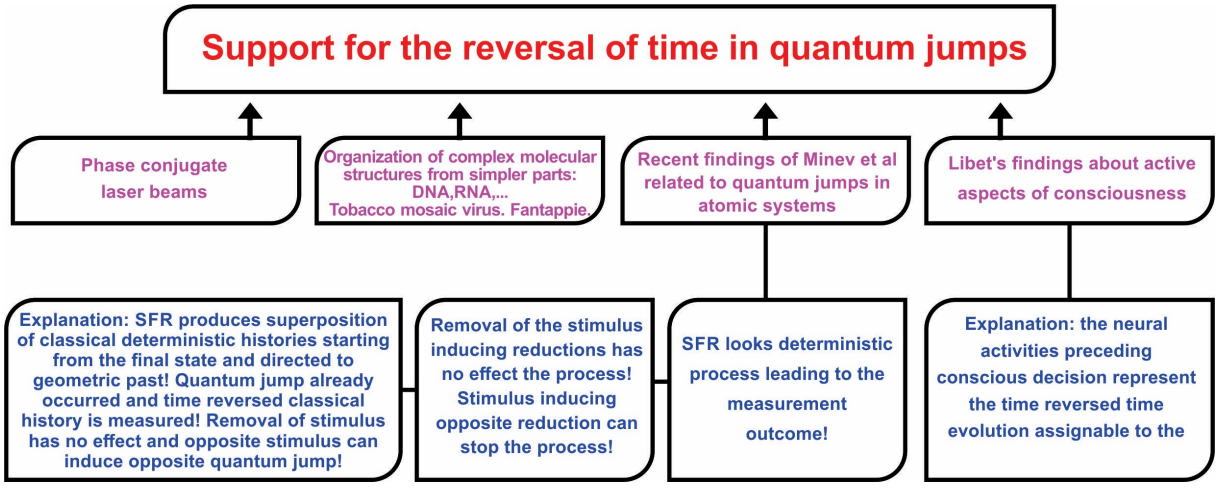

Figure 11: Time reversal occurs in BSFR

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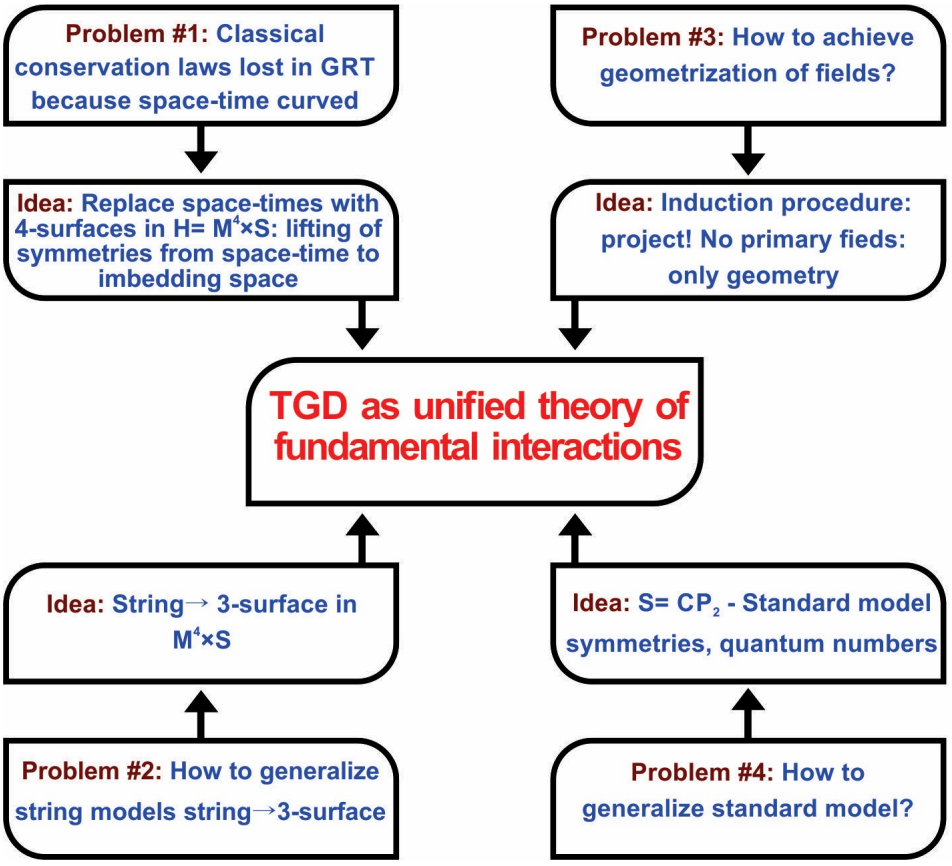


Figure 12: The problems leading to TGD as their solution.

TGD view of consciousness very briefly

The following is a very brief summary of the basic notions and ideas of TGD inspired theory of consciousness.

- TGD inspired theory of consciousness can be seen as a generalization of quantum measurement theory by bringing in the conscious observer. One can even say that Quantum TGD is basically a theory of conscious experience.

  The basic new elements are the resolution of the basic problem of the measurement theory by the introduction of ZEO, which brings new elements also to the quantum measurement theory and leads to a view about how the arrow of time and its flow are generated. Number theoretic physics brings in p-adic physics and the notion of negentropic entanglement. Negentropy Maximization Principle (NMP) was first proposed to serve as a variational principle of consciousness but turned out to follow from number theoretical evolution as a mathematical analog of the second law and implying it. The possibility of negentropic entanglement indeed predicts evolution as gradual increase of negentropic resources of the Universe.

- There are two kinds of state function reductions: the "small" ones (SSFRs) and the "big" ones (BSFRs). The sequence of SSFRs is the counterpart for the repeated measurements of the same observables or at least for a sequence involving measurements of sets of mutually commuting observables such that these sets commute with each other. The state function

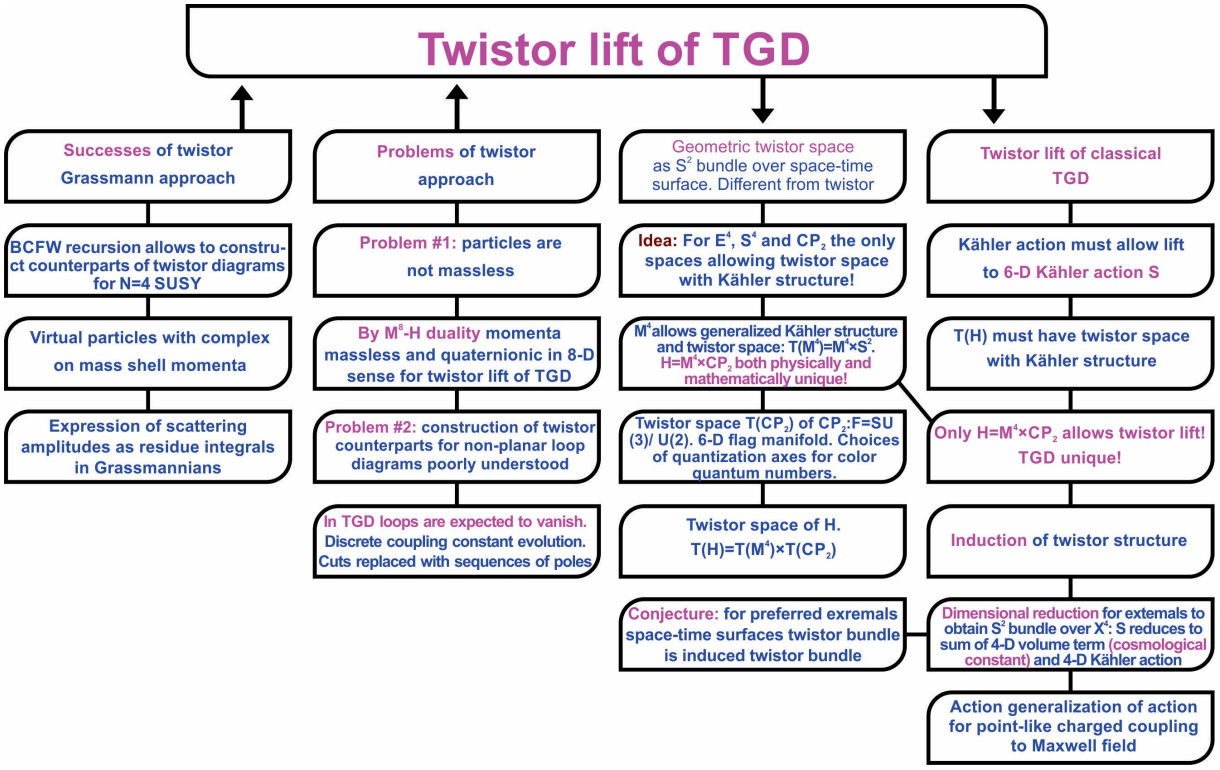


Figure 13: Twistor lift

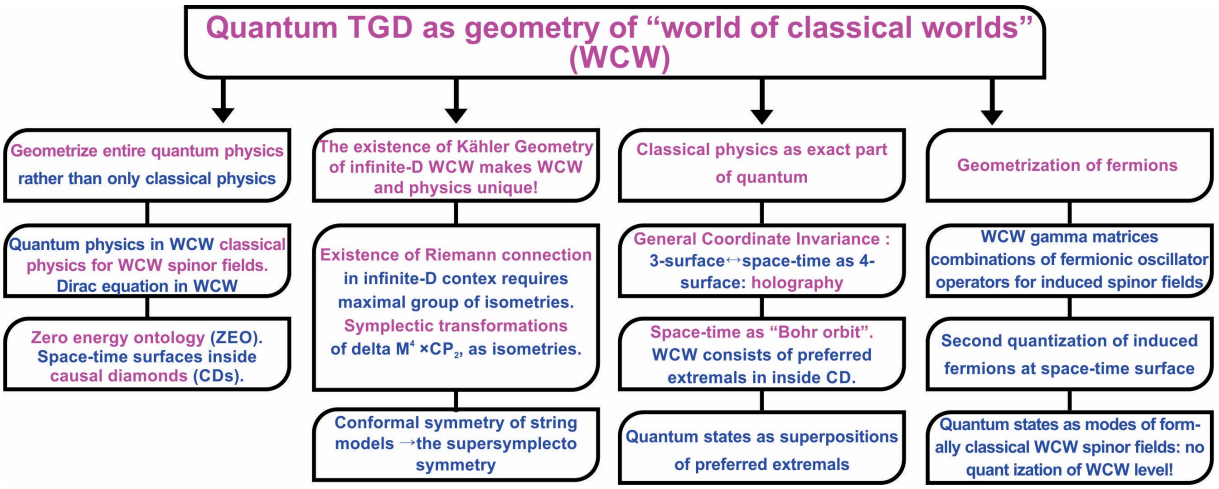


Figure 14: Geometrization of quantum physics in terms of WCW

reductions which leave invariant only the second part of the zero energy state but change the other one: this is the counterpart of the Zeno effect.

Self can be identified as the sequence of SSFRs preceded by the TGD counterparts of unitary time evolutions. The generation of "Akashic records" defined by negentropically entangled systems plays a vital role in the understanding of evolution.

When the set of observables measured in does not commute with the preceding set, SSFR is not possible and BSFR occurs and changes the arrow of time. The roles of the boundaries of CD are changed. Self reincarnates with an opposite arrow of time. Since the classical signals generated by self propagate to opposite time direction, "classical" memories about this period are not possible.

This prediction is something totally new and profoundly affects the view of physics even in cosmological scales since the hierarchy of effective Planck constants allows quantum coherence and consciousness are therefore possible in all scales. For the outsider BSFR looks like a loss of consciousness, death, or falling asleep. The system starts to live consciously in the opposite time direction and reincarnates in the next BSFR.

The strongest simplifying assumption is that the size of CD increases steadily in the sequences of SSFRs. A more precise view is achieved by introducing the finite-dimensional space of CDs. A given SSFR is preceded by a TGD counterpart of a unitary time evolution as a dispersion in the space of CDs. SSFR means a localization in this moduli space and implies the statistical increase of the size CD and the correlation between experienced time as sequence of SSFRs with the geometric time identifiable as the distance between the tips of CD.

- CDs serve as correlates of selves and a hierarchy of selves is predicted and closely relates to

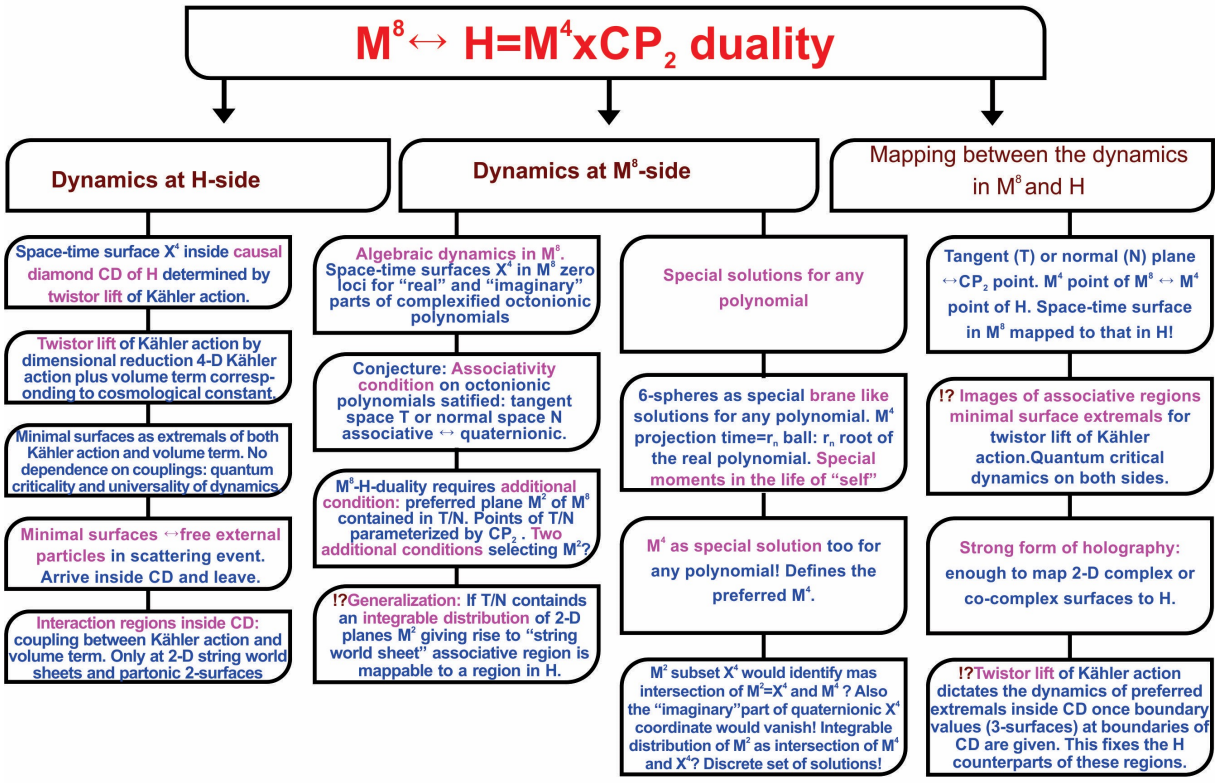


Figure 15: $M^8 - H$ duality

the p-adic hierarchy and hierarchy of Planck constants. Subselves are interpreted as mental images of self and the sharing of mental images by fusion of subselves gives rise to a kind of stereo consciousness.

Figures

What I have said above is strongly biased view about the recent situation in quantum TGD. This vision is single man's view and doomed to contain unrealistic elements as I know from experience. My dream is that young critical readers could take this vision seriously enough to try to demonstrate that some of its basic premises are wrong or to develop an alternative based on these or better premises. I must be however honest and tell that 45 years of TGD is a really vast bundle of thoughts and quite a challenge for anyone who is not able to cheat himself by taking the attitude of a blind believer or a light-hearted debunker trusting on the power of easy rhetoric tricks.

Karkkila, April 22, 2024, Finland

Matti Pitkänen

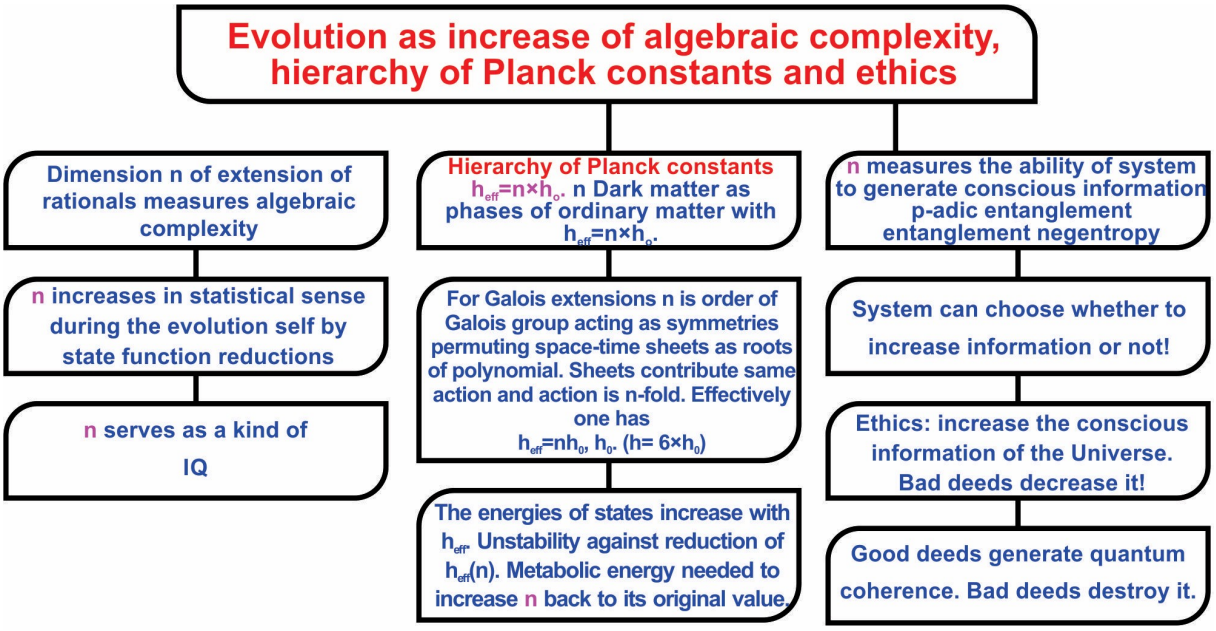
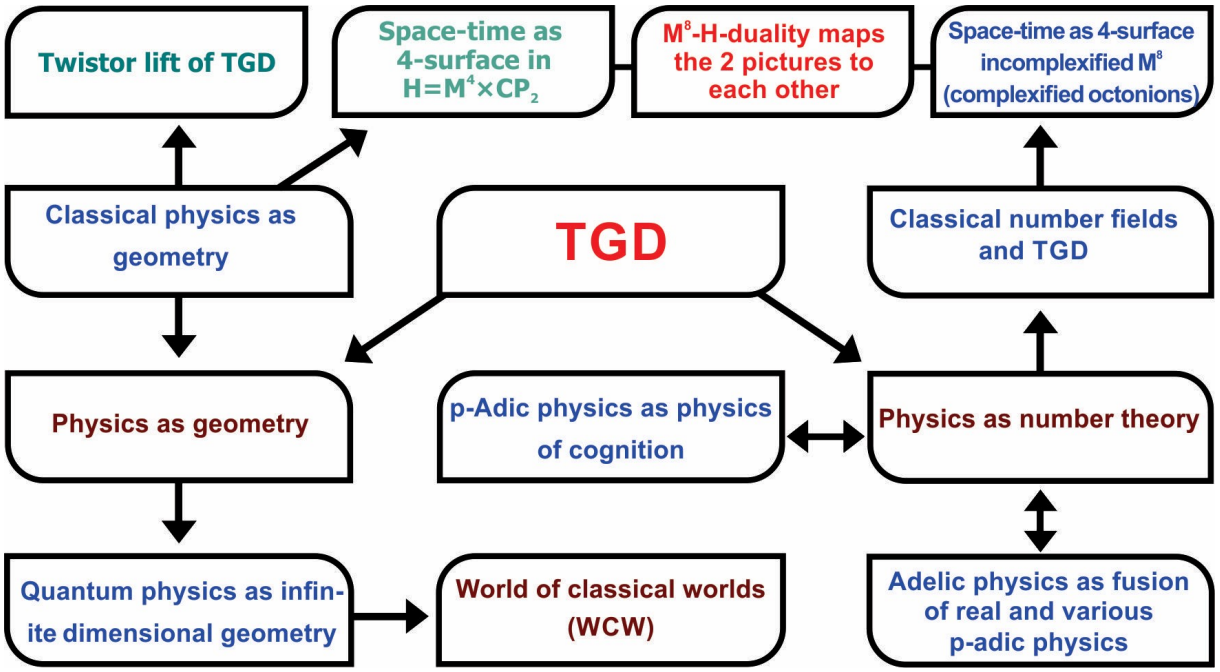


Figure 16: Number theoretic view of evolution



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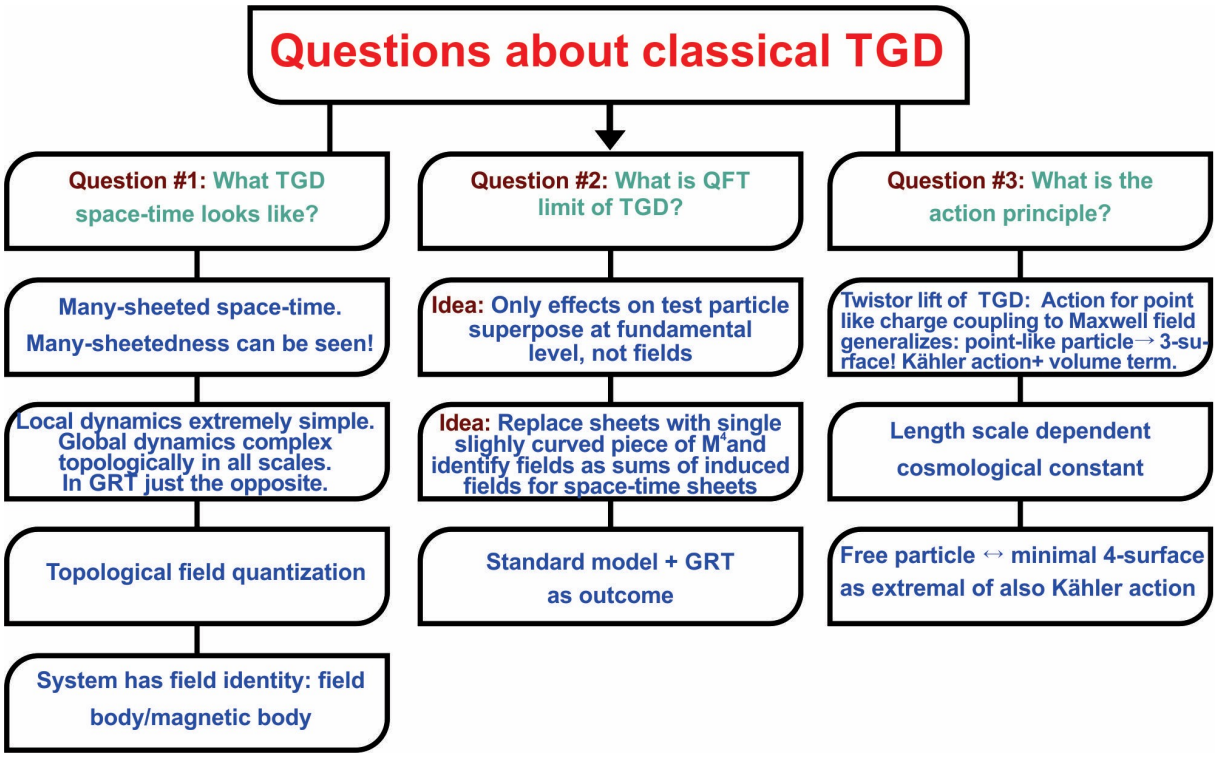

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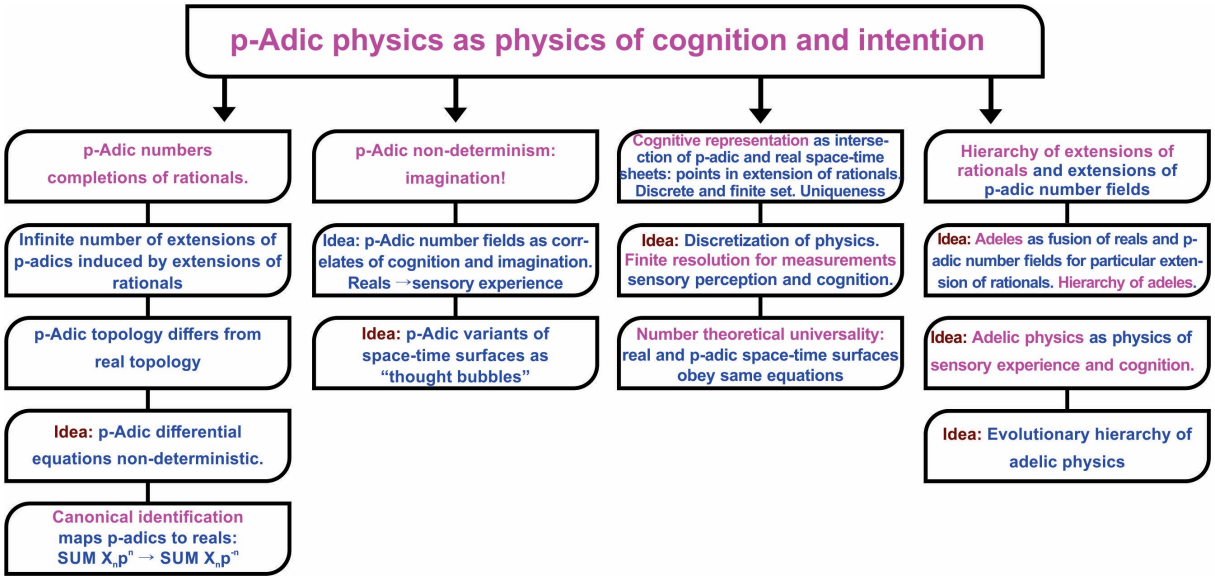


Figure 19: p-Adic physics as physics of cognition and imagination.

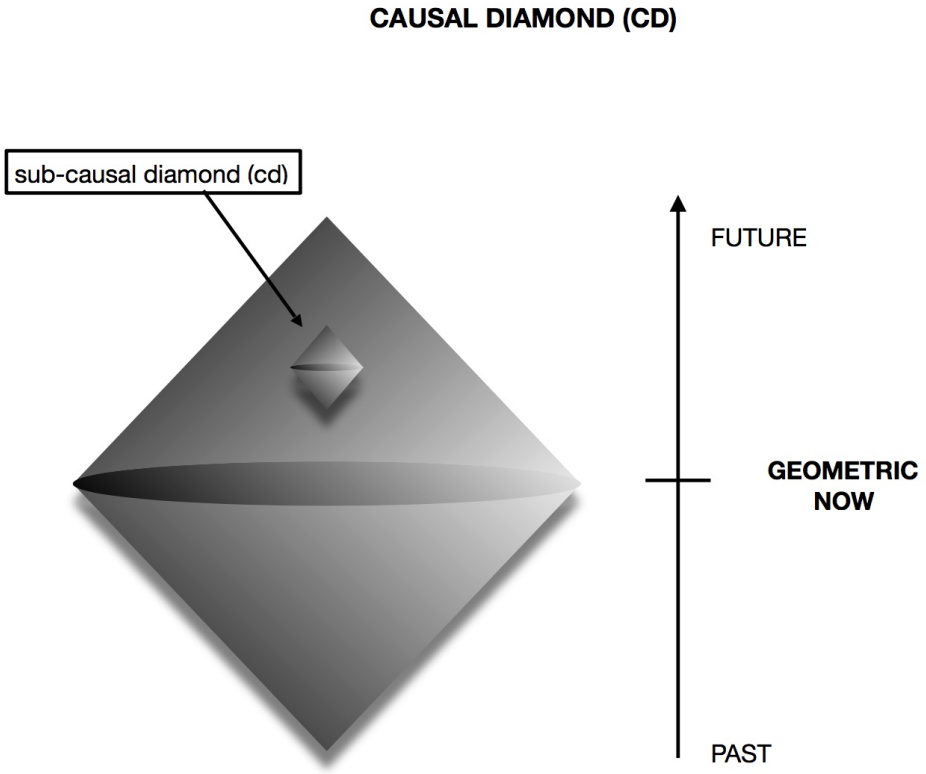
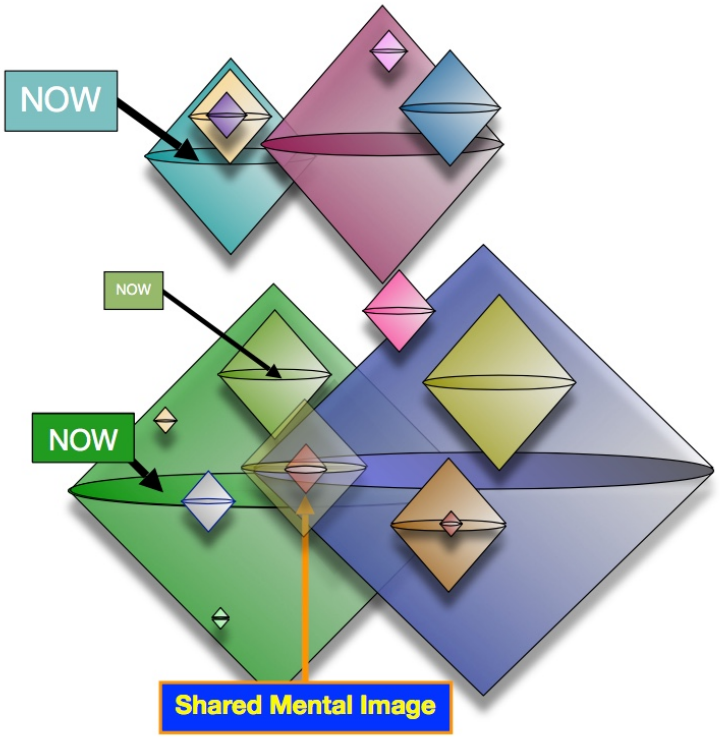


Figure 20: Causal diamond



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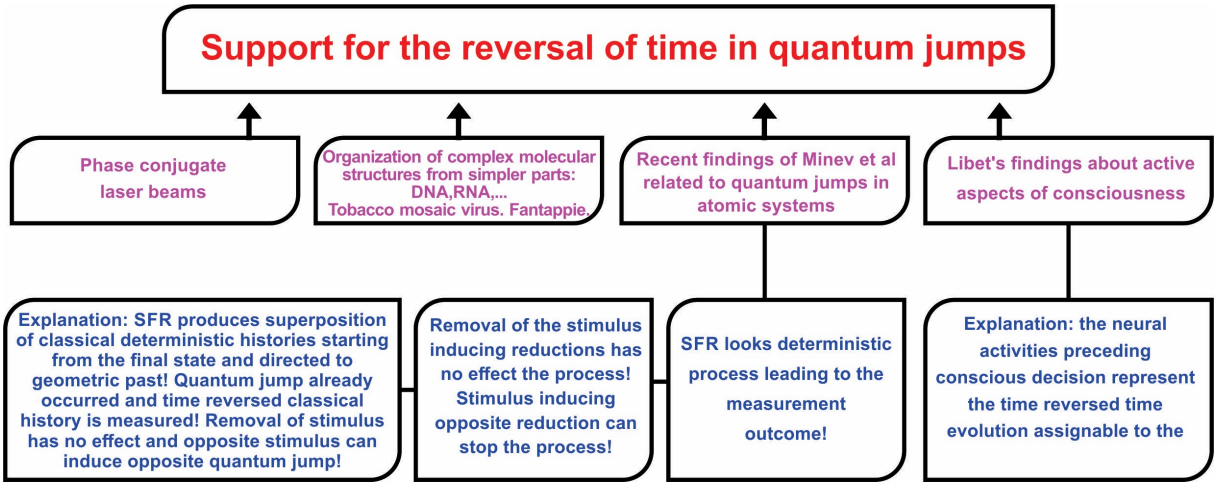

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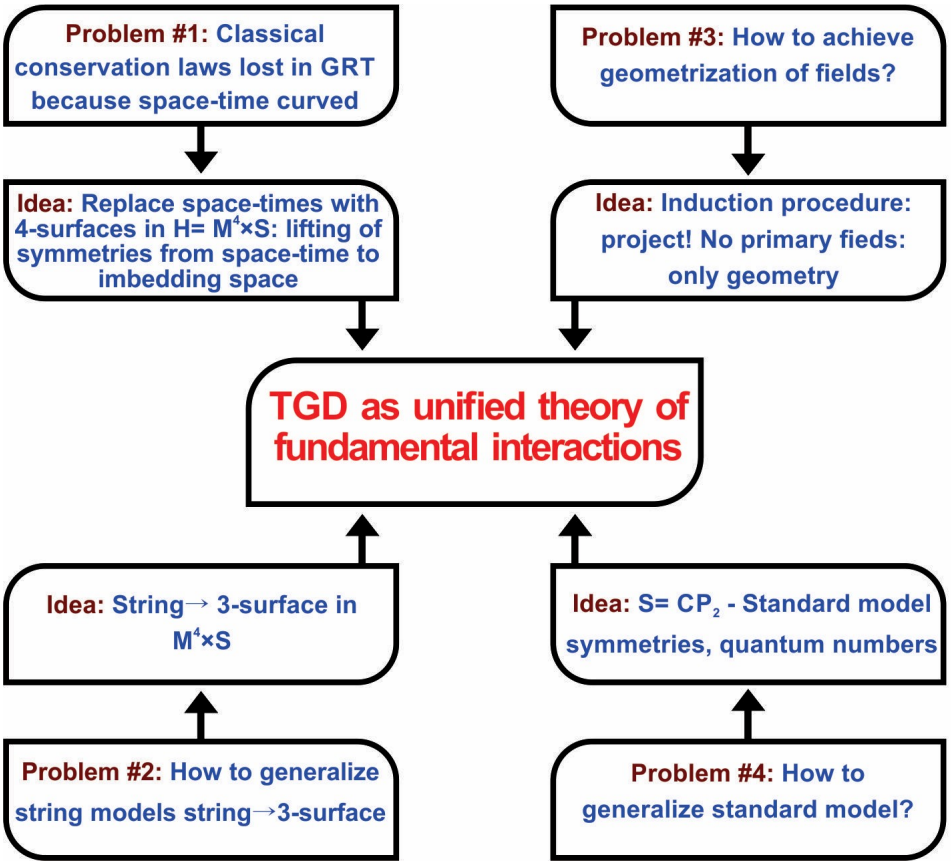

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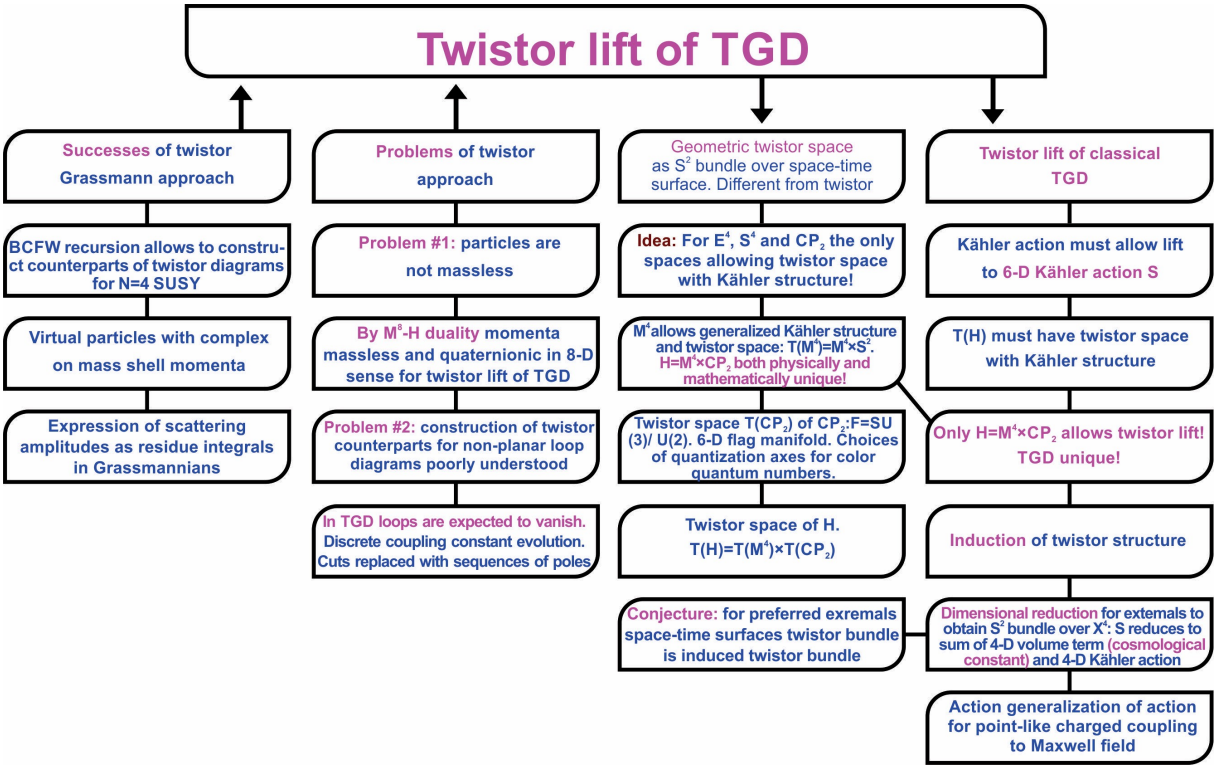

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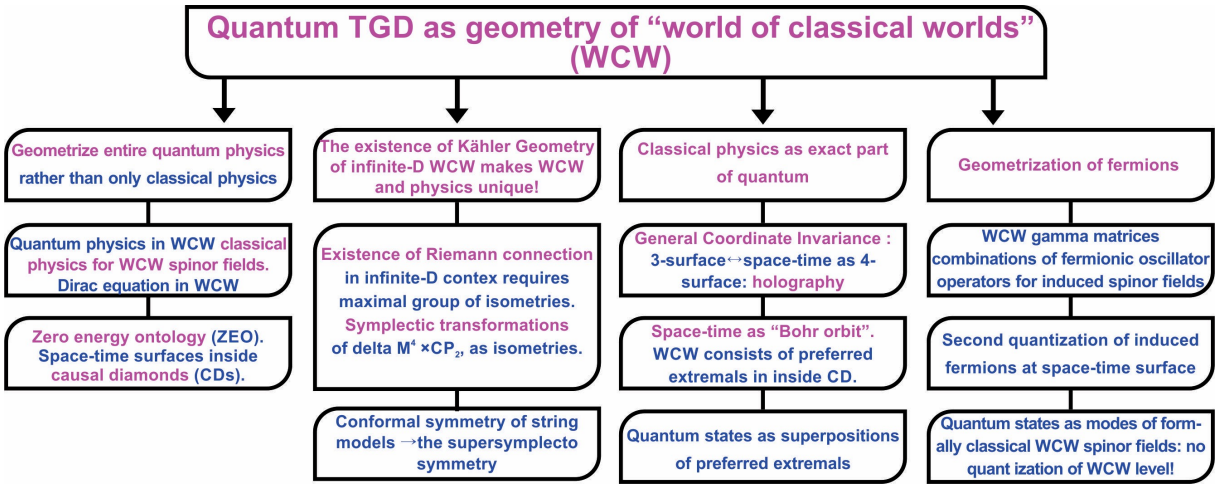

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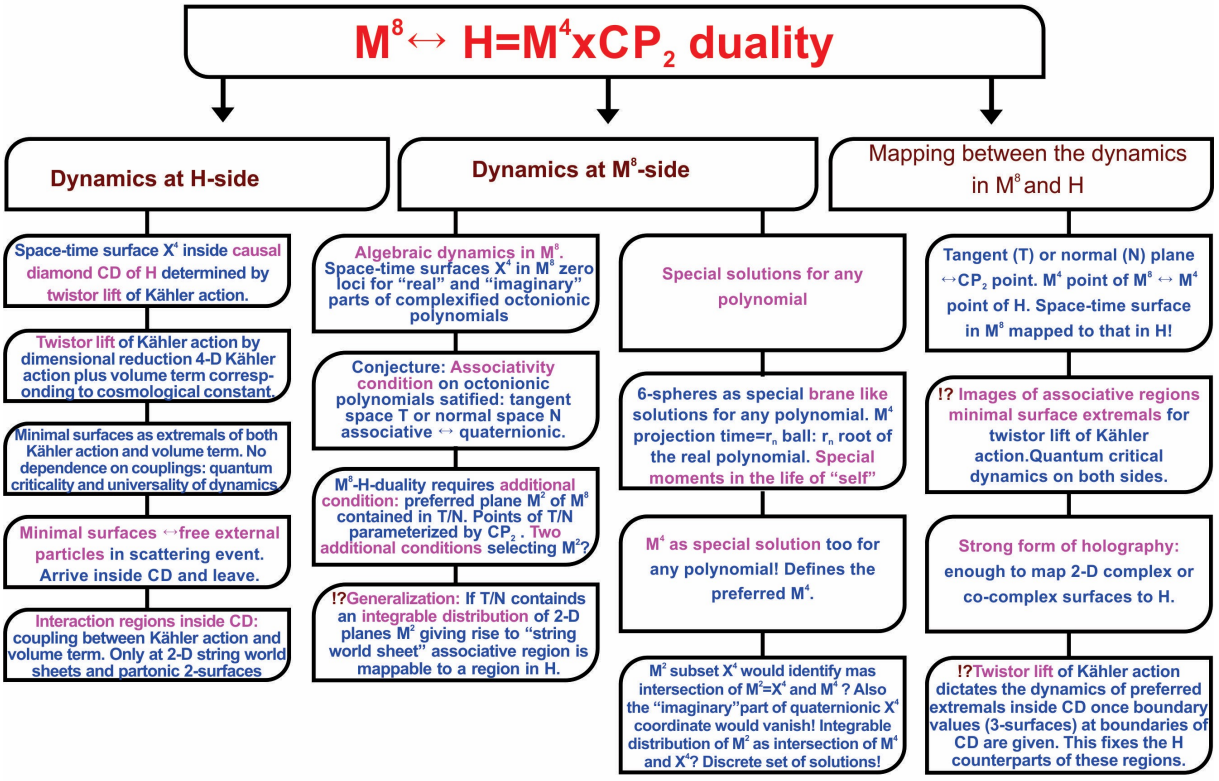
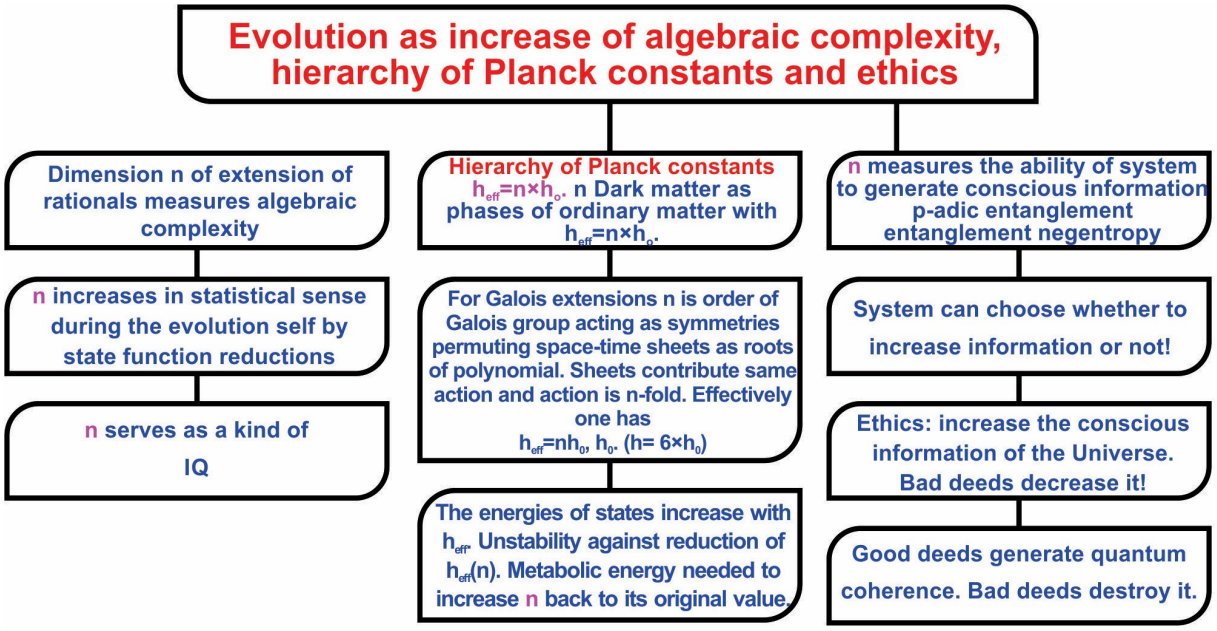


Figure 26: $M^8 - H$ duality



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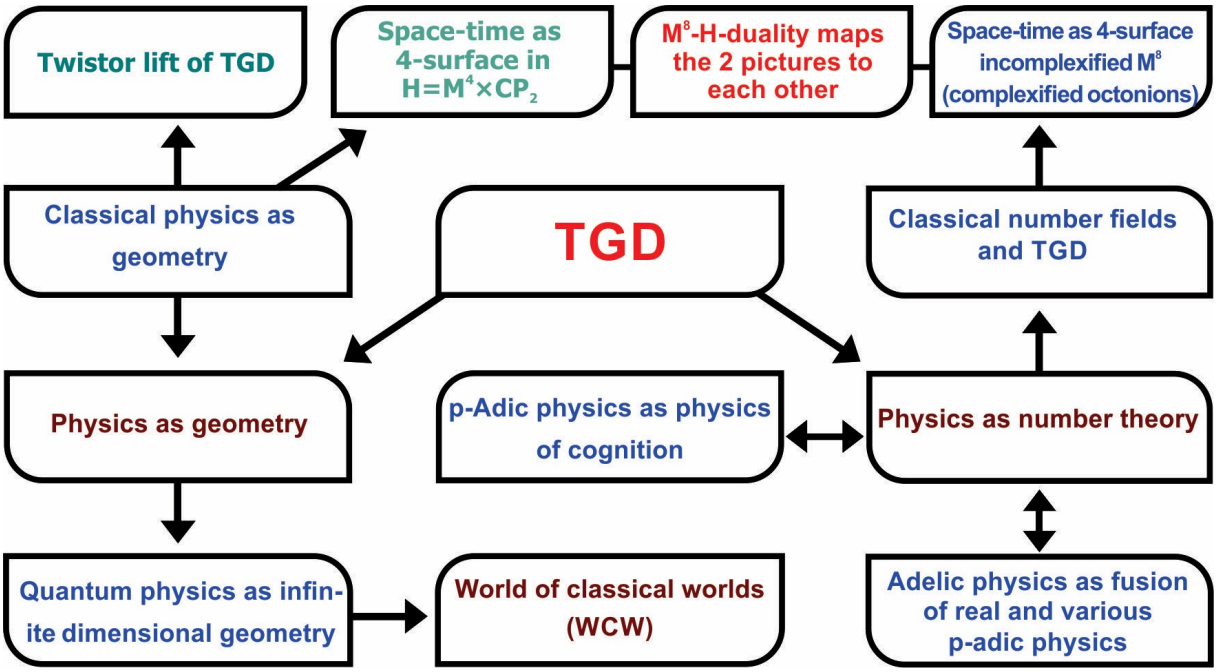

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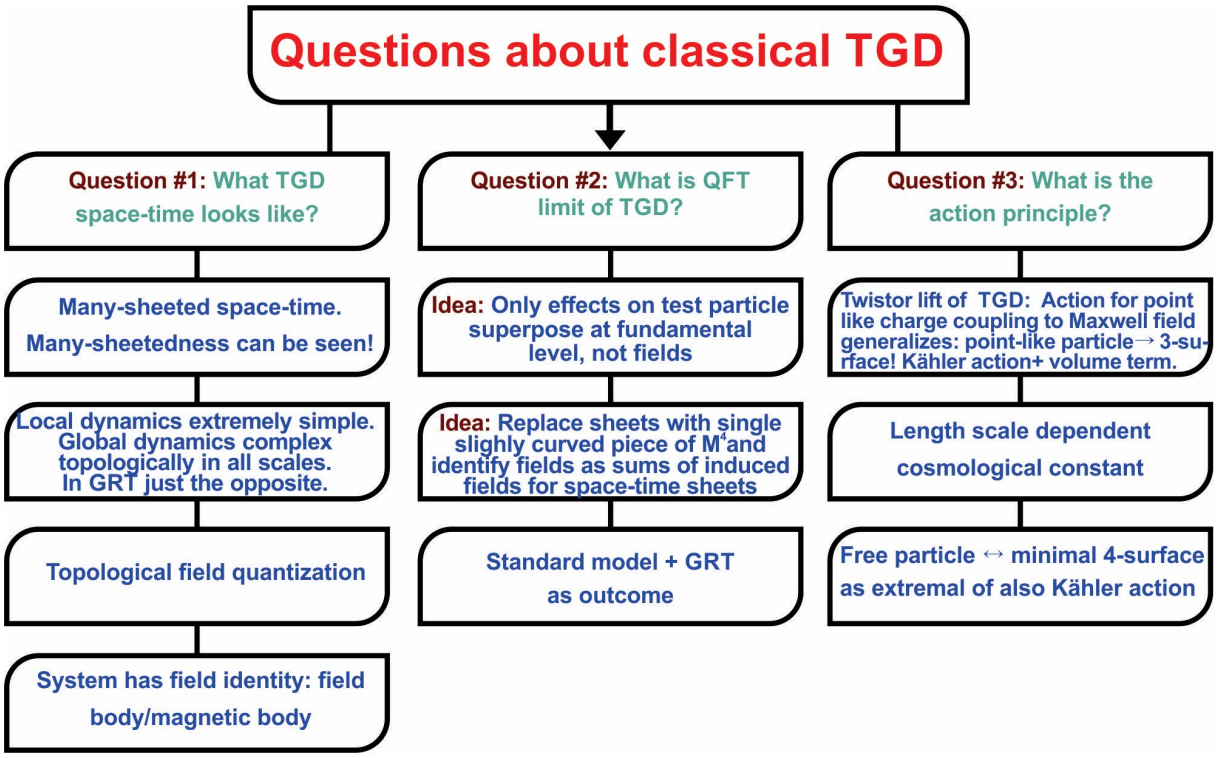

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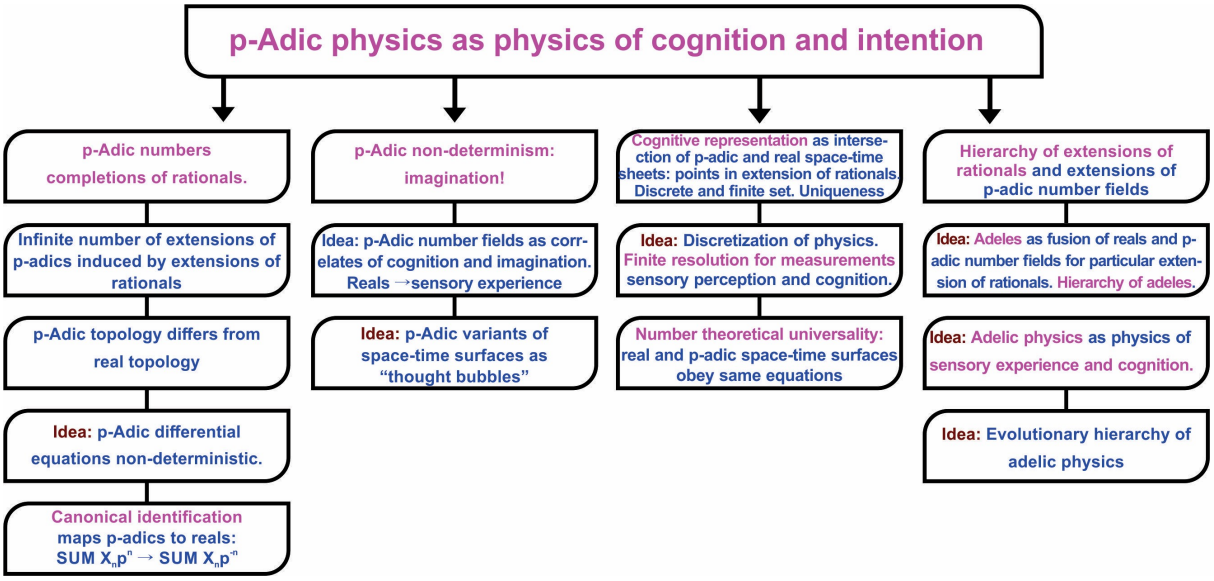

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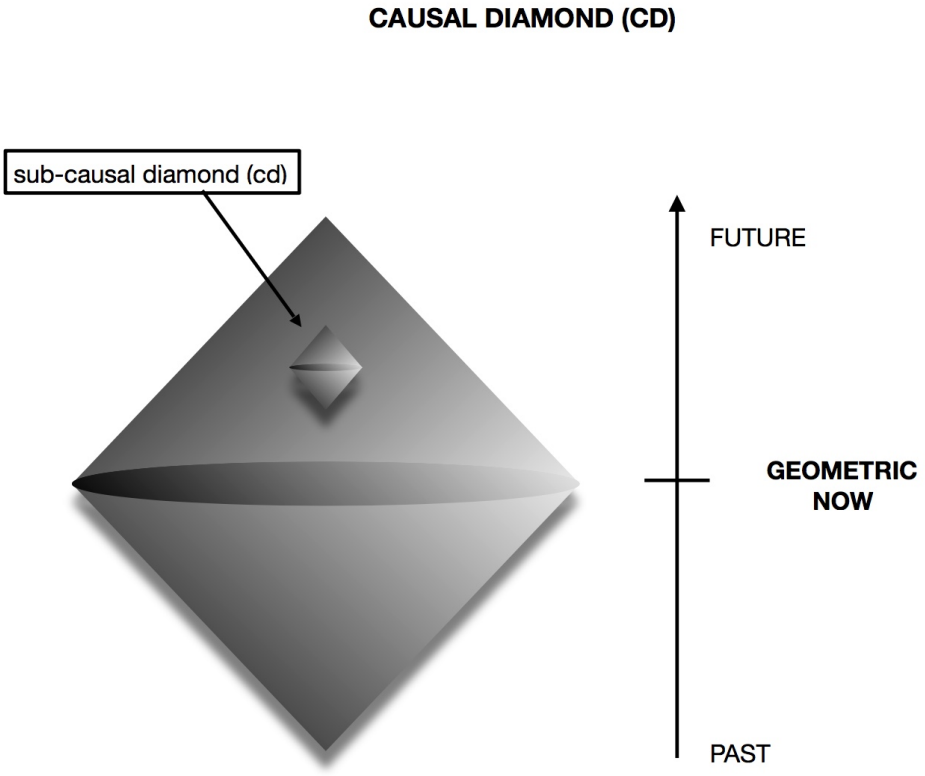

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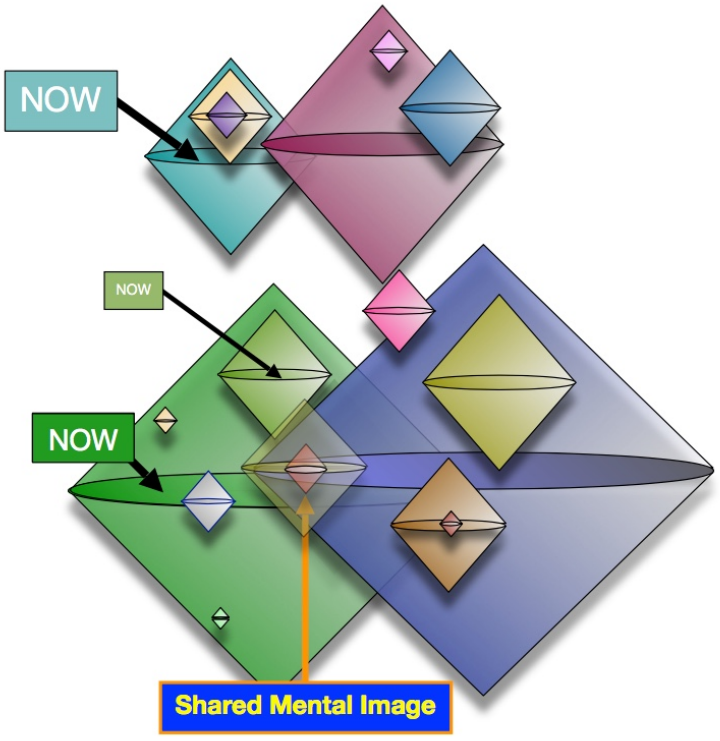

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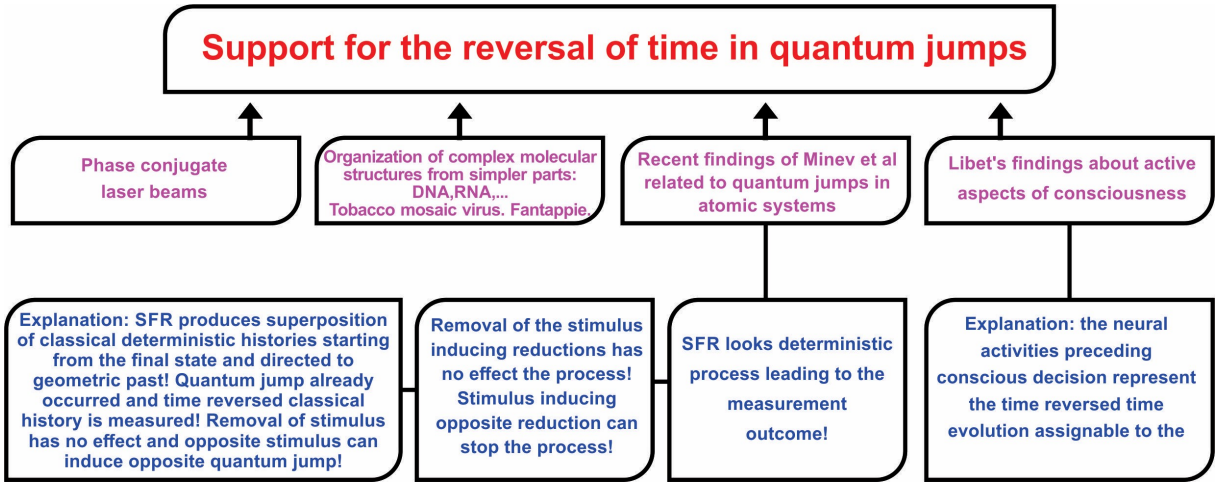

Figure 33: Time reversal occurs in BSFR

ACKNOWLEDGEMENTS

Neither TGD nor these books would exist without the help and encouragement of many people. The friendship with Heikki and Raija Haila and their family and Kalevi and Ritva Tikkanen and their family have been kept me in contact with the everyday world and without this friendship I would not have survived through these lonely 45 lonely years most of which I have remained unemployed as a scientific dissident. I am happy that my children have understood my difficult position and like my friends have believed that what I am doing is something valuable although I have not received any official recognition for it.

During the last decade Tapio Tammi has helped me quite concretely by providing the necessary computer facilities and being one of the few persons in Finland with whom to discuss my work. Pertti Kärkkäinen is my old physicist friend and has provided continued economic support for a long time. I have also had stimulating discussions with Samuli Penttinen who has also helped to get through the economical situations in which there seemed to be no hope. The continual updating of fifteen online books means quite a heavy bureaucracy at the level of bits and without a systemization one ends up with endless copying and pasting and internal consistency is soon lost. Tommi Ullgren has provided both economic support and encouragement during years. Pekka Rapinoja has offered his help in this respect and I am especially grateful to him for my Python skills.

During the last five years I have had inspiring discussions with many people in Finland interested in TGD. We have had video discussions with Sini Kunnas and had podcast discussions with Marko Manninen related to the TGD based view of physics and consciousness. Marko has also helped in the practical issues related to computers and quite recently he has done a lot of testing of chatGPT helping me to get an overall view of what it is. The discussions in a Zoom group involving Marko Manninen, Tuomas Sorakivi and Rode Majakka have given me the valuable opportunity to clarify my thoughts.

The collaboration with Lian Sidorov was extremely fruitful and she also helped me to survive economically through the hardest years. The participation in CASYS conferences in Liege has been an important window to the academic world and I am grateful for Daniel Dubois and Peter Marcer for making this participation possible. The discussions and collaboration with Eduardo de Luna and Istvan Dienes stimulated the hope that the communication of new vision might not be a mission impossible after all. Also blog discussions have been very useful. During these years I have received innumerable email contacts from people around the world. I am grateful to Mark McWilliams, Paul Kirsch, Gary Ehlenberg, and Ulla Matfolk and many others for providing links to possibly interesting websites and articles. We have collaborated with Peter Gariaev and Reza Rastmanesh. These contacts have helped me to avoid the depressive feeling of being some kind of Don Quixote of Science and helped me to widen my views: I am grateful for all these people.

In the situation in which the conventional scientific communication channels are strictly closed it is important to have some loop hole through which the information about the work done can at least in principle leak to the public through the iron wall of academic censorship. Without any exaggeration I can say that without the world wide web I would not have survived as a scientist nor as an individual. Homepage and blog are however not enough since only the formally published result is a result in recent day science. Publishing is however impossible without direct support from power holders- even in archives like arXiv.org.

Situation changed as Andrew Adamatsky proposed the writing of a book about TGD when I had already gotten used to the thought that my work would not be published during my lifetime. The Prespacetime Journal and two other journals related to quantum biology and consciousness - all of them founded by Huping Hu - have provided this kind of loophole. In particular, Dainis Zeps,

Phil Gibbs, and Arkadiusz Jadczyk deserve my gratitude for their kind help in the preparation of an article series about TGD catalyzing a considerable progress in the understanding of quantum TGD. Also the viXra archive founded by Phil Gibbs and its predecessor Archive Freedom have been of great help: Victor Christianto deserves special thanks for doing the hard work needed to run Archive Freedom. Also the Neuroquantology Journal founded by Sultan Tarlaci deserves a special mention for its publication policy.

And last but not least: there are people who experience as a fascinating intellectual challenge to spoil the practical working conditions of a person working with something which might be called unified theory: I am grateful for the people who have helped me to survive through the virus attacks, an activity which has taken roughly one month per year during the last half decade and given a strong hue of grey to my hair.

For a person approaching his 73th birthday it is somewhat easier to overcome the hard feelings due to the loss of academic human rights than for an inpatient youngster. Unfortunately the economic situation has become increasingly difficult during the twenty years after the economic depression in Finland which in practice meant that Finland ceased to be a constitutional state in the strong sense of the word. It became possible to depose people like me from society without fear about public reactions and the classification as dropout became a convenient tool of ridicule to circumvent the ethical issues. During the period when the right wing held political power this trend was steadily strengthening and the situation is the same as I am writing this. In this kind of situation the concrete help from individuals has been and will be of utmost importance. Against this background it becomes obvious that this kind of work is not possible without the support from outside and I apologize for not being able to mention all the people who have helped me during these years.

Karkkila, August 30, 2023, Finland

Matti Pitkänen

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Introduction

1.1 Basic Ideas of Topological Geometrodynamics (TGD)

Standard model describes rather successfully both electroweak and strong interactions but sees them as totally separate and contains a large number of parameters which it is not able to predict. For about four decades ago unified theories known as Grand Unified Theories (GUTs) trying to understand electroweak interactions and strong interactions as aspects of the same fundamental gauge interaction assignable to a larger symmetry group emerged. Later superstring models trying to unify even gravitation and strong and weak interactions emerged. The shortcomings of both GUTs and superstring models are now well-known. If TGD - whose basic idea emerged towards the end of 1977 - would emerge now it would be seen as an attempt to solve the difficulties of these approaches to unification.

The basic physical picture behind the geometric vision of TGD corresponds to a fusion of two rather disparate approaches: namely TGD as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model. After 1995 number theoretic vision started to develop and was initiated by the success of mass calculations based on p-adic thermodynamics. Number theoretic vision involves all number fields and is complementary to the geometric vision: one can say that this duality is analogous to momentum-position duality of wave mechanics. TGD can be also regarded as topological quantum theory in a very general sense as already the attribute "Topological" in "TGD" makes clear. Space-time surfaces as minimal surfaces can be regarded as representatives of homology equivalence classes and p-adic topologies generalize the notion of local topology and apply to the description of correlates of cognition.

1.1.1 Geometric Vision Very Briefly

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [K1].

The basic vision and its relationship to existing theories is now rather well understood.

1. Space-times are representable as 4-surfaces in the 8-dimensional embedding space $H = M^4 \times CP_2$, where M^4 is 4-dimensional (4-D) Minkowski space and CP_2 is 4-D complex projective space (see Appendix).

2. Induction procedure (a standard procedure in fiber bundle theory, see Appendix) allows to geometrize various fields. Space-time metric characterizing gravitational fields corresponds to the induced metric obtained by projecting the metric tensor of H to the space-time surface. Electroweak gauge potentials are identified as projections of the components of CP_2 spinor connection to the space-time surface, and color gauge potentials as projections of CP_2 Killing vector fields representing color symmetries. Also spinor structure can be induced: induced spinor gamma matrices are projections of gamma matrices of H and induced spinor fields just H spinor fields restricted to space-time surface. Spinor connection is also projected. The interpretation is that distances are measured in embedding space metric and parallel translation using spinor connection of embedding space.

Twistor lift of TGD means that one can lift space-time surfaces in H to 6-D surfaces a analogs of twistor space of space-time surface in the Cartesian product of the twistor spaces of M^4 and CP_2, which are the only 4-manifolds allowing twistor space with Kähler structure [A30]. The twistor structure would be induced in some sense, and should coincide with that associated with the induced metric. Clearly, the 2-spheres defining the fibers of twistor spaces of M^4 and CP_2 must allow identification: this 2-sphere defines the S^2 fiber of the twistor space of the space-time surface. This poses a constraint on the embedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces. The existence of Kähler structure allows to lift 4-D Kähler action to its 6-D counterparts and the 6-D counterpart of twistor space is obtained by its dimensional reduction so that one obtains a sphere bundle. This makes possible twistorialization for all space-time surfaces: in general relativity the general metric does not allow this.

3. A geometrization of quantum numbers is achieved. The isometry group of the geometry of CP_2 codes for the color gauge symmetries of strong interactions. Vierbein group codes for electroweak symmetries, and explains their breaking in terms of CP_2 geometry so that standard model gauge group results. There are also important deviations from the standard model: color quantum numbers are not spin-like but analogous to orbital angular momentum: this difference is expected to be seen only in CP_2 scale. In contrast to GUTs, quark and lepton numbers are separately conserved and family replication has a topological explanation in terms of topology of the partonic 2-surface carrying fermionic quantum numbers.

   M^4 and CP_2 are unique choices for many other reasons. For instance, they are the unique 4-D space-times allowing twistor space with Kähler structure. M^4 light-cone boundary allows a huge extension of 2-D conformal symmetries. M^4 and CP_2 allow quaternionic structures. Therefore standard model symmetries have number theoretic meaning.

4. Induced gauge potentials are expressible in terms of embedding space coordinates and their gradients and general coordinate invariance implies that there are only 4 field-like variables locally. Situation is thus extremely simple mathematically. The objection is that one loses linear superposition of fields. The resolution of the problem comes from the generalization of the concepts of particle and space-time.

   Space-time surfaces can be also particle like having thus finite size. In particular, space-time regions with Euclidian signature of the induced metric (temporal and spatial dimensions in the same role) emerge and have interpretation as lines of generalized Feynman diagrams. Particles in space-time can be identified as a topological inhomogeneities in background space-time surface which looks like the space-time of general relativity in long length scales.

   One ends up with a generalization of space-time surface to many-sheeted space-time with space-time sheets having extremely small distances of about 10^4 Planck lengths (CP_2 size). As one adds a particle to this kind of structure, it touches various space-time sheets and thus interacts with the associated classical fields. Their effects superpose linearly in good approximation and linear superposition of fields is replaced with that for their effects.

   This resolves the basic objection. It also leads to the understanding of how the space-time of general relativity and quantum field theories emerges from TGD space-time as effective space-time when the sheets of many-sheeted space-time are lumped together to form a region of Minkowski space with metric replaced with a metric identified as the sum of empty Minkowski metric and deviations of the metrics of sheets from empty Minkowski metric. Gauge potentials are identified as sums of the induced gauge potentials. TGD is therefore a microscopic theory from which the standard model and general relativity follow as a topological simplification, however forcing a dramatic increase of the number of fundamental field variables.

5. A further objection is that classical weak fields identified as induced gauge fields are long ranged and should cause large parity breaking effects due to weak interactions. These effects are indeed observed but only in living matter. The basic problem is that one has long ranged classical electroweak gauge fields. The resolution of the problem is that the quantum averages of induced weak and color gauge fields vanish due to the fact that color rotations affect both space-time surfaces and induced weak and color fields. Only the averages of

electromagnetic fields are nonvanishing. The correlations functions for weak fields are nonvanishing below Compton lengths of weak bosons. In living matter large values of effective Planck constant labelling phases of ordinary matter identified as dark matter make possible long ranged weak fields and color fields.

6. General coordinate invariance requires holography so that space-time surfaces are analogous to Bohr orbits for particles identified as 3-surfaces. Bohr orbit property would be naturally realized by a 4-D generalization of holomorphy of string world sheets and implies that the space-time surfaces are minimal surfaces apart from singularities. This holds true for any action as long as it is general coordinate invariant and constructible in terms of the induced geometry. String world sheets and light-like orbits of partonic 2-surfaces correspond to singularities at which the minimal surface property of the space-time surfaces realizing the preferred extremal property fails. Preferred extremals are not completely deterministic, which implies what I call zero energy ontology (ZEO) meaning that the Bohr orbits are the fundamental objects. This leads to a solution of the basic paradox of quantum measurement theory. Also the mathematically ill-defined path integral disappears and leaves only the well-defined functional integral over the Bohr orbits.

7. A string model-like picture emerges from TGD and one ends up with a rather concrete view about the topological counterpart of Feynman diagrammatics. The natural stringy action would be given by the string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant could be present as a fundamental constant in string action and the ratio $\hbar/G/R^2$ would be determined by quantum criticality conditions. The hierarchy of Planck constants $h_{eff}/h = n$ assigned to dark matter in TGD framework would allow to circumvent the objection that only objects of length of order Planck length are possible since string tension given by $T = 1/\hbar_{eff}G$ apart from numerical factor could be arbitrary small. This would make possible gravitational bound states as partonic 2-surfaces as structures connected by strings and solve the basic problem of superstring theories. This option allows the natural interpretation of M^4 type vacuum extremals with CP_2 projection, which is Lagrange manifold as good approximations for space-time sheets at macroscopic length scales. String area does not contribute to the Kähler function at all.

   Whether induced spinor fields associated with Kähler-Dirac action and de-localized inside the entire space-time surface should be allowed remains an open question: super-conformal symmetry strongly suggests their presence. A possible interpretation for the corresponding spinor modes could be in terms of dark matter, sparticles, and hierarchy of Planck constants.

It is perhaps useful to make clear what TGD is not and also what new TGD can give to physics.

1. TGD is *not* just General Relativity made concrete by using embeddings: the 4-surface property is absolutely essential for unifying standard model physics with gravitation and to circumvent the incurable conceptual problems of General Relativity. The many-sheeted space-time of TGD gives rise only at the macroscopic limit to GRT space-time as a slightly curved Minkowski space. TGD is *not* a Kaluza-Klein theory although color gauge potentials are analogous to gauge potentials in these theories.

   TGD space-time is 4-D and its dimension is due to completely unique conformal properties of light-cone boundary and 3-D light-like surfaces implying enormous extension of the ordinary conformal symmetries. Light-like 3-surfaces represent orbits of partonic 2-surfaces and carry fundamental fermions at 1-D boundaries of string world sheets. TGD is *not* obtained by performing Poincare gauging of space-time to introduce gravitation and is plagued by profound conceptual problems.

2. TGD is *not* a particular string model although string world sheets emerge in TGD very naturally as loci for spinor modes: their 2-dimensionality makes among other things possible quantum deformation of quantization known to be physically realized in condensed matter, and conjectured in TGD framework to be crucial for understanding the notion of finite measurement resolution. Hierarchy of objects of dimension up to 4 emerge from TGD: this obviously means analogy with branes of super-string models.

TGD is *not* one more item in the collection of string models of quantum gravitation relying on Planck length mystics. Dark matter becomes an essential element of quantum gravitation and quantum coherence in astrophysical scales is predicted just from the assumption that strings connecting partonic 2-surfaces are responsible for gravitational bound states.

TGD is *not* a particular string model although AdS/CFT duality of super-string models generalizes due to the huge extension of conformal symmetries and by the identification of WCW gamma matrices as Noether super-charges of super-symplectic algebra having a natural conformal structure.

3. TGD is *not* a gauge theory. In TGD framework the counterparts of also ordinary gauge symmetries are assigned to super-symplectic algebra (and its Yangian [A5] [B12, B9, B10]), which is a generalization of Kac-Moody algebras rather than gauge algebra and suffers a fractal hierarchy of symmetry breakings defining hierarchy of criticalities. TGD is *not* one more quantum field theory like structure based on path integral formalism: path integral is replaced with functional integral over 3-surfaces, and the notion of classical space-time becomes an exact part of the theory. Quantum theory becomes formally a purely classical theory of WCW spinor fields: only state function reduction is something genuinely quantal.

4. TGD view about spinor fields is *not* the standard one. Spinor fields appear at three levels. Spinor modes of the embedding space are analogs of spinor modes characterizing incoming and outgoing states in quantum field theories. Induced second quantized spinor fields at space-time level are analogs of stringy spinor fields. Their modes are localized by the well-definedness of electro-magnetic charge and by number theoretic arguments at string world sheets. Kähler-Dirac action is fixed by supersymmetry implying that ordinary gamma matrices are replaced by what I call Kähler-Dirac gamma matrices - this something new. WCW spinor fields, which are classical in the sense that they are not second quantized, serve as analogs of fields of string field theory and imply a geometrization of quantum theory.

5. TGD is in some sense an extremely conservative geometrization of entire quantum physics: *no* additional structures such as gauge fields as independent dynamical degrees of freedom are introduced: Kähler geometry and associated spinor structure are enough. "Topological" in TGD should not be understood as an attempt to reduce physics to torsion (see for instance [B8]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of the everyday world represent non-trivial topology of space-time in the TGD Universe.

6. Twistor space - or rather, a generalization of twistor approach replacing masslessness in 4-D sense with masslessness in 8-D sense and thus allowing description of also massive particles - emerged originally as a technical tool, and its Kähler structure is possible only for $H = M^4 \times CP_2$. It however turned out that much more than a technical tool is in question. What is genuinely new is the infinite-dimensional character of the Kähler geometry making it highly unique, and its generalization to p-adic number fields to describe correlates of cognition. Also the hierarchy of Planck constants $h_{eff} = n \times h$ reduces to the quantum criticality of the TGD Universe and p-adic length scales and Zero Energy Ontology represent something genuinely new.

The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last 45 years to the realization of this dream and this has resulted in 26 online books about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology.

A collection of 30 online books is now (August 2023) under preparation. The goal is to minimize overlap between the topics of the books and make the focus of a given book sharper.

1.1.2 Two Visions About TGD as Geometrization of Physics and Their Fusion

As already mentioned, TGD as a geometrization of physics can be interpreted both as a modification of general relativity and generalization of string models.

TGD as a Poincare Invariant Theory of Gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_{\times} CP_2$, where M^4 denotes Minkowski space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [A22, A29, A17, A27].

The identification of the space-time as a sub-manifold [A24, A38] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity.

It soon however turned out that sub-manifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

The choice of H is unique from the condition that TGD has standard model symmetries. Also number theoretical vision selects $H = M^4 \times CP_2$ uniquely. M^4 and CP_2 are also unique spaces allowing twistor space with Kähler structure.

TGD as a Generalization of the Hadronic String Model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

This decay vertex does not however correspond to a direct generalization of trouser vertex of string models. Indeed, the important difference between TGD and string models is that the analogs of string world sheet diagrams do not describe particle decays but the propagation of particles via different routes. Particle reactions are described by generalized Feynman diagrams for which 3-D light-like surface describing particle propagating join along their ends at vertices. As 4-manifolds the space-time surfaces are therefore singular like Feynman diagrams as 1-manifolds.

Quite recently, it has turned out that fermionic strings inside space-time surfaces define an exact part of quantum TGD and that this is essential for understanding gravitation in long length scales. Also the analog of AdS/CFT duality emerges in that the Kähler metric can be defined either in terms of Kähler function identifiable as Kähler action assignable to Euclidian space-time regions or Kähler action + string action assignable to Minkowskian regions.

The recent view about construction of scattering amplitudes is very "stringy". By strong form of holography string world sheets and partonic 2-surfaces provide the data needed to construct scattering amplitudes. Space-time surfaces are however needed to realize quantum-classical correspondence necessary to understand the classical correlates of quantum measurement. There is a huge generalization of the duality symmetry of hadronic string models.

The proposal is that scattering amplitudes can be regarded as sequences of computational operations for the Yangian of super-symplectic algebra. Product and co-product define the basic vertices and realized geometrically as partonic 2-surfaces and algebraically as multiplication for the elements of Yangian identified as super-symplectic Noether charges assignable to strings. Any computational sequences connecting given collections of algebraic objects at the opposite boundaries of causal diamond (CD) produce identical scattering amplitudes.

Fusion of the Two Approaches via a Generalization of the Space-Time Concept

The problem is that the two approaches to TGD seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically

trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there could be "vapor phase" that is a "gas" of particle like 3-surfaces and string like objects (counterpart of the "baby universes" of GRT) and the non-conservation of energy in GRT corresponds to the transfer of energy between different sheets of the space-time and possible existence vapour phase.

. What one obtains is what I have christened as many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig. 16.4** in the appendix of this book). One particular aspect is topological field quantization meaning that various classical fields assignable to a physical system correspond to space-time sheets representing the classical fields to that particular system. One can speak of the field body of a particular physical system. Field body consists of topological light rays, and electric and magnetic flux quanta. In Maxwell's theory the physical system does not possess this kind of field identity. The notion of the magnetic body is one of the key players in TGD inspired theory of consciousness and quantum biology. The existence of monopole flux tubes requiring no current as a source of the magnetic field makes it possible to understand the existence of magnetic fields in cosmological and astrophysical scales.

This picture became more detailed with the advent of zero energy ontology (ZEO). The basic notion of ZEO is causal diamond (CD) identified as the Cartesian product of CP_2 and of the intersection of future and past directed light-cones and having scale coming as an integer multiple of CP_2 size is fundamental. CDs form a fractal hierarchy and zero energy states decompose to products of positive and negative energy parts assignable to the opposite boundaries of CD defining the ends of the space-time surface. The counterpart of zero energy state in positive energy ontology is the pair of initial and final states of a physical event, say particle reaction.

At space-time level ZEO means that 3-surfaces are pairs of space-like 3-surfaces at the opposite light-like boundaries of CD. Since the extremals of Kähler action connect these, one can say that by holography the basic dynamical objects are the space-time surface connecting these 3-surfaces and identifiable as analogs of Bohr orbits. This changes totally the vision about notions like self-organization: self-organization by quantum jumps does not take for a 3-D system but for the entire 4-D field pattern associated with it.

General Coordinate Invariance (GCI) allows to identify the basic dynamical objects as space-like 3-surfaces at the ends of space-time surface at boundaries of CD: this means that space-time surface is analogous to Bohr orbit. An alternative identification of the lines of generalized Feynman diagrams is as light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian . Also the Euclidian 4-D regions can have a similar interpretation. The requirement that the two interpretations are equivalent, leads to a strong form of General Coordinate Invariance. The outcome is effective 2-dimensionality stating that the partonic 2-surfaces identified as intersections of the space-like ends of space-time surface and light-like wormhole throats are the fundamental objects. That only effective 2-dimensionality is in question is due to the effects caused by the failure of strict determinism of Kähler action. In finite length scale resolution these effects can be neglected below UV cutoff and above IR cutoff. One can also speak about a strong form of holography.

The understanding of the super symplectic invariance leads to the proposal that super symplectic algebra and other Kac-Moody type algebras labelled by non-negative multiples of basic conformal weights allow a hierarchy of symmetry breakings in which the analog of gauge symmetry breaks down to a genuine dynamical symmetry. This gives rise to fractal hierarchies of algebras and symmetry breakings. This breaking can occur also for ordinary conformal algebras if one restricts the conformal weights to be non-negative integers.

1.1.3 Basic Objections

Objections are the most powerful tool in theory building. The strongest objection against TGD is the observation that all classical gauge fields are expressible in terms of four embedding space coordinates only- essentially CP_2 coordinates. The linear superposition of classical gauge fields taking place independently for all gauge fields is lost. This would be a catastrophe without many-

sheeted space-time. Instead of gauge fields, only the effects such as gauge forces are superposed. Particles topologically condense to several space-time sheets simultaneously and experience the sum of gauge forces. This transforms the weakness to extreme economy: in a typical unified theory the number of primary field variables is countered in hundreds if not thousands, now it is just four.

Second objection is that TGD space-time is quite too simple as compared to GRT space-time due to the embeddability to 8-D embedding space. One can also argue that Poincare invariant theory of gravitation cannot be consistent with General Relativity. The above interpretation makes it possible to understand the relationship to GRT space-time and how the Equivalence Principle (EP) follows from Poincare invariance of TGD. The interpretation of GRT space-time is as effective space-time obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrics of the space-time sheets from Minkowski metric. Poincare invariance strongly suggests classical EP for the GRT limit in long length scales at least. One can also consider other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with a very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of the standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

Topological Field Quantization

Topological field quantization distinguishes between TGD based and more standard - say Maxwellian - notion of field. In Maxwell's fields created by separate systems superpose and one cannot tell which part of field comes from which system except theoretically. In TGD these fields correspond to different space-time sheets and only their effects on test particle superpose. Hence physical systems have well-defined field identifies - field bodies - in particular magnetic bodies.

The notion of magnetic body carrying dark matter with non-standard large value of Planck constant has become central concept in TGD inspired theory of consciousness and living matter, and by starting from various anomalies of biology one ends up to a rather detailed view about the role of magnetic body as intentional agent receiving sensory input from the biological body and controlling it using EEG and its various scaled up variants as a communication tool. Among other thins this leads to models for cell membrane, nerve pulse, and EEG.

1.1.4 Quantum TGD as Spinor Geometry of World of Classical Worlds

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and have been the following ones.

World of Classical Worlds

The notion of WCW reduces the interacting quantum theory to a theory of free WCW spinor fields.

1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude identified as WCW spinor in the configuration space CH ("world of classical worlds", WCW) consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included.

2. 4-D general coordinate invariance forces holography and replaces the ill-defined path integral over all space-time surfaces with a discrete sum over 4-D analogs of Bohr orbits for particles identified as 3-surfaces. Holography means that basic objects are these analogs of Bohr orbits. Since there is no quantization at the level of WCW, one has an analog of wave mechanics with point-like particles replaced with 4-D Bohr orbits.

3. One must geometrize WCW as the space of Bohr orbits. In an infinite-dimensional situation the existence of geometry requires maximal symmetries already in the case of loop spaces. Physics is unique from its mathematical existence.

   WCW is endowed with metric and spinor structure so that one can define various metric related differential operators, say Dirac operators, appearing in the field equations of the theory [1]

Identification of Kähler function

The evolution of these basic ideas has been rather slow but has gradually led to a rather beautiful vision. One of the key problems has been the definition of Kähler function. Kähler function is Kähler action for a preferred extremal assignable to a given 3-surface but what this preferred extremal is? The obvious first guess was as absolute minimum of Kähler action but could not be proven to be right or wrong. One big step in the progress was boosted by the idea that TGD should reduce to almost topological QFT in which braids would replace 3-surfaces in finite measurement resolution, which could be inherent property of the theory itself and imply discretization at partonic 2-surfaces with discrete points carrying fermion number.

It took long time to realize that there is no discretization in 4-D sense - this would lead to difficulties with basic symmetries. Rather, the discretization occurs for the parameters characterizing co-dimension 2 objects representing the information about space-time surface so that they belong to some algebraic extension of rationals. These 2-surfaces - string world sheets and partonic 2-surfaces - are genuine physical objects rather than a computational approximation. Physics itself approximates itself, one might say! This is of course nothing but strong form of holography.

1. TGD as almost topological QFT vision suggests that Kähler action for preferred extremals reduces to Chern-Simons term assigned with space-like 3-surfaces at the ends of space-time (recall the notion of causal diamond (CD)) and with the light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. Minkowskian and Euclidian regions would give at wormhole throats the same contribution apart from coefficients and in Minkowskian regions the $\sqrt{g_4}$ factorc coming from metric would be imaginary so that one would obtain sum of real term identifiable as Kähler function and imaginary term identifiable as the ordinary Minkowskian action giving rise to interference effects and stationary phase approximation central in both classical and quantum field theory.

   Imaginary contribution - the presence of which I realized only after 33 years of TGD - could also have topological interpretation as a Morse function. On physical side the emergence of Euclidian space-time regions is something completely new and leads to a dramatic modification of the ideas about black hole interior.

2. The way to achieve the reduction to Chern-Simons terms is simple. The vanishing of Coulomb contribution to Kähler action is required and is true for all known extremals if one makes a general ansatz about the form of classical conserved currents. The so called weak form of electric-magnetic duality defines a boundary condition reducing the resulting 3-D terms to Chern-Simons terms. In this way almost topological QFT results. But only "almost" since the Lagrange multiplier term forcing electric-magnetic duality implies that Chern-Simons action for preferred extremals depends on metric.

WCW spinor fields

Classical WCW spinor fields are analogous to Schrödinger amplitudes and the construction of WCW Kähler geometry reduces to the second quantization of free spinor fields of H.

[1] There are four kinds of Dirac operators in TGD. The geometrization of quantum theory requires Kähler metric definable either in terms of Kähler function identified as a the bosonic action for Euclidian space-time regions or as anti-commutators for WCW gamma matrices identified as conformal Noether super-charges associated with the second quantized modified Dirac action consisting of string world sheet term and possibly also modified Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

1. The WCW metric is given by anticommutators of WCW gamma matrices which also have interpretation as supercharges assignable to the generators of WCW isometries and allowing expression as non-conserved Noether charges. Holography implies zero energy ontology (ZEO) meaning that zero energy states are superpositions of Bohr orbits connecting boundaries of causal diamond (CD). CDs form a fractal hierarchy and their space forming the spine of WCW is finite-dimensional and can be geometrized. The alternative interpretation is as a superposition of pairs of ordinary 3-D fermionic states assignable to the ends of the space-time surfaces.

2. There are several Dirac operators. WCW Dirac operator D_{WCW} appears in Super-symplectic gauge conditions analogous to Super Virasoro conditions. The algebraic variant of the H Dirac operator D_H appears in fermionic correlation functions: this is due to the fact that free fermions appearing as building bricks of WCW gamma matrices are modes of D_H. The modes of ${}_DH$ define the ground states of super-symplectic representations. There is also the modified Dirac operator D_{X^4} acting on the induced spinors at space-time surfaces and it is dictated by symmetry one the action fixing the space-time surfaces as Bohr orbits is fixed. D_H is needed since it determines the expressions of WCW gamma matrices as Noether charges assignable to 3-surfaces at the ends of WCW.

The role of modified Dirac action

1. By quantum classical correspondence, the construction of WCW spinor structure in sectors assignable to CDs reduces to the second quantization of the induced spinor fields of H. The basic action is so called modified Dirac action in which gamma matrices are replaced with the modified) gamma matrices defined as contractions of the canonical momentum currents of the bosonic action defining the space-time surfaces with the embedding space gamma matrices. In this way one achieves super-conformal symmetry and conservation of fermionic currents among other things and a consistent Dirac equation.

   Modified Dirac action is needed to define WCW gamma matrices as super charges assignable to WCW isometry generators identified as generators of symplectic transformations and by holography are needed only at the 3-surface at the boundaries of WCW. It is important to notice that the modified Dirac equation does not determine propagators since induced spinor fields are obtained from free second quantized spinor fields of H. This means enormous simplification and makes the theory calculable.

2. An important interpretational problem relates to the notion of the induced spinor connection. The presence of classical W boson fields is in conflict with the classical conservation of em charge since the coupling to classical W fields changes em charge.

   One way out of the problem is the fact that the quantum averages of weak and gluon fields vanish unlike the quantum average of the em field. This leads to a rather precise understanding of electroweak symmetry breaking as being due the fact that color symmetries rotate space-time surfaces and also affect the induced weak fields.

   One can also consider a stronger condition. If one requires that the spinor modes have well-defined em charge, one must assume that the modes in the generic situation are localized at 2-D surfaces - string world sheets or perhaps also partonic 2-surfaces - at which classical W boson fields vanish. Covariantly constant right handed neutrinos generating super-symmetries forms an exception. The vanishing of the Z^0 field is possible for Kähler-Dirac action and should hold true at least above weak length scales. This implies that the string model in 4-D space-time becomes part of TGD. Without these conditions classical weak fields can vanish above weak scale only for the GRT limit of TGD for which gauge potentials are sums over those for space-time sheets.

   The localization would simplify the mathematics enormously and one can solve exactly the Kähler-Dirac equation for the modes of the induced spinor field just like in super string models.

   At the light-like 3-surfaces the signature of the induced metric changes from Euclidian to Minkowskian so that $\sqrt{g_4}$ vanishes. One can pose the condition that the algebraic analog of

the massless Dirac equation is satisfied by the modes of the modified-Dirac action assignable to the Chern-Simons-Kähler action.

1.1.5 Construction of scattering amplitudes

Reduction of particle reactions to space-time topology

Particle reactions are identified as topology changes [A34, A41, A46]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \to B + C$. Classically this corresponds to a path of WCW leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

During years this naïve and very rough vision has of course developed a lot and is not anymore quite equivalent with the original insight. In particular, the space-time correlates of Feynman graphs have emerged from theory as Euclidian space-time regions and the strong form of General Coordinate Invariance has led to a rather detailed and in many respects un-expected visions. This picture forces to give up the idea about smooth space-time surfaces and replace space-time surface with a generalization of Feynman diagram in which vertices represent the failure of manifold property. I have also introduced the word "world of classical worlds" (WCW) instead of rather formal "configuration space". I hope that "WCW" does not induce despair in the reader having tendency to think about the technicalities involved!

Construction of the counterparts of S-matrices

What does one mean with the counterpart of S-matrix in the TGD framework has been a long standing problem. The development of ZEO based quantum measurement theory has led to a rough overall view of the situation.

1. There are two kinds of state function reductions (SFRs). "Small" SFRs (SSFRs) following the TGD counterpart of a unitary time evolution defines a sequence of SFRs, which is analogous to a sequence of repeated quantum measurements associated with the Zeno effect. In wave mechanics nothing happens in these measurements. In quantum optics these measurements correspond to weak measurements. In TGD SSFR affects the zero energy state but leaves the 3-D state at the passive boundary of CD unaffected.

2. In TGD framework each SSFR is preceded by a counterpart of a unitary time evolution, which means dispersion in the space of CDs and unitary time evolution in fermionic degrees of freedom such that the passive boundary of CDs and 3-D states at it are unaffected but a superposition of CDs with varying active boundaries in the space of CDs is formed. In SSFR a localization in the space of CDs occurs such that the active is fixed. In a statistical sense the size of the CD increases and the increasing distance between the tips of the CD gives rise to the arrow of geometric time.

3. Also "big" SFRS (BSFRs) can occur and they correspond to ordinary SFRs. In BSFR the roles of the active and passive boundary are changed and this means that the arrow of time is changed. Big SFR occurs when the SSFR corresponds to a quantum measurement, which does not commute with the operators, which define the states at the passive boundary of CD as their eigenstates. This means a radical deviation from standard quantum measurement theory and has predictions in all scales.

4. One can assign the counterpart of S-matrix to the unitary time evolution between two subsequent SSFRs and also to the counterpart of S-matrix associated with BSFR. At least in the latter case the dimension of the state space can increase since at least BSFRs lead to the increase of the dimension of algebraic extension of rationals assignable to the space-time surface by $M^8 - H$ duality. Unitarity is therefore replaced with isometry.

5. I have also considered the possibility that unitary S-matrix could be replaced in the fermionic degrees of freedom with Kähler metric of the state space satisfying analogs of unitarity conditions but it seems that this is un-necessary and also too outlandish an idea.

The notion of M-matrix

1. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operators associated with WCWs associated with the spaces of CDs with fixed passive boundary: this would define an S-matrix assignable to SFR. Also the analog of S-matrix for the localizations of the states to the active boundary assignable to the BSFR changing the state at the passive boundary of CD is needed.

2. If one allows entanglement between positive and energy parts of the zero energy state but assumes that the states at the passive boundary are fixed, one must introduce the counterpart of the density matrix, or rather its square root. This classical free field theory would dictate what I have called M-matrices defined between positive and negative energy parts of zero energy states which form orthonormal rows of what I call U-matrix as a matrix defined between zero energy states. A biven M-matrix in turn would decompose to a product of a hermitian square root of density matrix and unitary S-matrix.

3. M-matrix would define time-like entanglement coefficients between positive and negative energy parts of zero energy states (all net quantum numbers vanish for them) and can be regarded as a hermitian square root of density matrix multiplied by a unitary S-matrix. Quantum theory would be in a well-defined sense a square root of thermodynamics. The orthogonality and hermiticity of the M-matrices commuting with S-matrix means that they span infinite-dimensional Lie algebras acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in a well-defined sense.

4. In fact the Lie algebra of Hermitian M-matrices extends to Kac-Moody type algebra obtained by multiplying hermitian square roots of density matrices with powers of the S-matrix. Also the analog of Yangian algebra involving only non-negative powers of S-matrix is possible and would correspond to a hierarchy of CDs with the temporal distances between tips coming as integer multiples of the CP_2 time.

   The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to a representation matrix of scaling: $S(n) = S^n$, where S is unitary S-matrix associated with the minimal CD [K78]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

5. I have also considered the notion of U-matrix. U-matrix elements between M-matrices for various CDs are proportional to the inner products $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2} \lambda]$, where λ represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and H^i form an orthonormal basis of Hermitian square roots of density matrices. $\circ$ tells that S acts at the active boundary of CD only. I have proposed a general representation for the U-matrix, reducing its construction to that of the S-matrix.

1.1.6 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space ("world of classical worlds", WCW), p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. The fourth thread deserves the name "TGD as a generalized number theory". It involves three separate threads: the fusion of real and various p-adic physics to a single coherent whole by requiring number theoretic universality discussed already, the formulation of quantum TGD in terms of complexified counterparts of classical number fields, and the notion of infinite prime. Note that one can identify subrings such as hyper-quaternions and hyper-octonions as sub-spaces of complexified classical number fields with Minkowskian signature of the metric defined by the complexified inner product.

The Threads in the Development of Quantum TGD

The development of TGD has involved several strongly interacting threads: physics as infinite-dimensional geometry; TGD as a generalized number theory, the hierarchy of Planck constants interpreted in terms of dark matter hierarchy, and TGD inspired theory of consciousness. In the following these threads are briefly described.

1. Quantum T(opological) G(eometro)D(ynamics) as a classical spinor geometry for infinite-dimensional WCW, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness and of quantum biology have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

2. The discussions with Tony Smith initiated a fourth thread which deserves the name "TGD as a generalized number theory". The basic observation was that classical number fields might allow a deeper formulation of quantum TGD. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and rather fruitful revision of the basic views about what the final form and physical content of quantum TGD might be. Together with the vision about the fusion of p-adic and real physics to a larger coherent structure these sub-threads fused to the "physics as generalized number theory" thread.

3. A further thread emerged from the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and strongly suggested by the failure of strict determinism for the fundamental variational principle. The identification of hierarchy of Planck constants labelling phases of dark matter would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

The chronology based identification of the threads is quite natural but not logical and it is much more logical to see p-adic physics, the ideas related to classical number fields, and infinite primes as sub-threads of a thread which might be called "physics as a generalized number theory". In the following I adopt this view. This reduces the number of threads to three corresponding to geometric, number theoretic and topological views of physics.

TGD forces the generalization of physics to a quantum theory of consciousness, and TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations.

Number theoretic vision very briefly

Number theoretic vision about quantum TGD involves notions like adelic physics, $M^8 - H$ duality and number theoretic universality. A short review of the basic ideas that have developed during years is in order.

1. The physical interpretation of M^8 is as an analog of momentum space and $M^8 - H$ duality is analogous to momentum-position duality of ordinary wave mechanics.

2. Adelic physics means that all classical number fields, all p-adic number fields and their extensions induced by extensions of rationals and defining adeles, and also finite number fields are basic mathematical building bricks of physics.

   The complexification of M^8, identified as complexified octonions, would provide a realization of this picture and $M^8 - H$ duality would map the algebraic physics in M^8 to the ordinary physics in $M^4 \times CP_2$ described in terms of partial differential equations.

3. Negentropy Maximization Principle (NMP) states that the conscious information assignable with cognition representable measured in terms of p-adic negentropy increases in statistical sense.

   NMP is mathematically completely analogous to the second law of thermodynamics and number theoretic evolution as an unavoidable statistical increase of the dimension of the algebraic extension of rationals characterizing a given space-time region implies it. There is no paradox involved: the p-adic negentropy measures the conscious information assignable to the entanglement of two systems regarded as a conscious entity whereas ordinary entropy measures the lack of information about the quantums state of either entangled system.

4. Number theoretical universality requires that space-time surfaces or at least their $M^8 - H$ duals in M_c^8 are defined for both reals and various p-adic number fields. This is true if they are defined by polynomials with integer coefficients as surfaces in M^8 obeying number theoretic holography realized as associativity of the normal space of 4-D surface using as holographic data 3-surfaces at mass shells identified in terms of roots of a polynomial. A physically motivated additional condition is that the coefficients of the polynomials are smaller than their degrees.

5. Galois confinement is a key piece of the number theoretic vision. It states that the momenta of physical states are algebraic integers in the extensions of rationals assignable to the space-time region considered. These numbers are in general complex and are not consistent with particle in box quantization. The proposal is that physical states satisfy Galois confinement being thus Galois singlets and having therefore total momenta, whose components are ordinary integers, when momentum unit defined by the scale of causal diamond (CD) is used.

6. The notion of p-adic prime was introduced in p-adic mass calculations that started the developments around 1995. p-Adic length scale hypothesis states that p-adic primes near powers of 2 have a special physical role (as possibly also the powers of other small primes such as $p = 3$).

   The proposal is that p-adic primes correspond to ramified primes assignable to the extension and identified as divisors of the polynomial defined by the products of the root differences for the roots of the polynomial defining space-time space and having interpretation as values of, in general complex, virtual mass squared.

p-Adic TGD and fusion of real and p-adic physics to single coherent whole

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzles and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired "Universe as Computer" vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

In string model context one tries to reduces the physics to Planck scale. The price is the inability to say anything about physics in long length scales. In TGD p-adic physics takes care of this shortcoming by predicting the physics also in long length scales.

There were many interpretational and technical questions crying for a definite answer.

1. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *the* Physics? Should one perform p-adicization also at the level of the WCW? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations.

2. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question. Quite recently I however learned that the problem of making sense about p-adic integration has been for decades central problem in the frontier of mathematics and a lot of profound work has been done along same intuitive lines as I have proceeded in TGD framework. The basic idea is certainly the notion of algebraic continuation from the world of rationals belonging to the intersection of real world and various p-adic worlds.

Despite various uncertainties, the number of the applications of the poorly defined p-adic physics has grown steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

The key challenge is to fuse various p-adic physics and real physics to single larger structure. This has inspired a proposal for a generalization of the notion of number field by fusing real numbers and various p-adic number fields and their extensions along rationals and possible common algebraic numbers. This leads to a generalization of the notions of embedding space and space-time concept and one can speak about real and p-adic space-time sheets. One can talk about adelic space-time, embedding space, and WCW.

The corresponds of real 4-surfaces with the p-adic ones is induced by number theoretical discretization using points of 4-surfaces $Y^4 \subset M_c^8$ identifiable as 8-momenta, whose components are assumed to be algebraic integers in an extension of rationals defined by the extension of rationals associated with a polynomial P with integer coefficients smaller than the degree of P. These points define a cognitive representation, which is universal in the sense that it exists also in the algebraic extensions of p-adic numbers. The points of the cognitive representations associated with the mass shells with mass squared values identified as roots of P are enough since $M^8 - H$ duality can be used at both M^8 and H sides and also in the p-adic context. The mass shells are special in that they allow for Minkowski coordinates very large cognitive representations unlike the interiors of the 4-surfaces determined by holography by using the data defined by the 3-surfaces at the mass shells. The higher the dimension of the algebraic extension associated with P, the better the accuracy of the cognitive representation.

Adelization providing number theoretical universality reduces to algebraic continuation for the amplitudes from this intersection of reality and various p-adicities - analogous to a back of a book - to various number fields. There are no problems with symmetries but canonical identification is needed: various group invariant of the amplitude are mapped by canonical identification to various p-adic number fields. This is nothing but a generalization of the mapping of the p-adic mass squared to its real counterpart in p-adic mass calculations.

This leads to surprisingly detailed predictions and far reaching conjectures. For instance, the number theoretic generalization of entropy concept allows negentropic entanglement central for the applications to living matter (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). One can also understand how preferred p-adic primes could

emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K73].

The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to "mind stuff", the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably a brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

Infinite primes

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory.

After the realization that infinite primes can be mapped to polynomials possibly representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of complexified quaternions and octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

The infinite primes at the first level of hierarchy, which represent analogs of bound states, can be mapped to irreducible polynomials, which in turn characterize the algebraic extensions of rationals defining a hierarchy of algebraic physics continuable to real and p-adic number fields. The products of infinite primes in turn define more general algebraic extensions of rationals. The interesting question concerns the physical interpretation of the higher levels in the hierarchy of infinite primes and integers mappable to polynomials of $n > 1$ variables.

1.1.7 An explicit formula for $M^8 - H$ duality

$M^8 - H$ duality is a generalization of momentum-position duality relating the number theoretic and geometric views of physics in TGD and, despite that it still involves poorly understood aspects, it has become a fundamental building block of TGD. One has 4-D surfaces $Y^4 \subset M^8_c$, where M^8_c is complexified M^8 having interpretation as an analog of complex momentum space and 4-D spacetime surfaces $X^4 \subset H = M^4 \times CP_2$. M^8_c, equivalently E^8_c, can be regarded as complexified octonions. M^8_c has a subspace M^4_c containing M^4.

Comment: One should be very cautious with the meaning of "complex". Complexified octonions involve a complex imaginary unit i commuting with the octonionic imaginary units I_k. i is assumed to also appear as an imaginary unit also in complex algebraic numbers defined by the roots of polynomials P defining holographic data in M^8_c.

In the following $M^8 - H$ duality and its twistor lift are discussed and an explicit formula for the dualities are deduced. Also possible variants of the duality are discussed.

Holography in H

$X^4 \subset H$ satisfies holography and is analogous to the Bohr orbit of a particle identified as a 3-surface. The proposal is that holography reduces to a 4-D generalization of holomorphy so that X^4 is a simultaneous zero of two functions of complex CP_2 coordinates and of what I have called Hamilton-Jacobi coordinates of M^4 with a generalized Kähler structure.

The simplest choice of the Hamilton-Jacobi coordinates is defined by the decomposition $M^4 = M^2 \times E^2$, where M^2 is endowed with hypercomplex structure defined by light-like coordinates (u, v), which are analogous to z and $\overline{z}$. Any analytic map $u \to f(u)$ defines a new set

of light-like coordinates and corresponds to a solution of the massless d'Alembert equation in M^2. E^2 has some complex coordinates with imaginary unit defined by i.

The conjecture is that also more general Hamilton-Jacobi structures for which the tangent space decomposition is local are possible. Therefore one would have $M^4 = M^2(x) \times E^2(x)$. These would correspond to non-equivalent complex and Kähler structures of M^4 analogous to those possessed by 2-D Riemann surfaces and parametrized by moduli space.

Number theoretic holography in M_c^8

$Y^4 \subset M_c^8$ satisfies number theoretic holography defining dynamics, which should reduce to associativity in some sense. The Euclidian complexified normal space $N^4(y)$ at a given point y of Y^4 is required to be associative, i.e. quaternionic. Besides this, $N^4(i)$ contains a preferred complex Euclidian 2-D subspace $Y^2(y)$. Also the spaces $Y^2(x)$ define an integrable distribution. I have assumed that $Y^2(x)$ can depend on the point y of Y^4.

These assumptions imply that the normal space $N(y)$ of Y^4 can be parameterized by a point of $CP_2 = SU(3)/U(2)$. This distribution is always integrable unlike quaternionic tangent space distributions. $M^8 - H$ duality assigns to the normal space $N(y)$ a point of CP_2. M_c^4 point y is mapped to a point $x \in M^4 \subset M^4 \times CP_2$ defined by the real part of its inversion (conformal transformation): this formula involves effective Planck constant for dimensional reasons.

The 3-D holographic data, which partially fixes 4-surfaces Y^4 is partially determined by a polynomial P with real integer coefficients smaller than the degree of P. The roots define mass squared values which are in general complex algebraic numbers and define complex analogs of mass shells in $M_c^4 \subset M_c^8$, which are analogs of hyperbolic spaces H^3. The 3-surfaces at these mass shells define 3-D holographic data continued to a surface Y^4 by requiring that the normal space of Y^4 is associative, i.e. quaternionic. These 3-surfaces are not completely fixed but an interesting conjecture is that they correspond to fundamental domains of tessellations of H^3.

What does the complexity of the mass shells mean? The simplest interpretation is that the space-like M^4 coordinates (3-momentum components) are real whereas the time-like coordinate (energy) is complex and determined by the mass shell condition. One would have $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3 when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as a time coordinate. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to an equation of mass shell when $\sqrt{(Re(E)^2 - Im(E)^2)}$, expressed in terms of $Re(E)$, is taken as new energy coordinate $E_{eff} = \sqrt{(Re(E)^2 - Im(E)^2)}$. Is this deformation of H^3 in imaginary time direction equivalent with a region of the hyperbolic 3-space H^3?

One can look at the formula in more detail. Mass shell condition gives $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3, when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as an effective energy. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to a dispersion relation for $Re(E)^2$.

$$Re(E)^2 = \frac{1}{2}(Re(m^2) - Im(m^2) + p^2)(1 \pm \sqrt{1 + \frac{2Im(m^2)^2}{(Re(m^2) - Im(m^2) + p^2)^2}}) \quad . \tag{1.1.1}$$

Only the positive root gives a non-tachyonic result for $Re(m^2) - Im(m^2) > 0$. For real roots with $Im(m^2) = 0$ and at the high momentum limit the formula coincides with the standard formula. For $Re(m^2) = Im(m^2)$ one obtains $Re(E)^2 \to Im(m^2)/\sqrt{2}$ at the low momentum limit $p^2 \to 0$. Energy does not depend on momentum at all: the situation resembles that for plasma waves.

Can one find an explicit formula for $M^8 - H$ duality?

The dream is an explicit formula for the $M^8 - H$ duality mapping $Y^4 \subset M_c^8$ to $X^4 \subset H$. This formula should be consistent with the assumption that the generalized holomorphy holds true for X^4.

The following proposal is a more detailed variant of the earlier proposal for which Y^4 is determined by a map g of $M_c^4 \to SU(3)_c \subset G_{2,c}$, where $G_{2,c}$ is the complexified automorphism group of octonions and $SU(3)_c$ is interpreted as a complexified color group.

This map defines a trivial $SU(3)_c$ gauge field. The real part of g however defines a non-trivial real color gauge field by the non-linearity of the non-abelian gauge field with respect to the gauge potential. The quadratic terms involving the imaginary part of the gauge potential give an additional condition to the real part in the complex situation and cancel it. If only the real part of g contributes, this contribution would be absent and the gauge field is non-vanishing.

How could the automorphism $g(x) \subset SU(3) \subset G_2$ give rise to $M^8 - H$ duality?

1. The interpretation is that $g(y)$ at given point y of Y^4 relates the normal space at y to a fixed quaternionic/associative normal space at point y_0, which corresponds is fixed by some subgroup $U(2)_0 \subset SU(3)$. The automorphism property of g guarantees that the normal space is quaternionic/associative at y. This simplifies the construction dramatically.

2. The quaternionic normal sub-space (which has Euclidian signature) contains a complex sub-space which corresponds to a point of sphere $S^2 = SO(3)/O(2)$, where $SO(3)$ is the quaternionic automorphism group. The interpretation could be in terms of a selection of spin quantization axes. The local choice of the preferred complex plane would not be unique and is analogous to the possibility of having non-trivial Hamilton Jacobi structures in M^4 characterized by the choice of $M^2(x)$ and equivalently its normal subspace $E^2(x)$.

   These two structures are independent apart from dependencies forced by the number theoretic dynamics. Hamilton-Jacobi structure means a selection of the quantization axis of spin and energy by fixing a distribution of light-like tangent vectors of M^4 and the choice of the quaternionic normal sub-space fixes a choice of preferred quaternionic imaginary unit defining a quantization axis of the weak isospin.

3. The real part $Re(g(y))$ defines a point of $SU(3)$ and the bundle projection $SU(3) \to CP_2$ in turn defines a point of $CP_2 = SU(3)/U(2)$. Hence one can assign to g a point of CP_2 as $M^8 - H$ duality requires and deduce an explicit formula for the point. This means a realization of the dream.

4. The construction requires a fixing of a quaternionic normal space N_0 at y_0 containing a preferred complex subspace at a single point of Y^4 plus a selection of the function g. If M^4 coordinates are possible for Y^4, the first guess is that g as a function of complexified M^4 coordinates obeys generalized holomorphy with respect to complexified M^4 coordinates in the same sense and in the case of X^4. This might guarantee that the $M^8 - H$ image of Y^4 satisfies the generalized holomorphy.

5. Also space-time surfaces X^4 with M^4 projection having a dimension smaller than 4 are allowed. I have proposed that they might correspond to singular cases for the above formula: a kind of blow-up would be involved. One can also consider a more general definition of Y^4 allowing it to have a M^4 projection with dimension smaller than 4 (say cosmic strings). Could one have implicit equations for the surface Y^4 in terms of the complex coordinates of $SU(3)_c$ and M^4? Could this give for instance cosmic strings with a 2-D M^4 projection and CP_2 type extremals with 4-D CP_2 projection and 1-D light-like M^4 projection?

What could the number theoretic holography mean physically?

What could be physical meaning of the number theoretic holography? The condition that has been assumed is that the CP_2 coordinates at the mass shells of $M^4_c \subset M^8_c$ mapped to mass shells H^3 of $M^4 \subset M^4 \times CP_2$ are constant at the H^3. This is true if the $g(y)$ defines the same CP_2 point for a given component X^3_i of the 3-surface at a given mass shell. g is therefore fixed apart from a local $U(2)$ transformation leaving the CP_2 point invariant. A stronger condition would be that the CP_2 point is the same for each component of X^3_i and even at each mass shell but this condition seems to be unnecessarily strong.

Comment: One can o criticize this condition as too strong and one can consider giving up this condition. The motivation for this condition is that the number of algebraic points at the 3-surfaces associated with H^3 explodes since the coordinates associated with normal directions vanish. Kind of cognitive explosion would be in question.

$SU(3)$ corresponds to a subgroup of G_2 and one can wonder what the fixing of this subgroup could mean physically. G_2 is 14-D and the coset space $G_2/SU(3)$ is 6-D and a good guess is that

it is just the 6-D twistor space $SU(3)/U(1) \times U(1)$ of CP_2: at least the isometries are the same. The fixing of the $SU(3)$ subgroup means fixing of a CP_2 twistor. Physically this means the fixing of the quantization axis of color isospin and hypercharge.

Twistor lift of the holography

What is interesting is that by replacing $SU(3)$ with G_2, one obtains an explicit formula form the generalization of $M^8 - H$ duality to that for the twistorial lift of TGD!

One can also consider a twistorial generalization of the above proposal for the number theoretic holography by allowing local G_2 automorphisms interpreted as local choices of the color quantization axis. G_2 elements would be fixed apart from a local $SU(3)$ transformation at the components of 3-surfaces at mass shells. The choice of the color quantization axes for a connected 3-surface at a given mass shell would be the same everywhere. This choice is indeed very natural physically since 3-surface corresponds to a particle.

Is this proposal consistent with the boundary condition of the number theoretical holography mean in the case of 4-surfaces in M_c^8 and $M^4 \times CP_2$?

1. The selection of $SU(3) \subset G_2$ for ordinary $M^8 - H$ duality means that the $G_{2,c}$ gauge field vanishes everywhere and the choice of color quantization axis is the same at all points of the 4-surface. The fixing of the CP_2 point to be constant at H^3 implies that the color gauge field at $H^3 \subset M_c^8$ and its image $H^3 \subset H$ vanish. One would have color confinement at the mass shells H_i^3, where the observations are made. Is this condition too strong?

2. The constancy of the G_2 element at mass shells makes sense physically and means a fixed color quantization axis. The selection of a fixed $SU(3) \subset G_2$ for entire space-time surface is in conflict with the non-constancy of G_2 element unless G_2 element differs at different points of 4-surface only by a multiplication of a local $SU(3)_0$ element, that is local $SU(3)$ transformation. This kind of variation of the G_2 element would mean a fixed color group but varying choice of color quantization axis.

3. Could one consider the possibility that the local $G_{2,c}$ element is free and defines the twistor lift of $M^8 - H$ duality as something more fundamental than the ordinary $M^8 - H$ duality based on $SU(3)_c$. This duality would make sense only at the mass shells so that only the spaces $H^3 \times CP_2$ assignable to mass shells would make sense physically? In the interior CP_2 would be replaced with the twistor space $SU(3)/U(1) \times U(1)$. Color gauge fields would be non-vanishing at the mass shells but outside the mass shells one would have G_2 gauge fields.

   There is also a physical objection against the G_2 option. The 14-D Lie algebra representation of G_2 acts on the imaginary octonions which decompose with respect to the color group to $1 \oplus 3 \oplus \overline{3}$. The automorphism property requires that 1 can be transformed to 3 or $\overline{3}$ to themselves: this requires that the decomposition contains $3 \oplus \overline{3}$. Furthermore, it must be possible to transform 3 and $\overline{3}$ to themselves, which requires the presence of 8. This leaves only the decomposition $8 \oplus 3 \oplus \overline{3}$. G_2 gluons would both color octet and triplets. In the TDG framework the only conceivable interpretation would be in terms of ordinary gluons and leptoquark-like gluons. This does not fit with the basic vision of TGD.

The choice of twistor as a selection of quantization axes should make sense also in the M^4 degrees of freedom. M^4 twistor corresponds to a choice of light-like direction at a given point of M^4. The spatial component of the light-like vector fixes the spin quantization axis. Its choice together with the light-likeness fixes the time direction and therefore the rest system and energy quantization axis. Light-like vector fixes also the choice of M^2 and of E^2 as its orthogonal complement. Therefore the fixing of M^4 twistor as a point of $SU(4)/SU(3) \times U(1)$ corresponds to a choice of the spin quantization axis and the time-like axis defining the rest system in which the energy is measured. This choice would naturally correspond to the Hamilton-Jacobi structure fixing the decompositions $M^2(x) \times E^2(x)$. At a given mass shell the choice of the quantization axis would be constant for a given X_i^3.

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark Matter as Large $\hbar$ Phases

D. Da Rocha and Laurent Nottale [E1] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests that astrophysical systems are at some levels of the hierarchy of space-time sheets macroscopic quantum systems. The space-time sheets in question would carry dark matter.

Nottale's hypothesis would predict a gigantic value of h_{gr}. Equivalence Principle and the independence of gravitational Compton length on mass m implies however that one can restrict the values of mass m to masses of microscopic objects so that h_{gr} would be much smaller. Large h_{gr} could provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K112].

It is natural to assign the values of Planck constants postulated by Nottale to the space-time sheets mediating gravitational interaction and identifiable as magnetic flux tubes (quanta) possibly carrying monopole flux and identifiable as remnants of cosmic string phase of primordial cosmology. The magnetic energy of these flux quanta would correspond to dark energy and magnetic tension would give rise to negative "pressure" forcing accelerate cosmological expansion. This leads to a rather detailed vision about the evolution of stars and galaxies identified as bubbles of ordinary and dark matter inside magnetic flux tubes identifiable as dark energy.

Certain experimental findings suggest the identification $h_{eff} = n\times = h_{gr}$. The large value of h_{gr} can be seen as a way to reduce the string tension of fermionic strings so that gravitational (in fact all!) bound states can be described in terms of strings connecting the partonic 2-surfaces defining particles (analogous to AdS/CFT description). The values $h_{eff}/h = n$ can be interpreted in terms of a hierarchy of breakings of super-conformal symmetry in which the super-conformal generators act as gauge symmetries only for a sub-algebras with conformal weights coming as multiples of n. Macroscopic quantum coherence in astrophysical scales is implied. If also Kähler-Dirac action is present, part of the interior degrees of freedom associated with the Kähler-Dirac part of conformal algebra become physical. A possible is that tfermionic oscillator operators generate super-symmetries and sparticles correspond almost by definition to dark matter with $h_{eff}/h = n > 1$. One implication would be that at least part if not all gravitons would be dark and be observed only through their decays to ordinary high frequency graviton ($E = hf_{high} = h_{eff}f_{low}$) of bunch of n low energy gravitons.

Hierarchy of Planck Constants from the Anomalies of Neuroscience and Biology

The quantal ELF effects of ELF em fields on vertebrate brain have been known since seventies. ELF em fields at frequencies identifiable as cyclotron frequencies in magnetic field whose intensity is about 2/5 times that of Earth for biologically important ions have physiological effects and affect also behavior. What is intriguing that the effects are found only in vertebrates (to my best knowledge). The energies for the photons of ELF em fields are extremely low - about 10^{-10} times

lower than thermal energy at physiological temperatures- so that quantal effects are impossible in the framework of standard quantum theory. The values of Planck constant would be in these situations large but not gigantic.

This inspired the hypothesis that these photons correspond to so large a value of Planck constant that the energy of photons is above the thermal energy. The proposed interpretation was as dark photons and the general hypothesis was that dark matter corresponds to ordinary matter with non-standard value of Planck constant. If only particles with the same value of Planck constant can appear in the same vertex of Feynman diagram, the phases with different value of Planck constant are dark relative to each other. The phase transitions changing Planck constant can however make possible interactions between phases with different Planck constant but these interactions do not manifest themselves in particle physics. Also the interactions mediated by classical fields should be possible. Dark matter would not be so dark as we have used to believe.

The hypothesis $h_{eff} = h_{gr}$ - at least for microscopic particles - implies that cyclotron energies of charged particles do not depend on the mass of the particle and their spectrum is thus universal although corresponding frequencies depend on mass. In bio-applications this spectrum would correspond to the energy spectrum of bio-photons assumed to result from dark photons by h_{eff} reducing phase transition and the energies of bio-photons would be in visible and UV range associated with the excitations of bio-molecules.

Also the anomalies of biology (see for instance [K94, K95, K92]) support the view that dark matter might be a key player in living matter.

Dark Matter as a Source of Long Ranged Weak and Color Fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics.

The recent view about the solutions of Kähler- Dirac action assumes that the modes have a well-defined em charge and this implies that localization of the modes to 2-D surfaces (right-handed neutrino is an exception). Classical W boson fields vanish at these surfaces and also classical Z^0 field can vanish. The latter would guarantee the absence of large parity breaking effects above intermediate boson scale scaling like h_{eff}.

1.1.9 Twistors in TGD and connection with Veneziano duality

The twistorialization of TGD has two aspects. The attempt to generalize twistor Grassmannian approach emerged first. It was however followed by the realization that also the twistor lift of TGD at classical space-time level is needed. It turned out that the progress in the understanding of the classical twistor lift has been much faster - probably this is due to my rather limited technical QFT skills.

Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K126]. The reason is that M^4 and CP_2 are completely exceptional in the sense that they are the only 4-D manifolds allowing twistor space with Kähler structure [A30]. The twistor space of $M^4 \times CP_2$ is Cartesian product of those of M^4 and CP_2. The obvious idea is that space-time surfaces allowing twistor structure if they are orientable are representable as surfaces in H such that the properly induced twistor structure coincides with the twistor structure defined by the induced metric.

In fact, it is enough to generalize the induction of spinor structure to that of twistor structure so that the induced twistor structure need not be identical with the ordinary twistor structure possibly assignable to the space-time surface. The induction procedure reduces to a dimensional reduction of 6-D Kähler action giving rise to 6-D surfaces having bundle structure with twistor

sphere as fiber and space-time as base. The twistor sphere of this bundle is imbedded as sphere in the product of twistor spheres of twistor spaces of M^4 and CP_2.

This condition would define the dynamics, and the original conjecture was that this dynamics is equivalent with the identification of space-time surfaces as preferred extremals of Kähler action. The dynamics of space-time surfaces would be lifted to the dynamics of twistor spaces, which are sphere bundles over space-time surfaces. What is remarkable that the powerful machinery of complex analysis becomes available.

It however turned out that twistor lift of TGD is much more than a mere technical tool. First of all, the dimensionally reduction of 6-D Kähler action contained besides 4-D Kähler action also a volume term having interpretation in terms of cosmological constant. This need not bring anything new, since all known extremals of Kähler action with non-vanishing induced Kähler form are minimal surfaces. There is however a large number of embeddings of twistor sphere of space-time surface to the product of twistor spheres. Cosmological constant has spectrum and depends on length scale, and the proposal is that coupling constant evolution reduces to that for cosmological constant playing the role of cutoff length. That cosmological constant could transform from a mere nuisance to a key element of fundamental physics was something totally new and unexpected.

1. The twistor lift of TGD at space-time level forces to replace 4-D Kähler action with 6-D dimensionally reduced Kähler action for 6-D surface in the 12-D Cartesian product of 6-D twistor spaces of M^4 and CP_2. The 6-D surface has bundle structure with twistor sphere as fiber and space-time surface as base.

   Twistor structure is obtained by inducing the twistor structure of 12-D twistor space using dimensional reduction. The dimensionally reduced 6-D Kähler action is sum of 4-D Kähler action and volume term having interpretation in terms of a dynamical cosmological constant depending on the size scale of space-time surface (or of causal diamond CD in zero energy ontology (ZEO)) and determined by the representation of twistor sphere of space-time surface in the Cartesian product of the twistor spheres of M^4 and CP_2.

2. The preferred extremal property as a representation of quantum criticality would naturally correspond to minimal surface property meaning that the space-time surface is separately an extremal of both Kähler action and volume term almost everywhere so that there is no coupling between them. This is the case for all known extremals of Kähler action with non-vanishing induced Kähler form.

   Minimal surface property could however fail at 2-D string world sheets, their boundaries and perhaps also at partonic 2-surfaces. The failure is realized in minimal sense if the 3-surface has 1-D edges/folds (strings) and 4-surface 2-D edges/folds (string world sheets) at which some partial derivatives of the embedding space coordinates are discontinuous but canonical momentum densities for the entire action are continuous.

   There would be no flow of canonical momentum between interior and string world sheet and minimal surface equations would be satisfied for the string world sheet, whose 4-D counterpart in twistor bundle is determined by the analog of 4-D Kähler action. These conditions allow the transfer of canonical momenta between Kähler- and volume degrees of freedom at string world sheets. These no-flow conditions could hold true at least asymptotically (near the boundaries of CD).

   $M^8 - H$ duality suggests that string world sheets (partonic 2-surfaces) correspond to images of complex 2-sub-manifolds of M^8 (having tangent (normal) space which is complex 2-plane of octonionic M^8).

3. Cosmological constant would depend on p-adic length scales and one ends up to a concrete model for the evolution of cosmological constant as a function of p-adic length scale and other number theoretic parameters (such as Planck constant as the order of Galois group): this conforms with the earlier picture.

   Inflation is replaced with its TGD counterpart in which the thickening of cosmic strings to flux tubes leads to a transformation of Kähler magnetic energy to ordinary and dark matter. Since the increase of volume increases volume energy, this leads rapidly to energy minimum at some flux tube thickness. The reduction of cosmological constant by a phase transition

however leads to a new expansion phase. These jerks would replace smooth cosmic expansion of GRT. The discrete coupling constant evolution predicted by the number theoretical vision could be understood as being induced by that of cosmological constant taking the role of cutoff parameter in QFT picture [L87].

Twistor lift at the level of scattering amplitudes and connection with Veneziano duality

The classical part of twistor lift of TGD is rather well-understood. Concerning the twistorialization at the level of scattering amplitudes the situation is much more difficult conceptually - I already mentioned my limited QFT skills.

1. From the classical picture described above it is clear that one should construct the 8-D twistorial counterpart of theory involving space-time surfaces, string world sheets and their boundaries, plus partonic 2-surfaces and that this should lead to concrete expressions for the scattering amplitudes.

   The light-like boundaries of string world sheets as carriers of fermion numbers would correspond to twistors as they appear in twistor Grassmann approach and define the analog for the massless sector of string theories. The attempts to understand twistorialization have been restricted to this sector.

2. The beautiful basic prediction would be that particles massless in 8-D sense can be massive in 4-D sense. Also the infrared cutoff problematic in twistor approach emerges naturally and reduces basically to the dynamical cosmological constant provided by classical twistor lift.

   One can assign 4-momentum both to the spinor harmonics of the embedding space representing ground states of super-conformal representations and to light-like boundaries of string world sheets at the orbits of partonic 2-surfaces. The two four-momenta should be identical by quantum classical correspondence: this could be seen as a concretization of Equivalence Principle. Also a connection with string model emerges.

3. As far as symmetries are considered, the picture looks rather clear. Ordinary twistor Grassmannian approach boils down to the construction of scattering amplitudes in terms of Yangian invariants for conformal group of M^4. Therefore a generalization of super-symplectic symmetries to their Yangian counterpart seems necessary. These symmetries would be gigantic but how to deduce their implications?

4. The notion of positive Grassmannian is central in the twistor approach to the scattering amplitudes in $calN = 4$ SUSYs. TGD provides a possible generalization and number theoretic interpretation of this notion. TGD generalizes the observation that scattering amplitudes in twistor Grassmann approach correspond to representations for permutations. Since 2-vertex is the only fermionic vertex in TGD, OZI rules for fermions generalizes, and scattering amplitudes are representations for braidings.

   Braid interpretation encourages the conjecture that non-planar diagrams can be reduced to ordinary ones by a procedure analogous to the construction of braid (knot) invariants by gradual un-braiding (un-knotting).

This is however not the only vision about a solution of non-planarity. Quantum criticality provides different view leading to a totally unexpected connection with string models, actually with the Veneziano duality, which was the starting point of dual resonance model in turn leading via dual resonance models to super string models.

1. Quantum criticality in TGD framework means that coupling constant evolution is discrete in the sense that coupling constants are piecewise constant functions of length scale replaced by dynamical cosmological constant. Loop corrections would vanish identically and the recursion formulas for the scattering amplitudes (allowing only planar diagrams) deduced in twistor Grassmann would involve no loop corrections. In particular, cuts would be replaced by sequences of poles mimicking them like sequences of point charge mimic line charges. In momentum discretization this picture follows automatically.

2. This would make sense in finite measurement resolution realized in number theoretical vision by number-theoretic discretization of the space-time surface (cognitive representation) as points with coordinates in the extension of rationals defining the adele [L70]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?

3. Maybe it is! The basic idea of behind the original Veneziano amplitudes (see `http://tinyurl.com/yyhwvbqb`) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holber-Beck Nielsen, and Leonard Susskind to N-particle amplitude (see `http://tinyurl.com/yyvkx7as`) based on string picture, and the resulting model was called dual resonance model. The model was forgotten as QCD emerged. Later came superstring models and led to M-theory. Now it has become clear that something went wrong, and it seems that one must return to the roots. Could the return to the roots mean a careful reconsideration of the dual resonance model?

4. Recall that Veneziano duality (1968) was deduced by assuming that scattering amplitude can be described as sum over s-channel resonances or t-channel Regge exchanges and Veneziano duality stated that hadronic scattering amplitudes have representation as sums over s- or t-channel resonance poles identified as excitations of strings. The sum over exchanges defined by t-channel resonances indeed reduces at larger values of s to Regge form.

   The resonances had zero width, which was not consistent with unitarity. Further, there were no counterparts for the *sum* of s-, t-, and u-channel diagrams with continuous cuts in the kinematical regions encountered in QFT approach. What puts bells ringing is the u-channel diagrams would be non-planar and non-planarity is the problem of twistor Grassmann approach.

5. Veneziano duality is true only for s- and t- channels but not been s- and u-channel. Stringy description makes t-channel and s-channel pictures equivalent. Could it be that in fundamental description u-channels diagrams cannot be distinguished from s-channel diagrams or t-channel diagrams? Could the stringy representation of the scattering diagrams make u-channel twist somehow trivial if handles of string world sheet representing stringy loops in turn representing the analog of non-planarity of Feynman diagrams are absent? The permutation of external momenta for tree diagram in absence of loops in planar representation would be a twist of π in the representation of planar diagram as string world sheet and would not change the topology of the string world sheet and would not involve non-trivial world sheet topology.

   For string world sheets loops would correspond to handles. The presence of handle would give an edge with a loop at the level of 3-surface (self energy correction in QFT). Handles are not allowed if the induced metric for the string world sheet has Minkowskian signature. If the stringy counterparts of loops are absent, also the loops in scattering amplitudes should be absent.

   This argument applies only inside the Minkowskian space-time regions. If string world sheets are present also in Euclidian regions, they might have handles and loop corrections could emerge in this manner. In TGD framework strings (string world sheets) are identified to 1-D edges/folds of 3-surface at which minimal surface property and topological QFT property fails (minimal surfaces as calibrations). Could the interpretation of edge/fold as discontinuity of some partial derivatives exclude loopy edges: perhaps the branching points would be too singular?

A reduction to a sum over s-channel resonances is what the vanishing of loops would suggest. Could the presence of string world sheets make possible the vanishing of continuous cuts even at the continuum limit so that continuum cuts would emerge only in the approximation as the density of resonances is high enough?

The replacement of continuous cut with a sum of *infinitely* narrow resonances is certainly an approximation. Could it be that the stringy representation as a sum of resonances with *finite* width is an essential aspect of quantum physics allowing to get rid of infinities necessarily accompanying loops? Consider now the arguments against this idea.

1. How to get rid of the problems with unitarity caused by the zero width of resonances? Could *finite* resonance widths make unitarity possible? Ordinary twistor Grassmannian approach predicts that the virtual momenta are light-like but complex: obviously, the imaginary part of the energy in rest frame would have interpretation as resonance with.

   In TGD framework this generalizes for 8-D momenta. By quantum-classical correspondence (QCC) the classical Noether charges are equal to the eigenvalues of the fermionic charges in Cartan algebrable (maximal set of mutually commuting observables) and classical TGD indeed predicts complex momenta (Kähler coupling strength is naturally complex). QCC thus supports this proposal.

2. Sum over resonances/exchanges picture is in conflict with QFT picture about scattering of particles. Could *finite* resonance widths due to the complex momenta give rise to the QFT type scattering amplitudes as one develops the amplitudes in Taylor series with respect to the resonance width? Unitarity condition indeed gives the first estimate for the resonance width.

   QFT amplitudes should emerge in an approximation obtained by replacing the discrete set of finite width resonances with a cut as the distance between poles is shorter than the resolution for mass squared.

   In superstring models string tension has single very large value and one cannot obtain QFT type behavior at low energies (for instance, scattering amplitudes in hadronic string model are concentrated in forward direction). TGD however predicts an entire hierarchy of p-adic length scales with varying string tension. The hierarchy of mass scales corresponding roughly to the lengths and thickness of magnetic flux tubes as thickened cosmic strings and characterized by the value of cosmological constant predicted by twistor lift of TGD. Could this give rise to continuous QCT type cuts at the limit when measurement resolution cannot distinguish between resonances?

   The dominating term in the sum over sums of resonances in t-channel gives near forward direction approximately the lowest mass resonance for strings with the smallest string tension. This gives the behavior $1/(t - m_{min}^2)$, where m_{min} corresponds to the longest mass scale involved (the largest space-time sheet involved), approximating the $1/t$-behavior of massless theories. This also brings in IR cutoff, the lack of which is a problem of gauge theories. This should give rise to continuous QFT type cuts at the limit when measurement resolution cannot distinguish between resonances.

1.2 TGD As A Generalization Of Physics To A Theory Consciousness

General Coordinate Invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. The basic idea is that quantum jump can be identified as momentum of consciousness. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [K124, K20, K91, K18, K51, K63, K67, K114, K122].

It is good to list first the basic challenges of TGD inspired theory of consciousness. The challenges can be formulated as questions. Reader can decide how satisfactory the answered proposed by TGD are.

1. What does one mean with quantum jump? Can one overcome the basic problem of the standard quantum measurement theory, that which forcing Bohr to give up totally the idea about objective reality?

2. How do the experienced time and geometric time relate in this framework? How the arrow of subjective time translates to that of geometric time?

3. How to define conscious information? Is it conserved or even increased during time evolution as biological evolution suggests? How does this increase relate to second law implied basically by the randomness of state function reduction?

4. Conscious entities/selves/observers seem to exist. If they are real how do they emerge?

1.2.1 Quantum Jump As A Moment Of Consciousness

The identification of quantum jump between deterministic quantum histories (WCW spinor fields) as a moment of consciousness defines microscopic theory of consciousness. Quantum jump involves the steps

$$\Psi_i \to U\Psi_i \to \Psi_f \quad ,$$

where U is informational "time development" operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics. U is formally analogous to Schrödinger time evolution of infinite duration. The time evolution can however interpreted as a sequence of discrete scalings and Lorentz boosts of causal diamond (CD) and the time corresponds to the change of the proper time distance between between the tips of CD.

In TGD framework S-matrix is generalized to a triplet of U-, M-, and S-matrices. M-matrix is a hermitian square root of density matrix between positive and negative energy states multiplied by universal S-matrix depending on the scale of CD only. The square roots of projection operators form an orthonormal basis. U-matrix and S-matrix are completely universal objects characterizing the dynamics of evolution by self-organization.

The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to S^n, where S is the S-matrix associated with the minimal CD. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S.

U-matrix elements between M-matrices for various CDs are proportional to the inner products $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2}\lambda]$, where λ represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and H^i form an orthonormal basis of Hermitian square roots of density matrices. $\circ$ tells that S acts at the active boundary of CD only. I turns out possible to construct a general representation for the U-matrix reducing its construction to that of S-matrix.

The requirement that quantum jump corresponds to a measurement in the sense of quantum field theories implies that each quantum jump involves localization in zero modes which parameterize also the possible choices of the quantization axes. Thus the selection of the quantization axes performed by the Cartesian outsider becomes now a part of quantum theory. Together these requirements imply that the final states of quantum jump correspond to quantum superpositions of space-time surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. At least formally quantum jump can be interpreted also as a quantum computation in which matrix U represents unitary quantum computation which is however not identifiable as unitary translation in time direction and cannot be "engineered".

In ZEO U-matrix should correspond relates zero energy states to each other and M matrices defining the rows of U matrix should be assignable to a fixed CD. Zero energy states should have wave function in the moduli space of CDs such that the second boundary of every CD would belong to a boundary of fixed light-cone but second boundary would be free with possible constraint that the distance between the tips of CD is multiple of CP_2 time.

Zero energy states of ZEO correspond in positive energy ontology to physical events and break time reversal invariance. This because either the positive or negative energy part of the state is reduced/equivalently preparated whereas the second end of CD corresponds to a superposition of (negative/positive energy) states with varying particle numbers and single particle quantum numbers just as in ordinary particle physics experiment.

The first state function reduction at given boundary of CD must change the roles of the ends of CDs. This reduction can be followed by a sequence of reductions to the same boundary of CD and not changing the boundary nor the parts of zero energy states associated with it but changing the states at the second end and also quantum distribution of the second boundary in the moduli space of CDs. In standard measurement theory the follow-up reductions would not affect the state at all.

The understanding of how the arrow of time and experience about its flow emerge have been the most difficult problem of TGD inspired theory of consciousness and I have considered several proposals during years having the geometry of future light-cone as the geometric core element.

1. The basic objection is that the arrow of geometric time alternates at embedding space level but we know that arrow of time looks the same in the part of the Universe we live. Possible exceptions however exist, for instance phase conjugate laser beams seem to obey opposite arrow of time. Also biological phenomena might involve non-standard arrow of time at some levels. This led Fantappie [J121] to introduce the notion of syntropy. This suggests that the arrow of time depends on the size scale of CD and of space-time sheet.

2. It took some time to realize that the solution of the problem is trivial in ZEO. In the ordinary quantum measurement theory one must assume that state function reduction can occur repeatedly: the assumption is that nothing happens to the state during repeated reductions. The outcome is Zeno effect: the watched pot does not boil.

   In TGD framework situation is different. Repeated state function reduction leaves the already reduce parts of zero energy state invariant but can change the part of states at the opposite boundary. One must allow a delocalization of the second boundary of CDs and one assumes that the second tip has quantized distance to the fixed one coming as multiple of CP_2 time. Also Lorentz boosts leaving the second CD boundary invariant must be allowed. One must therefore introduce a wave function in the moduli space of CDs with second boundary forming part of fixed light-cone boundary ($\delta M^4_{\pm} \times CP_2$).

3. The sequence of state function reductions on a fixed boundary of CD leads to the increase of the average temporal distance between the tips of CDs and this gives rise to the experience about flow of time as shifting of contents of perception towards future if the change is what contributes to conscious experience and gives rise to a fixed arrow of time.

4. Contrary to original working hypothesis, state function reduction in the usual sense does not solely determine the ordinary conscious experience. It can however contribute to conscious experience and the act of free will is a good candidate in this respect. TGD view about realization of intentional action assumes that intentional actions involve negative energy signals propagating backwards in geometric time. This would mean that at some level of CD hierarchy the arrow of geometric time indeed changes and the reduction start to occur at opposite boundary of CD at some level of length scale hierarchy.

1.2.2 Negentropy Maximization Principle (NMP)

Information is the basic aspect of consciousness and this motivates the introduction of Negentropy Maximization Principle (NMP) [K73] as the fundamental variational principle of consciousness theory. The amount of negentropy of zero energy state should increase in each quantum jump. The ordinary entanglement entropy is also non-negative so that negentropy could be at best zero. Since p-adic physics is assumed to be a correlate of cognition, it is natural to generalizes Shannon entropy to its number theoretic variant by replacing the probabilities appearing as arguments of logarithms of probabilities with their p-adic norms. This gives negentropy which can be positive so that NMP can generates entanglement.

Consistency with quantum measurement theory allows only negentropic density matrices proportional to unit matrix and negentropy has the largest positive value for the largest power of prime factor of the dimension of density matrix. Entanglement matrix proportional to unitary matrix familiar from quantum computation corresponds to unit density matrix and large $h_{eff} = n \times h$ states are excellent candidates for forming negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book).

The interpretation of negentropic entanglement is as a rule. The instances of the rule correspond to the pairs appearing in the superposition and the large the number of pairs is, the higher the abstraction level of the rule is. NMP is not in conflict with the second law since negentropy in the sense of NMP is not single particle property. Ordinary quantum jumps indeed generate entropy at the level of ensemble as also quantum jumps for states for which the density matrix is direct sum of unit matrices with various dimensions.

NMP forces the negentropic entanglement resources of the Universe to grow and thus implies evolution. I have coined the name "Akashic records" for these resources forming something analogous to library. It has turned out that the only viable option is that negentropic entanglement is experienced directly.

1.2.3 The Notion Of Self

The concept of self seems to be absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness and would be counterpart for observer in quantum measurement theory.

1. The original view was that self corresponds to a subsystem able to remain un-entangled under the sequential informational "time evolutions" U. It is however unclear how it could be possible to avoid generation of entanglement.

2. In ZEO the situation changes. Self corresponds to a sequence of quantum jumps for which the parts of zero energy states at either boundary of CD remaim unchanged. Therefore one can say that self defined in terms of parts of states assignable to this boundary remains unaffected as sub-system and does not generate entanglement. At the other boundary changes occur and give rise to the experience of time flow and arrow of time since the average temporal distance between the tips of CD tends to increase.

   When the reductions begin to occur at the opposite boundary of CD, self "falls asleep": symmetry suggests that new self living in opposite direction of geometric time is generated. Also in biological the change of time direction at some level of hierarchy might take place.

3. It looks natural to assume that the experiences of the self after the last "wake-up" sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its sub-selves as kind of abstracted experience: the experiences of sub-selves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-sub-selves S_{ij}. Entanglement between selves, most naturally realized by the formation of flux tube bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.

4. Self corresponds in neuro science to self model defining a model for organism and for the external world. Information or negentropy seems to be necessary for understanding self. Negentropically entangled states - Akashic records - are excellent candidates for selves and would thus correspond to dark matter in TGD sense since the number of states in superposition corresponds to the integer n defining h_{eff}. It is enough that self is potentially conscious: this could mean that it conscious experience about self is generated only in interaction free measurement. Repeated state function reductions to given boundary of CD is second possibility. This would assign irreversibility and definite arrow of time and experience of time flow with self.

5. CDs would serve as embedding space correlates of selves and quantum jumps would be followed by cascades of state function reductions beginning from given CD and proceeding downwards to the smaller scales (smaller CDs). At space-time level space-time sheets in given p-adic length scale would be the natural correlates of selves. One ends also ends up with concrete ideas about how the localization of the contents of sensory experience and cognition to the "upper" (changing) boundary of CD could take place. One cannot exclude the possibility that state function reduction cascades could also take place in parallel branches of the quantum state.

1.2.4 Relationship To Quantum Measurement Theory

TGD based quantum measurement has several new elements. Negentropic entanglement and hierarchy of Planck constants, NMP, the prediction that state function reduction can take place to both boundaries of CD implying that the arrow of geometric time can change (this is expected to occur in microscopic scales whether the arrow of time is not established), and the possibility to understand the flow and arrow of geometric time.

1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of WCW spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

2. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It is also consistent with the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

3. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field, ...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

   This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the WCW of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

Standard quantum measurement theory involves also the notion of state preparation which reduces to the notion of self measurement. In ZEO state preparation corresponds at some level of the self hierarchy to the a state function reduction to boundary opposite than before. In biology sensory perception and motor action would correspond to state function reduction sequences at opposite boundaries of CDs at some levels of the hierarchy.

Self measurement is governed by Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given self localized in zero modes (after ordinary quantum measurement) is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement. In p-adic context NMP can be regarded as the variational principle defining the dynamics of cognition. In real context self measurement could be seen as a repair mechanism allowing the system to fight against quantum thermalization by reducing the entanglement for the subsystem for which it is largest (fill the largest hole first in a leaking boat).

1.2.5 Selves Self-Organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [K103]. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

Dissipation can be regarded as the ultimate Darwinian selector of both memes and genes. The mathematically ugly irreversible dissipative dynamics obtained by adding phenomenological dissipation terms to the reversible fundamental dynamical equations derivable from an action principle can be understood as a phenomenological description replacing in a well defined sense the series of reversible quantum histories with its envelope.

ZEO brings in important additional element to the theory of self-organization. The maxima of Kähler function corresponds to the most probable 3-surfaces. Kähler function receives contributions only from the Euclidian regions ("lines" of generalized Feynman diagrams) whereas the contribution to vacuum functional from Minkowskian regions is exponent of imaginary action so that saddle points with stationary phase are in question in these regions. In ZEO 3-surfaces are replaced by pairs of 3-surfaces at opposite boundaries of CD. The maxima actually correspond to temporal patterns of classical fields connecting these 3-surfaces: this means that self-organization is four spatiotemporal rather than spatial patterns - a crucial distinction from the usual view allowing to understand the evolution of behavioral patterns quantally. In biology this allows to understand temporal evolutions of organisms as the most probable self-organization patterns having as correlates the evolutions of the magnetic body of the system.

1.2.6 Classical Non-Determinism Of Kähler Action

A further basic element is non-determinism of Kähler action. This led to the concepts of association sequence and cognitive space-time sheet, which are not wrong notions but replaced by new ones.

1. The huge vacuum degeneracy of the Kähler action suggests strongly that the preferred is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.

2. In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simulation of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration.

Later a more detailed view about non-determinism in the framework of ZEO has emerged and quantum criticality is here the basic notion. The space-time surface connecting two 3-surfaces at the ends of CD is not unique. Conformal transformations which act trivially at the ends of space-time surface generate a continuum of new extremals with the same value of Kähler action and classical conserved quantities. The number n of conformal equivalence classes is finite and defines the value of h_{eff} (see **Fig.** `http://tgdtheory.fi/appfigures/planckhierarchy.jpg` or **Fig. ??** in the appendix of this book). There exists a hierarchy of breakdowns of conformal symmetry labelled by n. The fractal hierarchy of CDs gives rise to fractal hierarchy of non-determinisms of this kind.

1.2.7 P-Adic Physics As Physics Of Cognition

A further basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$ p-Adic regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration

constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [K119] . The application this notion at the level of the embedding space implies that embedding space has a book like structure with various variants of the embedding space glued together along common rationals (algebraics, see **Fig.** `http://tgdtheory.fi/appfigures/book.jpg` or **Fig. ??** in the appendix of this book). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real embedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

This view implies also that purely local p-adic physics codes for the p-adic fractality characterizing long range real physics and provides an explanation for p-adic length scale hypothesis stating that the primes $p \simeq 2^k$, k integer are especially interesting. It also explains the long range correlations and short term chaos characterizing intentional behavior and explains why the physical realizations of cognition are always discrete (say in the case of numerical computations). Furthermore, a concrete quantum model for how intentions are transformed to actions emerges.

The discrete real projections of p-adic space-time sheets serve also space-time correlate for a logical thought. It is very natural to assign to p-adic pinary digits a p-valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggest that the $p = 2^k - n$ pinary digits represent a Boolean logic B^k with k elementary statements (the points of the k-element set in the set theoretic realization) with n taboos which are constrained to be identically true.

1.2.8 P-Adic And Dark Matter Hierarchies And Hierarchy Of Selves

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

1. Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

2. The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [K37].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [K37]. The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [K37]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K65, K37]. A particularly fascinating implication is the possibility

to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K37].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [K36, K37]. The larger the value of Planck constant, the longer the life-time of self measured as the increase of the average distance between tips of CDs appearing in the quantum superposition during the period of repeated reductions not affecting the part of the zero energy state at the other boundary of CD- Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self experiencse subselves as separate mental images. Averaging over experiences of sub-selves of sub-self would however occur.

3. The time span of long term memories as signature for the level of dark matter hierarchy

The basic question is what time scale can one assign to the geometric duration of quantum jump measured naturally as the size scale of the space-time region about which quantum jump gives conscious information. This scale is naturally the size scale in which the non-determinism of quantum jump is localized. During years I have made several guesses about this time scales but zero energy ontology and the vision about fractal hierarchy of quantum jumps within quantum jumps leads to a unique identification.

CD as an embedding space correlate of self defines the time scale τ for the space-time region about which the consciousness experience is about. The temporal distances between the tips of CD as come as integer multiples of CP_2 length scales and for prime multiples correspond to what I have christened as secondary p-adic time scales. A reasonable guess is that secondary p-adic time scales are selected during evolution and the primes near powers of two are especially favored. For electron, which corresponds to Mersenne prime $M_{127} = 2^{127} - 1$ this scale corresponds to.1 seconds defining the fundamental time scale of living matter via 10 Hz biorhythm (alpha rhythm). The unexpected prediction is that all elementary particles correspond to time scales possibly relevant to living matter.

Dark matter hierarchy brings additional finesse. For the higher levels of dark matter hierarchy τ is scaled up by $\hbar/\hbar_0$. One could understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ.

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question. The level would determine also the time span of long term memories as discussed in [K37]. The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K65, K37]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible

social rules and moral.

1.3 Quantum Biology And Quantum Neuroscience In TGD Universe

Quantum biology - rather than only quantum brain - is an essential element of Quantum Mind in TGD Universe. Cells, biomolecules, and even elementary particles are conscious entities and the biological evolution is evolution of consciousness so that it would be very artificial to restrict the discussion to brain, neurons, or microtubules.

1.3.1 Basic Physical Ideas

The following list gives the basic elements of TGD inspire quantum biology.

1. Many-sheeted space-time allows the interpretation of the structures of macroscopic world around us in terms of space-time topology. Magnetic/field body acts as intentional agent using biological body as a sensory receptor and motor instrument and controlling biological body and inheriting its hierarchical fractal structure. Fractal hierarchy of EEGs and its variants can be seen as communication and control tools of magnetic body. Also collective levels of consciousness have a natural interpretation in terms of magnetic body. Magnetic body makes also possible entanglement in macroscopic length scales. The braiding of magnetic flux tubes makes possible topological quantum computations and provides a universal mechanism of memory. One can also undersand the real function of various information molecules and corresponding receptors by interpreting the receptors as addresses in quantum computer memory and information molecules as ends of flux tubes which attach to these receptors to form a connection in quantum web.

2. Magnetic body carrying dark matter and forming an onion-like structure with layers characterized by large values of Planck constant is the key concept of TGD inspired view about Quantum Mind to biology. Magnetic body is identified as intentional agent using biological body as sensory receptor and motor instrument. EEG and its fractal variants are identified as a communication and control tool of the magnetic body and a fractal hierarchy of analogs of EEG is predicted. Living system is identified as a kind of Indra's net with biomolecules representing the nodes of the net and magnetic flux tubes connections between then.

   The reconnection of magnetic flux tubes and phase transitions changing Planck constant and therefore the lengths of the magnetic flux tubes are identified as basic mechanisms behind DNA replication and analogous processes and also behind the phase transitions associated with the gel phase in cell interior. The braiding of magnetic flux makes possible universal memory representation recording the motions of the basic units connected by flux tubes. Braiding also defines topological quantum computer programs updated continually by the flows of the basic units. The model of DNA as topological quantum computer is discussed as an application. In zero energy ontology the braiding actually generalize to 2-braiding for string world sheets in 4-D space-time and brings in new elements.

3. Zero energy ontology (ZEO) makes possible the proposed p-adic description of intentions and cognitions and their transformations to action. Time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of the book) based on sending of negative energy signal to geometric past would apply to both long term memory recall, remote metabolism, and realization of intentional acting as an activity beginning in the geometric past in accordance with the findings of Libet. ZEO gives a precise content to the notion of negative energy signal in terms of zero energy state for which the arrow of geometric time is opposite to the standard one.

   The associated notion of causal diamond (CD) is essential element and assigns to elementary particles new fundamental time scales which are macroscopic: for electron the time scale is.1 seconds, the fundamental biorhythm. An essentially new element is time-like entanglement which allows to understand among other things the quantum counterparts of Boolean functions in terms of time-like entanglement in fermionic degrees of freedom.

4. The assignment of dark matter with a hierarchy of Planck constants gives rise to a hierarchy of macroscopic quantum phases making possible macroscopic and macrotemporal quantum coherence and allowing to understand evolution as a gradual increase of Planck constant. The model for dark nucleons leads to a surprising conclusion: the states of nucleons correspond to DNA, RNA, tRNA, and amino-acids in a natural manner and vertebrate genetic code as correspondence between DNA and amino-acids emerges naturally. This suggests that genetic code is realized at the level of dark hadron physics and living matter in the usual sense provides a secondary representation for it.

   The hierarchy of Planck constants emerges from basic TGD under rather general assumptions. The key element is the huge vacuum degeneracy which implies that preferred non-vacuum extremals of Kähler action form a 4-D spin glass phase. The basic implications following from the extreme non-linearity of Kähler action is that normal derivatives of embedding space coordinates at 3-D light-like orbits of partonic 2-surfaces and at space-like 3-surfaces at ends of CDs are many-valued functions of canonical momentum densities: this is one of the reasons that forced to develop physics as an infinite-D Kähler geometry vision instead of trying to develop path integral formalism or canonical quantization. A convenient manner to treat the situation is to introduce local many-sheeted covering of embedding space such that the sheets are completely degenerate at partonic 2-surfaces. This leads in natural manner to the hierarchy of Planck constants as effective hierarchy hierarchy and integer multiples of Planck constants emerge naturally.

5. p-Adic physics can be identified as physics of cognition and intentionality. The hierarchy of p-adic length scales predicts a hierarchy of universal metabolic quanta as increments of zero point kinetic energies. Negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds. NMP respects negentropic entanglement and the attractive idea is that the experience of understanding and positively colored emotions relate to negentropic entanglement.

6. Living matter as conscious hologram is one of the basic ideas of TGD inspired biology and consciousness theory. The basic objection against TGD is that the interference of classical fields is impossible in the standard sense for the reason that classical fields are not primary dynamical variables in TGD Universe. The resolution is based on the observation that only the interference of the effects caused by these fields can be observed experimentally and that many-sheeted space-time allows to realized the summation of effects in terms of multiple topological condensations of particles to several parallel space-time sheets. One concrete implication is fractality of qualia. Qualia appear in very wide range of scales: our qualia could in fact be those of magnetic body. The proposed mechanism for the generation of qualia realizes the fractality idea.

1.3.2 Brain In TGD Universe

Brain cognizes and one should find physical correlates for cognition. Also the precise role of brain in information processing and its relationship to metabolism should be understood. Here magnetic body brings as a third player to the couple formed by environment and organism.

1. An attractive idea is that the negentropic entanglement can be assigned with magnetic flux tubes somehow and that ATP serves as a correlate for negentropic entanglement. This leads to a rather detailed ideas about the role of phosphate bond and provides interpretation for the fact that the number of valence bonds tend to be maximized in living matter. In a loose sense one could even call ATP a consciousness molecule. The latest view encourages to consider the possibility that negentropic entanglement with what might be called Mother Gaia is what is transferred in metabolism.

2. The view about the function of brain differs from the standard view. The simplest option is that brain is a builder of symbolic representations building percepts and giving them names rather than the seat of primary qualia relevant to our conscious experience. Sensory organs

would carry our primary qualia and brain would build sensory percepts as standardized mental images by using virtual sensory input to the sensory organs. The new view about time is absolutely essential for circumventing the objections against this vision. The prediction is that also neuronal and even cell membranes define sensory maps with primary qualia assignable to the lipids serving as pixels of the sensory screen. These qualia would not however represent our qualia but lower level qualia. At this moment it is not possible to choose between these two options.

3. The role of EEG and its various counterparts at fractally scaled frequency ranges is to make possible communications to the various onion-like layers of the magnetic body and the control by magnetic body. Dark matter at these layers could be seen as the intentional agent and sensory perceiver.

1.3.3 Anomalies

Various anomalies of living matter have been in vital role in the development of not only TGD view about living matter but also TGD itself.

1. TGD approach to living matter was strongly motivated by the findings about strange behavior of cell membrane and of cellular water, and gel behavior of cytoplasm. Also the findings about effects of ELF em fields on vertebrate brain were decisive and led to the proposal of the hierarchy of Planck constants found later to emerge naturally from the non-determinism of Kähler action. Rather satisfactorily, the other manner to introduce the hierarchy of Planck constants is in terms of gravitational Planck constant: at least in microscopic scales the equivalence of these approaches makes sense and leads to highly non-trivial predictions. The basic testable prediction is that dark photons have cyclotron frequencies inversely proportional to their massess but universal energy spectrum in visible and UV range which corresponds to the transition energies for biomolecules so that they are ideal for biocontrol at the level of both magnetic bodies and at the level of biochemistry.

2. Water is in key role in living matter and also in TGD inspired view about living matter. The anomalies of water lead to a model for dark nuclei as dark proton strings with the surprising prediction that DNA, RNA, anino-acids and even tRNA are in one-one correspondence with the resulting 3-quark states and that vertebrate genetic code emerges naturally. This leads to a vision about water as primordial life form still playing a vital role in living organisms. The model of water memory and homeopathy in turn generalizes to a vision about how immune system might have evolved.

3. Metabolic energy is necessary for conscious information processing in living matter. This suggests that metabolism should be basically transfer of negentropic entanglement from nutrients to the organism. ATP could be seen as a molecule of consciousness in this picture and high energy phosphate bond would make possible the transfer of negentropy.

1.4 Bird's Eye of View about the Topics of the Book

This book tries to give an overall view about TGD inspired theory of consciousness as it stands now. In nutshell TGD based view about consciousness relies following ideas and concepts.

1. The basic notions TGD inspired theory of consciousness are quantum jump identified as a moment of consciousness, self identified as sequence of quantum jumps analogous to bound state of particles, self hierarchy with sub-selves experienced by self as mental images, and sharing and fusion of mental images by quantum entanglement.

2. Dark matter hierarchy, the levels of which are labeled by increasing quantized value of Planck constant, suggests that the geometric durations for the moments of consciousness form defined as the scale of the space-time volume from which conscious experience is about, form an increasing hierarchy so that the highest level associated with a given self would correspond to single moment of consciousness. This would actually eliminate the notion of self and self hierarchy would correspond to a fractal hierarchy of quantum jumps.

3. The anatomy of quantum jumps must be consistent with the notions of state preparation, state function reduction, and unitary evolution and this leads to a detailed view what quantum jump means for quantum states of the Universe identified as classical spinor fields in configuration space, the "world of classical worlds". The zero modes of the configuration space geometry which do not contribute to its metric and thus do not quantum fluctuate, correspond to classical observables. A direct connection with quantum measurement theory emerges.

4. Negentropy Maximization Principle (NMP) defines the basic variational principle of TGD inspired theory of consciousness. NMP states that the negentropy gain in quantum jump is maximal. The allowance of a number theoretic variant of Shannon entropy making sense for rational or algebraic entanglement probabilities implies that quantum jump can also generate or increase the amount of entanglement. A possible interpretation is in terms of bound state entanglement to which conscious information can be assigned.

5. A natural characterization of the fundamental qualia is in terms of quantum number increments associated with the quantum jump. The classical non-determinism of Kähler action (in the usual sense of the world) means that the contents of the conscious experience of a given self comes from a 4-dimensional space-time region rather than representing 3-D snapshot of space-time. This together with the new view about energy and time (negative energies and communications to the geometric past are predicted) leads to a new vision about memory, intentional action, and also metabolism.

6. p-Adic physics as physics of cognition is a genuinely new element as compared to the existing theories of consciousness and forces to give up the view that cognition is localized in the sense of real physics. Indeed, p-adic space-time sheets representing intentions have literally infinite size since most p-adic integers, in particular those which are infinitesimally small, have infinitely large as real numbers. Cognition would quite literally see the real cosmos from outside. The transformations of p-adic space-time sheets to real ones in quantum jump define an attractive view about what happens when intention transforms to an action and is consistent with TGD based view about energy (also negative inertial energies are possible and the density of inertial energy vanishes in cosmological length scales). The discrete rational projection of p-adic space-time sheets to the real embedding space is excellent candidate for the realization of cognitive representations at the level of space-time since p-adic numbers define very naturally a generalization of binary logic and for primes satisfying p-adic length scale hypothesis the resulting logic has also Boolean interpretation as a logic in which certain number of statements are taboos so that the number of allowed statements is reduced from 2^k to $p = 2^k - n$.

7. The new view about the relationship between experienced and geometric time inspires a general model of memory, intentional action, and metabolism. In this model time mirror mechanism meaning communications with geometric past using negative energy (phase conjugate photons) is in central role. Also time-like entanglement plays a key role in the model of memories. A precise conceptualization for this vision is provided by zero energy ontology in which M-matrix generalizes S-matrix. M-matrix is identifiable as the "square" root of density matrix defines time like entanglement coefficients between positive and negative energy parts of the zero energy state located at past and future boundaries of the causal diamond defined by the intersection of future and past directed light-cones.

1.4.1 The organization of "TGD Inspired Theory of Consciousness"

The topics of the book are organized in the following manner.

1. In the 1st part of the book TGD inspired theory of consciousness is discussed at general level. There are three summarizing chapters give a view about how ideas have evolved. Besides this there are chapters devoted to Negentropy Maximization Principle (NMP), to a detailed exposition of the notion of self, and to a model of sensory representations.

   The views about what NMP really states have fluctuated during years and in the recent number theoretical vision NMP follows as almost trivial consequence and applies only in

statistical sense. What is however essential that any system pair can experience what can called quantum measurement of the density matrix describing their mutual entanglement.

In zero energy ontology (ZEO) second important aspect is that there are two kinds of quantum measurements: "big" state function reductions which correspond to state function reductions in the ordinary sense - in these the arrow of time is changed - and "small" state function reductions which would correspond to so called weak measurements. ZEO energy ontology can be said to lift quantum measurement theory to a theory of consciousness by making observer a part of the physical system.

2. 2nd part of the book contains three chapters about the relationship between experienced and geometric time. The first one is more than decade old. The second one - inspired by zero energy ontology and written quite recently - provides a rather detailed vision about how the arrow of geometric time correlating with the arrow of experienced time and the localization of the contents of sensory experience to a narrow time interval emerge. The chapter explaining TGD based view about long term memory is also included.

3. The 3rd part of the book summarizes roughly decade old view about intelligence and cognition. p-Adic physics as physics of cognition and intentionality and many-fermion states as representations of Boolean statements are the key notions. In zero energy ontology also quantal versions of logical rules $A \to B$ realized as quantum variants of Boolean functions emerge at the fundamental level.

   A chapter about the role of dark matter hierarchy, in particular about topological quantum computation as a universal information processing tool, and a chapter about adelic physics as a mathematical description of physics of both sensory experience and cognition, would be needed to make the picture correspond to the recent understanding.

4. The 4th part is devoted to remote mental interactions. The theoretical motivation for taking remote mental interactions seriously is that exactly the same mechanisms which are involved with the interaction between magnetic body and biological body apply also to remote mental interactions in TGD Universe. One could also understand why these phenomena are rare: a kind of immune system making it impossible for foreign magnetic bodies to control and communicate with the biological body possessed by a particular magnetic body would be a highly probable (but perhaps not unavoidable) outcome of evolutionary process.

1.5 Sources

The eight online books about TGD [K135, K127, K102, K83, K24, K79, K54, K115] and nine online books about TGD inspired theory of consciousness and quantum biology [K124, K20, K91, K18, K51, K63, K67, K114, K122] are warmly recommended for the reader willing to get overall view about what is involved.

My homepage (`http://tinyurl.com/ybv8dt4n`) contains a lot of material about TGD. In particular, a TGD glossary at `http://tinyurl.com/yd6jf3o7`).

I have published articles about TGD and its applications to consciousness and living matter in *Journal of Non-Locality* (`http://tinyurl.com/ycyrxj4o` founded by Lian Sidorov and in *Prespacetime Journal* (`http://tinyurl.com/ycvktjhn`), *Journal of Consciousness Research and Exploration* (`http://tinyurl.com/yba4f672`), and *DNA Decipher Journal* (`http://tinyurl.com/y9z52khg`), all of them founded by Huping Hu. One can find the list about the articles published at `http://tinyurl.com/ybv8dt4n`. I am grateful for these far-sighted people for providing a communication channel, whose importance one cannot overestimate.

1.6 The contents of the book

1.6.1 PART I: BASIC IDEAS OF TGD INSPIRED THEORY OF CONSCIOUSNESS

Matter, Mind, Quantum

This chapter is devoted to the TGD inspired theory of consciousness. TGD inspired theory of consciousness could be seen as a generalization of quantum measurement theory to make observer, which in standard quantum measurement theory remains an outsider, a genuine part of physical system subject to laws of quantum physics. The basic notions are quantum jump identified as moment of consciousness and the notion of self: zero energy ontology (ZEO) is essential for the notion of self. Negentropy Maximization Principle (NMP) defines the dynamics of consciousness and as a special case reproduces standard quantum measurement theory.

1. Quantum jump as moment of consciousness

TGD suggests that the quantum jump between quantum histories could identified as moment of consciousness and could therefore be for consciousness theory what elementary particle is for physics.

This means that subjective time evolution corresponds to the sequence of quantum jumps $\Psi_i \to U\Psi_i \to \Psi_f$ consisting of unitary process followed by state function process. In zero energy ontology (ZEO) U defines a unitary matrix between zero energy states and is naturally assignable to intentional actions whereas the ordinary S-matrix telling what happens in particle physics experiment (for instance) generalizes to M-matrix defining time-like entanglement between positive and negative energy parts of zero energy states. One might say that U process corresponds to a fundamental act of creation creating a quantum superposition of possibilities and the remaining steps generalizing state function reduction process select between them.

2. Negentropy Maximization Principle and the notion of self

U-process is followed by a cascade of state function reductions. Negentropy Maximization Principle (NMP) states that in a given quantum state the entangled subsystem-complement pair with largest entanglement entropy can perform the quantum jump. More precisely: the reduction of the entanglement entropy in the quantum jump is as large as possible. This selects the pair in question and in case of ordinary entanglement entropy leads the selected pair to a product state. The interpretation of the reduction of the entanglement entropy as conscious information gain makes sense. The sequence of state function reductions decomposes at first step the entire system to two parts in such a manner that the reduction entanglement entropy is maximal. This process repeats itself for subsystems. If the subsystem in question cannot be divided into a pair of entangled free system the process stops since energy conservation does not allow it to occur (binding energy) or the resulting entanglement is negentropic for all sub-system-complement divisions.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond (CD) leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

p-Adic physics as correlate for cognition and intention leads to the notion of negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness. Consistency with standard quantum measurement theory forces negentropic entanglement to correspond to density matrix proportional to unit matrix. Unitary entanglement

typical for quantum computing systems gives rise to unitary entanglement.

The first state function reduction - wake-up of self- at given boundary of CD is a hierarchical cascade proceeding from long to short scales. The reduction process can stop also if the self in question allows only decompositions to pairs systems with negentropic entanglement. This does not require that that the system forms a bound state for any pair of subsystems so that the systems decomposing it can be free (no binding energy). This defines a new kind of bound state not describable as a jail defined by the bottom of a potential well. Subsystems are free but remain correlated by negentropic entanglement.

Ordinary state function reductions imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of an iteration like process leading to the asympotic self-organization patterns. One could regard dissipation as a Darwinian selector as in standard theories of self-organization. NMP predicts that self organization and hence presumably also fractalization can occur inside selves. NMP would favor the generation of negentropic entanglement. This notion is highly attractive since it could allow to understand how quantum self-organization generates larger coherent structures. Note that state function reduction for negentropic entanglement is highly deterministic since the number of degenerate states with same negative entanglement entropy is expected to be small. This could allow to understand how living matter is able to develop almost deterministic cellular automaton like behaviors. In ZEO this self-organization is for 4-D spatio-temporal patterns since 3-surfaces are pairs of space-like surfaces at the boundaries of CD and maxima of Kähler function are selected in the process. These temporal patterns correspond to behaviors and functions in living matter.

The chapter is devoted to the discussion of detailed implications of these general ideas. The topics to be discussed include following basic questions.

1. How the general structure for the contents of consciousness of self are determined? The basic assumption is that self hierarchy in which subselves define mental images of self is responsible for the general structure of conscious experience. ZEO allows to derive the space-time correlates of selves.

2. How the physical realization of the hardware of consciousness differs from that assumed in neuroscience? Here the notion of magnetic body as intentional agent using biological body as motor instrument and sensory receptor is central.

3. What is the precise relationship between the geometric time of physicist and subjective time identified in terms of a sequence of quantum jumps? ZEO gives the most convincing answer to this question found hitherto.

4. What can one one say about various types of conscious experience in the proposed framework. This includes p-adic description of cognition and intentional action, model for sensory experience and sensory qualia, model for Boolean mind in terms of fermions, a model for directed attention, ideas about emotions, and also a general interpretation for altered states of consciousness based on the special features of negentgropic entanglement.

5. Can one provide solutions to the paradoxes of quantum physics, theories of consciousness, and logic in the proposed conceptual framework?

The discussion differs considerably from the earlier one. The reason is that the developments occurred during period 2005-2010 (ZEO, hierarchy of Planck constants assigned to dark matter, hyper-finite factors of type II_1, the implications of the number theoretical negentropies) are introduced from the beginning to the formulation of the theory rather than as additions to the existing text so that the representation is more coherent and the number of internal inconsistencies is minimized. The latest progress relates to the understanding of the notions of psychological time and self (2012-2014).

Negentropy Maximization Principle

In TGD Universe the moments of consciousness are associated with quantum jumps between quantum histories. The proposal is that the dynamics of consciousness is governed by Negentropy

Maximization Principle (NMP), which states the information content of conscious experience is maximal. The formulation of NMP is the basic topic of this chapter.

NMP codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step. In the generic case this implies at each step a decomposition of the system to unique unentangled subsystems and the process repeats itself for these subsystems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. The natural assumption is that self loses consciousness when it entangles via bound state entanglement.

There is an important exception to this vision based on ordinary Shannon entropy. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement (NE), which is not bound state entanglement in standard sense since the condition that state function reduction leads to an eigenstate of density matrix requires the final state density matrix to be a projection operator.

NE might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. For the generation of NE the outcome of the reduction is not random: the prediction is that second law is not a universal truth holding true in all scales. Since number theoretic entropies are natural in the intersection of real and p-adic worlds, this suggests that life resides in this intersection. The existence effectively bound states with no binding energy might have important implications for the understanding the stability of basic bio-polymers and the key aspects of metabolism. A natural assumption is that self experiences expansion of consciousness as it entangles in this manner. Quite generally, an infinite self hierarchy with the entire Universe at the top is predicted.

There are two options to consider. Strong form of NMP, which would demand maximal negentropy gain: this would not allow morally responsible free will if ethics is defined in terms of evolution as increase of NE resources. Weak form of NMP would allow self to choose also lower-dimensional sub-space of the projector defining the final state sub-space for strong form of NMP. Weak form turns out to have several highly desirable consequences: it favours dimensions of final state space coming as powers of prime, and in particular dimensions which are primes near powers of prime: as a special case, p-adic length scale hypothesis follows. Weak form of NMP allows also quantum computations, which halt unlike strong form of NMP.

Besides number theoretic negentropies there are also other new elements as compared to the earlier formulation of NMP.

1. ZEO modifies dramatically the formulation of NMP since U-matrix acts between zero energy states and can be regarded as a collection of orthonormal M-matrices, which generalize the ordinary S-matrix and define what might be called a complex square root of density matrix so that kind of a square root of thermodynamics at single particle level justifying also p-adic mass calculations based on p-adic thermodynamics is in question.

2. The hierarchy of Planck constants labelling a hierarchy of quantum criticalities is a further new element having important implications for conciousness and biology.

3. Hyper-finite factors of type II_1 represent an additional technical complication requiring separate treatment of NMP taking into account finite measurement resolution realized in terms of inclusions of these factors.

NMP has wide range of important implications.

1. In particular, one must give up the standard view about second law and replace it with NMP taking into account the hierarchy of CDs assigned with ZEO and dark matter hierarchy labelled by the values of Planck constants, as well as the effects due to NE. The breaking of second law in standard sense is expected to take place and be crucial for the understanding of evolution.

2. Self hierarchy having the hierarchy of CDs as embedding space correlate leads naturally to a description of the contents of consciousness analogous to thermodynamics except that the entropy is replaced with negentropy.

3. In the case of living matter NMP allows to understand the origin of metabolism. NMP demands that self generates somehow negentropy: otherwise a state function reduction to tjhe opposite boundary of CD takes place and means death and re-incarnation of self. Metabolism as gathering of nutrients, which by definition carry NE is the manner to avoid this fate. This leads to a vision about the role of NE in the generation of sensory qualia and a connection with metabolism. Metabolites would carry NE and each metabolite would correspond to a particular qualia (not only energy but also other quantum numbers would correspond to metabolites). That primary qualia would be associated with nutrient flow is not actually surprising!

4. NE leads to a vision about cognition. Negentropically entangled state consisting of a superposition of pairs can be interpreted as a conscious abstraction or rule: negentropically entangled Schrödinger cat knows that it is better to keep the bottle closed.

5. NMP implies continual generation of NE. One might refer to this ever expanding universal library as "Akaschic records". NE could be experienced directly during the repeated state function reductions to the passive boundary of CD - that is during the life cycle of sub-self defining the mental image. Another, less feasible option is that interaction free measurement is required to assign to NE conscious experience. As mentioned, qualia characterizing the metabolite carrying the NE could characterize this conscious experience.

6. A connection with fuzzy qubits and quantum groups with NE is highly suggestive. The implications are highly non-trivial also for quantum computation allowed by weak form of NMP since NE is by definition stable and lasts the lifetime of self in question.

Self and Binding: Part I

This chapter is the first part of a representation devoted to the notion of self. The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time. This view had however problems, which are rather obvious and it seems that new physics is needed.

The TGD based notion of self involves several new physics ingredients. These include Zero Energy Ontology (ZEO), hierarchy of Planck constants labelling a fractal hierarchy of quantum critical systems, and adelic view about quantum physics fusing real and various p-adic physics serving as correlates of cognition to single coherent whole.

Negentropic entanglement is a crucial notion. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that Negentropy Maximization Principle (NMP) favors generation of negentropic entanglement, which need not be bound state entanglement in standard sense. This leads to the vision that negentropic entanglement defines kind of Akashic records, kind of library storing potentially conscious information becoming conscious in interaction free measurement. Akashic records could define self model as opposed to self. Consistency with standard quantum measurement theory requires that density matrix for negentropic entanglement is projector and thus proportional to unit matrix associated to entanglement matrix characterized by a unitary matrix associated with quantum computation.

What is the precise identification of self allowing to understand both of the above mentioned aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO only rather recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in

TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will and death of self and its re-incarnation at the opposite boundary CD. Also the arrow of geometric time is changed.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble sub-sub-selves increases.

The sub-selves of two unentangled selves can entangle although selves remain unentangled. This is possible by the modification of the subsystem concept forced by the p-adic length scale cutoff. The entanglement of sub-selves means fusion and sharing of mental images providing a universal telepathy like quantum communication mechanism and presumably making possible both molecular, cellular, and human societies.

Self and Binding: Part II

This chapter is second part of a representation devoted to the notion of self as it is understood in TGD framework.

The possibility of negentropic entanglement has profound implications. It leads to a vision about learning as a basic quantum process possible in the intersection of real and p-adic worlds and made possible because state function reduction ceases to be a random process for negentropically quantum states. Quite concrete ideas about the role of synaptic transmission and neural transmitters for consciousness emerge. Music experience provides an especially interesting application for the vision about consciousness and zero energy ontology together with number theoretical vision inspires several concrete interpretations. Synchronous firing of neurons- in particular at 40 Hz frequency- is an attractive correlate for the negentropic entanglement and synesthesia can be interpreted as a particular manifestations of negentropic entanglement.

In TGD framework it is not at all obvious that the highest levels of our personal self hierarchy should correspond to the size of the physical body. Various empirical facts, in particular the observations related to the special effects of excitations of geomagnetic fields and ELF em fields in EEG frequency range on brain, inspire the hypothesis that our selves correspond to topological field quanta of em fields associated with EEG frequencies and thus by Uncertainty Principle have size scale of Earth. Indeed, the notion of magnetic body as a space-time correlate of self has become a key concept in TGD inspired biology. Magnetic body carrying dark matter identified as lare h_{eff} phases can be seen as intentional agent using biological body as motor instrument and sensory receptor.

Quantum Model for Sensory Representations

One of the toughest challenges of quantum theories of consciousness is to understand how sensory representations are constructed at quantum level. It became as a surprise that the vision about sensory representation which resulted from a long lasting thought experimentation is actually very much what the original experience about myself as a computer sitting at its own terminal, when taken very literally in some aspects, actually suggests. This vision adds to the standard view about brain an additional layer responsible for the sensory representations and brings in the quantum level of control so that nerve pulse patterns are only part of the control loop. In fact, it has turned out that the same basic theory applies to both geometric memories, precognition, sensory perception, and motor actions. The vision goes as follows.

1. As far as our consciousness is considered, primary sensory organs are the seats of sensory qualia and brain only constructs cognitive and symbolic representations. Various objections against this hypothesis can be circumvented by assuming that sensory organs entangle with the brain. The question how imagination differs from the sensory experience becomes trivial, and dreams and hallucinations can be understood as resulting via the back-projection of the imagined mental images to the primary sensory organs.

2. Libet's findings about passive aspects of consciousness lead to the view that sensory percept can be regarded as a geometric memory in time scale of .5 seconds involving entanglement with the geometric past mediated by negative energy MEs. Libet's experiments about the

active aspects of consciousness in turn lead to realization that motor actions and sensory perceptions are in a well-defined sense time-reversals of each other: pre-cognition is a definite aspect of motor action. One can say that motor action at the level of negative energy MEs is initiated from the level of muscles rather than brain and motor imagination is just a motor action starting from some level higher than muscles. The transformation of a p-adic ME to negative energy ME realizes the transformation of intention to action in a precisely targeted manner and the emission of negative energy makes possible extreme flexibility by buy now-let others pay mechanism of remote metabolism. This process is the basic step initiating motor action, neural activity leading to imagery, and active memory recall. This picture also explains why geometric memories occur more or less spontaneously whereas precognition is a rare phenomenon (pre-cognizer must *receive* negative energy MEs). Zero energy ontology (ZEO) provides a firm theoretical justification for the notion of negative energy signal to past obeying reversed arrow of time.

3. In TGD framework one can assign to any material structure a magnetic body having much large size. The closed flux loops composing magnetic bodies allow an elegant realization of the long term memories in terms of negative and positive energy MEs. A stronger hypothesis is that various magnetic bodies define sensory canvases at which various sensory representations are realized. Motor action can be seen as a geometric time reversal of sensory perception. Cortex can be seen as a collection of pre-existing symbolic and cognitive features possibly entangled with sensory mental images at sensory organs, and activated when they appear in the perceptive field or form a part of motor action. The basic task of the central nervous system is to identify these features from the sensory input. The mental images associated with various parts of the physical body are entangled with the points of the correspondin magnetic bodies representing objects of the perceptive field by sharing of mental images and in this manner define attributes of these objects. There is an entire hierarchy of representations corresponding to the hierarchy of magnetic bodies, and also sensory perception involves active selections by entangling a sequences of mental images defining paths along the tree-like structure defined by the hierarchy of magnetic bodies beginning from the personal magnetic body and ending at the roots defined by magnetic bodies of sensory organs. This explains phenomena like sensory rivalry.

4. The decomposition of the perceptive field to objects is one of the basic aspects of sensory experiencing and TGD provides a mechanism generating these objects as space-time sheets: the boundaries of these objects correspond to regions of strong Kähler electric field whose strength is assumed to correlate with the intensity of the neural input. It might be that even the objects of perceptive field or thoughts could be regarded as features. In zero energy ontology causal diamonds become the embedding space correlates of mental images and one can ask whether Negentropy Maximization Principle -perhaps suitably generalized- could force their generation.

5. The computational activities associated with the construction of the sensory representations (say estimating distances and directions of the objects of perceptive field) and virtual sensory representations representing the goals of motor action are presumably realized as iterated processes in which virtual sensory inputs characterizing the expected experiences are compared with the real world sensory input. In a similar manner the goal of the motor action is compared with the sensory representation resulting from effect of a virtual motor action on the representation of the recent state of world and body. This comparison does not necessarily require sensory representation at any level of the self hierarchy and could be based on comparison circuits defined by parallel supra currents in which the inputs which are sufficiently near to each other generate constructive interference giving rise to a large Josephson current.

6. Zero energy ontology together with the notion of causal diamond (CD) identified as embedding space correlate of self and the moduli space of CDs, the description of dark matter in terms of a hierarchy of Planck constants implying a generalization of the notion of the imbedding space, and the vision about living matter as something residing in the intersection of real and p-adic worlds and carrying positive entanglement negentropy allow to make this

vision more detailed and lead to surprisingly precise quantitative predictions and connect the basic biological time scales to those assignable to elementary particles in zero energy ontology. The notion of spectroscopy of consciousness can be formulated for the geometric aspects of conscious experience in terms of the moduli space of causal diamonds and the frequencies of the generalized EEG.

1.6.2 PART II: TIME AND CONSCIOUSNESS

Time and Consciousness

This chapter as also other chapters about the notion of time appearing in books about TGD inspired theory of consciousness should be taken as stories about how ideas developed through many tortuous twists and turns. In this abstract I only summarize the outcome and leave the description of the tortuous path to the chapter.

If one accepts the identification of moment of consciousness as quantum jump between quantum histories, the basic challenge is to explain how psychological time arises: why the contents of at least sensory experiences are concentrated around definite value of geometric time and what is the origin of the arrow of psychological time. It has become gradually clear that TGD cannot reproduce the common sense conception of time as such and that one can only require that the generalized view is consistent with our restricted conscious experiences and shows our position in the hierarchy of consciousness.

The understanding of the notion of psychological time and its arrow - or equivalently, the relationship between subjective and geometric time - turned out to be quite difficult challenge and led to a handful of proposals based on the identification of space-time sheet as a correlate of self and the idea that the experienced flow of geometric correspond to some kind of motion in space-time or in embedding space. These identifications did not lead to anything practical and generated paradoxes. Also the notion of self turned to be problematic.

The most recent proposal involves no ad hoc assumptions and relies on the recent formulation of quantum TGD using zero energy ontology (ZEO) and the understanding of both nature of time and self reduces to a more precise view about what happens in state function reduction in ZEO.

1. The embedding space correlate of self is so called causal diamond (pair of future and past directed light-cones) which is 8-D sub-manifold of the embedding space rather than space-time sheet.

2. In ZEO state function reduction can occur at both boundaries of CD but can occur repeatedly at given CD boundary. In the repeated reduction the already reduced positive/negative energy state remains the same just as the state function remains invariant in ordinary repeated state function reduction. Second boundary of CD corresponds to a wave function in the moduli space of CDs and changes: since the distance between the tips of CD is one particular modular degree of freedom, the average value of this distance tends to increase just as the distance of particle diffusing inside cone increases during diffusion. This gives rise to the experience flow of geometric time identified this temporal distance.

3. Self can be understood as a sequence of repeated state functions at the same boundary - the original identification was as sequence of all quantum jumps. The arrow of geometric time changes at some level of self hierarchy when quantum jump takes at the second boundary of CD and could correspond to volition, act of free will.

4. The notion of negentropic entanglement also leads to a model for self model to be carefully distinguished from self.

The concept of self led to the understanding of the subjective memory as an average over experiences of self experienced after its "wake-up". Subjective memories are always about past. Geometric memories are predictions for the future/past assuming that no quantum jumps would occur after/had occurred before the one giving rise to the geometric memory. Pre-cognitions can be seen as geometric memories about future. Intentions are p-adic variants of precognitions. It seems that long term memories must correspond to geometric memories: this hypothesis, when combined with the spin glass model of brain, the notion of quantum self-organization, and some key

aspects of many-sheeted physics, allows to understand the basic aspects of the long term memory and avoids the basic difficulties of the neural net models.

About the Nature of Time

This chapter as also other chapters about the notion of time appearing in books about TGD inspired theory of consciousness should be taken as stories about how ideas developed through many tortuous twists and turns. In this abstract I only summarize the outcome and leave the description of the tortuous path to the chapter.

The identification of the experienced time t_e and geometric time t_g involves well-known problems. Physicist is troubled by the reversibility of t_g contra irreversibility of t_e, by the conflict between determinism of Schrödinger equation and the non-determinism of state function reduction, and by the poorly understood the origin of the arrow of t_g. In biology the second law of thermodynamics might be violated in its standard form for short time intervals. Neuroscientist knows that the moment of sensory experience has a finite duration, does not understand what memories really are, and is bothered by the Libet's puzzling finding that neural activity seems to precede conscious decision.

These problems are discussed in the framework of Topological Geometrodynamics (TGD) and TGD inspired theory of consciousness constructed as a generalization of quantum measurement theory. In TGD space-times are regarded as 4-dimensional surfaces of 8-dimensional space-time $H = M^4 \times CP_2$ and obey classical field equations.

The basic notions of consciousness theory are quantum jump and self. Subjective timew as originally identified as a sequence of quantum jumps, which somehow integrate to form single coherent entity, self. Self has as a geometric correlate a fixed volume of H- "causal diamond"- defining the perceptive field of self. This picture leaves however open two key questions. How the arrow of time and localization of contents of sensory experience emerge and what self do really mean? This chapter discusses several approaches to the problem.

The most recent and one might hope also the final proposal involves no ad hoc assumptions and relies on the recent formulation of quantum TGD using zero energy ontology (ZEO) and the understanding of both nature of time and self reduces to a more precise view about what happens in state function reduction in ZEO.

1. The embedding space correlate of self is so called causal diamond (pair of future and past directed light-cones) which is 8-D sub-manifold of the embedding space rather than space-time sheet.

2. In ZEO state function reduction can occur at both boundaries of CD but can occur repeatedly at given CD boundary. In the repeated reduction the already reduced positive/negative energy state remains the same just as the state function remains invariant in ordinary repeated state function reduction. Second boundary of CD corresponds to a wave function in the moduli space of CDs and changes: since the distance between the tips of CD is one particular modular degree of freedom, the average value of this distance tends to increase just as the distance of particle diffusing inside cone increases during diffusion. This gives rise to the experience flow of geometric time identified this temporal distance.

3. Self can be understood as a sequence of repeated state functions at the same boundary - the original identification was as sequence of all quantum jumps. The arrow of geometric time changes at some level of self hierarchy when quantum jump takes at the second boundary of CD and could correspond to volition, act of free will.

4. The notion of negentropic entanglement also leads to a model for self model to be carefully distinguished from self.

Quantum Model of Memory

The neural realization of long term memories has remained to a high extent a mystery in the framework of the standard brain science. The TGD based quantum model for memory have developed gradually from the basic realization that in TGD framework the identification of quantum states

as quantum histories makes it un-necessary to store information about the geometric past to the geometric now. This has deep implications.

1. It is possible to separate genuine geometric memory recall from apparent memory recalls such as feature recognition, associations, and implicit and procedural memories. There are no memory storages in brain and only memory representations abstracting the essential aspects of experience are needed.

2. The models of long term memory based on the assumption that information about the geometric past is stored in the recent state of the system predict that the new memories should mask the old ones. It is however known that childhood memories are the stablest ones. In TGD framework this ceases to be a problem.

   Mirror mechanism provides a very general mechanism of long term memory. To remember something at a temporal distance T in the geometric past is to look at a mirror at a distance $cT/2$. If the mirror is quantum mirror only a timelike entanglement (allowed by the non-determinism of Kähler action) of the mental image of the geometric past with a mental image in brain now is needed. The un-necessity to communicate memories classically implies extreme generality of the mechanism: all kinds of memories: sensory, cognitive, verbal,.... can be recalled in this manner. Even the mechanism of memory recall by cue can be generalized since the notion of tele association makes in principle sense.

   The basic objections against this over-simplified picture is that there is no guarantee that the reflected ME returns to the brain and that there is no control over the time span of long term memories. The notion of magnetic body allows a more realistic formulation.

3. Zero energy ontology (ZEO) brings in the possibility of temporary change of the arrow of geometric time at some level of the hierarchy of space-time sheets. This provides a justification for the notion of negative energy signals. Brain or the personal magnetic body generates spontaneously negative energy MEs with all fundamental frequencies. These MEs can be also curved and are parallel to the closed flux tubes defining the personal magnetic body and connect geometric now with the brain of the geometric past: multiple reflections are probably required to achieve this. The length of the closed magnetic loop defines the time span of the corresponding long term memory. The sharing of mental images by timelike entanglement allows to communicate the desire to remember to the geometric past, and gives rise to the memory recall in the case of episodal memories. In the case of non-episodal/declarative memories the memory is communicated from the brain of the geometric past by classical communications using positive positive energy MEs which propagate with an effective phase velocity much lower than light velocity along closed magnetic flux tubes and generate in the receiving end symbolic representation of the memory.

Macrotemporal quantum coherence is a further important piece of the model. The understanding of how macrotemporal quantum coherence is made possible by the spin glass degeneracy led to a concrete realization of the mirror model and also provided a connection with the ideas of Hameroff and Penrose. When a bound state is formed the zero modes of the bound state entangled subsystems become quantum fluctuating degrees of freedom. This means that state function reduction and state preparation cease to occur in these degrees of freedom. The bound state is in a kind of long-lasting multiverse state, or state of "oneness" experientially, and the sequence of quantum jumps defined by the duration of the bound state behaves effectively as a single quantum jump. Macrotemporal quantum coherence making possible supercomputer like activities becomes possible.

The hierarchy of Planck constants emerging from the non-determinism of Kähler action implying also spin glass degeneracy provides a more precise view about the emergence of quantum coherence. Also a connection with quantum criticality and hierarchy of breakings of conformal invariance emerges.

The spin glass degeneracy associated with the join along boundaries bonds (the original space-time correlates for the bound state formation replaced later by magnetic flux tubes) lengthens the lifetimes of the bound states dramatically and solves thus the basic objections against quantum consciousness. The spin glass degeneracy is broken only by classical gravitational energy

of the system. The quantum jumps between different classical gravitational configurations involve the emission of gravitational (equivalently Z^0) MEs and the intention to remember is realized as a transformation of p-adic ME to negative energy gravitational ME. The fact that classical gravitational fields couple to classical gauge fields with a coupling which is about 10^8 stronger than the ordinary gravitational coupling, could play an important role too. Water clusters and macromolecules with sizes in the range of cell membrane thickness and cell size are good candidates for generating gravitonic MEs responsible for all geometric memories. Also classical Z^0 interaction might be involved since gravitonic MEs can be regarded also as Z^0 MEs.

A neuro level model of long term memory is discussed. The model conforms with the basic facts known about the relationship of hippocampus and long term memory.

1.6.3 PART III: INTELLIGENCE, INFORMATION, AND COGNITION

Conscious Information and Intelligence

The notions of information and intelligence are discussed in TGD framework. Possible definitions for the information measures of the configuration space spinor field and information gain of conscious experience as well as the information theoretic interpretation of Kähler action are discussed in detail the first sections of the chapter.

1. The key element of the approach is the number theoretic generalization of entanglement entropy. Quantum entanglement between real and p-adic degrees of freedom makes sense if entanglement coefficients are rational or even algebraic numbers. In this case one can define entanglement entropy using the p-adic variant of the logarithm. p-Adic entropy can be also negative, and the states for which the entropy is negative are stable against self measurements (NMP) and define macrotemporally quantum coherent states. The number-theoretic entropy serves as an information measure for cognitive entanglement, and positive entanglement negentropy can be interpreted as a correlate for the experience of understanding. Number theoretic entanglement measures are natural in what might be called the intersection of real and p-adic worlds (partonic 2-surfaces have mathematical representations making sense both p-adically and in real sense) and this leads to a vision about life as something residing in this intersection. The consistency with standard quantum measurement theory leads to the conclusion that negentropic entanglement must correspond to a density matrix proportional to unit matrix. Entanglement matrix proportional to a unitary matrix characterizing quantum computation gives therefore rise to negentropic entanglement.

2. Various measures for the information contents of consciousness are discussed.

   (a) The reduction of entanglement entropy defines a natural measure for conscious information gain in single step of the state of state function reduction process decomposing subsystem to a pair of un-entangled sub-systems. If entanglement is negentropic the entanglement negentropy either increases or the system is stable against state function reduction.

   (b) It seems natural to assume that the information measures are associated with the entire cascade and that they are additive in the sense that information gain is sum over the information gains of the steps of the cascade and that a given step contributes by the sum of the information gains associated with unentangled subsystems which are subject to self measurement in a given step of the cascade.

   (c) One can also assign information measures to the resulting indecomposable systems. For subsystem which is bound state in the normal sense and thus has entropic entanglement, one can consider all possible decomposition of the system to a sub-system and its complement and define the entanglement negentropy as the negative for the minimum value of entropy obtained in this manner. If the system is negentropically entangled one can define entanglement negentropy as the maximum of entanglement negentropy obtained in this manner. This means that one can assign to the final state of state

function reduction unique negentropy as the sum of the negative contributions associated with selves which are internally bound state entangled and positive contributions of negentropic selves.

(d) The information content of the conscious experience associated with self is more interesting practically. Since self defines a statistical ensemble, it is straightforward to define entropies associated with the increments of quantum numbers and zero modes defining non-geometric and geometric qualia. These entropies characterize the fuzziness of the quale and are "negative" information measures. One can also assign to non-decomposable subselves the information measures and they give either positive or negative contribution to the information content of self.

(e) In principle this allows to define also the net information gain of quantum jump as the difference of the total negentropies of the final and initial states of quantum jump identified as those produced by the state function reduction process. Initial and final state negentropies would characterize spinor fields of WCW ("world of classical worlds").

3. Information theoretic interpretation of the Kähler function is discussed in detail. Quantum classical correspondence suggests that the magnetic part of Kähler action would correspond to information content of negentropic entanglement and electric part to the negative information content of entropic bound state entanglement. Kähler function defined as the negative of the Kähler action can be interpreted as an entropy type measure for the information content of the space-time surface. Without quantum criticality entropic configurations carrying strong Kähler electric fields would be favored. The proposal is that the quantum criticality of Kähler action possible for the critical value of Kähler coupling strength makes possible large degeneracy of the negentropic extremals carrying large Kähler magnetic action and makes TGD universe maximally interesting and maximizes its intelligence so that even infinite negentropy is possible. Number theoretical criticality would relate to this criticality very closely. The proposal that living matter is near vacuum extremal so that the degeneracy of negentropic configurations is high is discussed.

4. The physical interpretation for the hierarchy of Planck constants would be in terms of a hierarchy of quantum criticalities concretizing the vision about quantum criticality of TGD Universe. TGD Universe would be like a hill at the top of a hill at .... The larger the Planck constant the larger the size scale of the hill. Criticality involves crucially the notion of conformal gauge symmetry. The conformal symmetries correspond to sub-algebra of the full algebra isomorphic to it acting as gauge symmetries and with conformal weights coming as n-multiples of those for the full symmetry algebra. $h_{eff} = n \times h$ would label the levels of the hierarchy. This hierarchy would correspond directly to the hierarchy of measurement resolutions and to hierarchy of hyperfinite factors of type II_1 (HFFs). Also now one obtains infinite hierarchies of symmetry breakings and the identification with the hierarchies of inclusions of HFFs is compelling. Hence various hierarchies reflect the same underlying phenomenon.

   The phase transitions reducing criticality would take place spontaneously unlike opposite phase transitions. This vision is especially powerful in biology, where homeostasis could be seen as mechanisms preventing the reduction of criticality but at expense of metabolic energy. The basic goal of living system would be staying at criticality. Eastern philosophies would formulate this fight for staying at criticality using the notions of ego and Karmic cycle. In the phase transition increasing $h_{eff} = n \times h$ part of gauge degrees of freedom assignable to a sub-algebra of the full super-symplectic algebra are transformed to physical ones and this implies better measurement resolution. The new HFF contains the previous one as sub-factor. Evolution understood as increase of h_{eff} forced by Negentropy Maximization Principle as also interpretation improvement of measurement/cognitive resolution.

Concerning the modelling of conscious intelligence the following aspects are important.

1. Zero energy states -which replace the earlier notion of association sequence inspired by the failure of strict determinism for Kähler action in standard sense - can be seen as memes

with M-matrices characterizing the time-like entanglement representing "laws of physics". Negentropic time like entanglement makes possible for fully state function reduced states to represent rules as quantum superposition of state pairs representing instances a→b for a general rule A→B. Also space-like negentropic quantum entanglement is important piece of the story. For fermion Fock states this gives Boolean rules as a special case. Zero energy states represent geometric memories, simulations for time development whereas selves represent subjective memories and conscious experience involves always the comparison of geometric and subjective memories telling whether expectations were realized. Quantum theory of self-organization applies also to the evolution of consciousness understood as self-organization in the ensemble of association sequences/selves and implies Darwinian selection also at the level of selves and conscious experiences.

2. TGD Universe is quantum computer in a very general sense. Negentropic quantum entanglement stabilizes qubits but makes them fuzzy. This leads to a modification of the standard paradigm of quantum computation. Quantum computationalism is shown to reproduce the relevant aspects of computationalism and connectionism without reducing conscious brain to a deterministic machine. Holographic brain is also one of the dominating ideas of neuroscience. TGD based realization of memory allows to reduce hologram idea to its essentials: what matters is that piece of hologram is like a small window giving same information as larger window but in less accurate form. This inspires the concept of neuronal window: each neuron has small window to the perceptive landscape and is typically specialized to detect particular feature in the landscape. Coherent photons emitted by mindlike space-time sheets and propagating along axonal microtubules serving as wave guides, realize neuronal windows quantum physically. Massless extremals allow rather precise definition for the notion of quantum hologram.

   A more refined formulation of these ideas is based on the notion of conscious hologram. Many-sheeted space-time is essentially a fractal Feynman diagram with lines thicknened to 4-surfaces. The lines are like wave guides carrying laser beams and vertices are like nodes where these laser beams interfere and generate the points of the hologram. The 3-dimensionality of the ordinary hologram generalizes to stereo consciousness resulting in the fusion of mental images associated with various nodes of the conscious hologram. An essential element is the possibility of negative energy space-time sheets analogous to the past directed lines of the Feynman diagram: negative energy MEs are the crucial element of sensory perception, motor action, and memory.

3. An important element is effective four-dimensionality of brain making possible to understand long term memories, planning and motor activities in a completely new manner. Further important ideas are music metaphor already described and the vision about brain as an associative net. ZEO and the notion of CD (causal diamond) provides justification for the memetic code and relates it to fundamental elementary particles time scales. The codewords of the memetic code consist of sequences of 126 bits and are represented in terms of nerve pulse sequences or membrane oscillations and time varying quark magnetization, is the key essential element of brain as cognitive system. Codewords can be interpreted either as elements of a Boolean algebra or as bits in the binary expansion of an integer in the range $(0, 2^{126})$ so that memetic code makes brain able to assign numbers with qualia. An attractive and testable identification for the memetic codewords is as phonemes of language.

p-Adic Physics as Physics of Cognition and Imagination

TGD as a generalized number theory vision supports the interpretation of the p-adic physics in terms of physical correlates of cognition and intentionality so that matter-mind dichotomy would correspond to real–p-adic dichotomy at the level of the geometric correlates of mind. This interpretation has far reaching implications for both TGD inspired theory of consciousness and for the general world view provided by TGD. Cognition is predicted to be present in all length scales and the success of the p-adic physics in elementary particle length scales forces to conclude that cognition and intention are present even at this level.

The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is the key guiding principle also in TGD inspired quantum biology.

The very fact that the notion of conscious information makes sense only in this intersection supports the proposed interpretation of p-adic physics. Zero energy ontology (ZEO) and the notion of causal diamond (CD) with zero energy states having interpretation as memes in very general sense is also of central importance, and allows a quantitative formulation reducing the fundamental bio-rhythms to fundamental elementary particle time scales. The hierarchy of Planck constants as an explanation of dark matter and energy as macroscopic quantum phases even in astrophysical scales and implying that dark matter is a key actor in the drama of life is the third key element.

In this chapter the implications of this vision are studied from the point of view of cognitive consciousness. The basic ideas behind the proposed vision about intentionality and cognition are following.

1. p-Adic space-time sheets are identified as the correlates of cognition and intention. The possibility to identify the inherent non-determinism of the p-adic field equations as the non-determinism of imagination makes this identification attractive. Only the p-adic space-time sheets in the intersection of real and p-adic worlds allow the transformation of intentions to actions and sensory input to cognitions. Cognitions and intentions are related by time reversal in zero energy ontology. The common algebraic points of real and p-adic partonic 2-surfaces in the algebraic extension or rationals guaranteing that the representation of 2-surface makes sense both in real and p-adic senses define fundamental cognitive representations as finite point sets.

2. The "phase transition" of a p-adic space-time sheet to a real space-time sheet taking place in quantum jump between quantum histories corresponds to the transformation of a thought into action or sensory experience (during dreams and hallucinations) whereas the reverse transformation corresponds to the transformation of the sensory input into cognition. This transition can be thought to occur in the intersection of real and p-adic worlds where the mathematical representations of partonic 2-surface make sense both in real and p-adic sense. Motor action would correspond to the transformation of p-adic space-time sheets to their real counterparts and during sensory experience the reversal of this transformation would take place. In zero energy ontology these transformations could reduce to quark and lepton level as is suggested by the fact that the time scales assignable to quarks and leptons correspond to 1 ms and .1 s defining fundamental time scales of nerve pulse activity and EEG.

3. The obvious question is how to test p-adic physics empirically. First of all, thinking could be interpreted as p-adic sensory experiencing. Hence the reduction of theories–experimental science dichotomy to p-adic–real dichotomy seems natural: just like experimental science is an extension of everyday real sensory experience, theories represent an extension of everyday p-adic sensory experience (common sense thinking). Thus the basic test is how well p-adic physics based theories describe cognition. Secondly, the p-adic models for physical systems are strictly speaking models for cognitive models for real physics. The successes of these highly predictive models (consider only p-adic elementary particle mass calculations involving only very few integer valued parameters) supports the vision about p-adic physics as physics of cognition. p-Adic–real phase transitions as models for how thought is transformed to action and sensory input to thought provide a further testing ground for the new paradigm.

The following topics are discussed in the chapter.

1. The relationship between p-adic physics, intentionality, and cognition are discussed on general level. Basic cognitive functions such as imagination, hallucinations, formation of cognitive representations, Boolean mind, and learning are discussed in this conceptual framework.

2. Possible - necessarily indirect - evidence for p-adic cognition is considered.

3. In the mathematical sections the relationship between intentionality, cognition and number theory is discussed. Also the relation between p-adic and real physics is discussed at general level with basic vision being that the intersection of real and p-adic space-time sheets in the intersection of real and p-adic worlds consists of points belonging to the algebraic extension of rational needed to guarantee that the mathematical representation of the partonic 2-surface makes sense both in real and p-adic sense.

4. Frontal lobes are known to be the seat of the higher level intentional action and are discussed from p-adic point of view.

5. A generalization of the memetic code to cognitive codes is discussed and some proposals about codes are made. This generalization is based on p-adic length scale hypothesis. If the time scales involved correspond to time scales assignable to the CDs of the known elementary particles, the generalization is not favored. On the other hand, dark matter sector could allow entire fractal hierarchy of elementary particle physics whose existence is reflected as fundamental bio-rhytms and cognitive codes.

6. The intersection of real and p-adic partonic 2-surfaces defining space-like cognitive representations consist of algebraic points. The hypothesis that these intersections obey various kind of symmetries identifiable as molecular symmetries is discussed.

1.6.4 PART IV: PARANORMAL PHENOMENA

Quantum Model of Paranormal Phenomena

The general quantum model for bio-systems leads to a model for bio-control which applies to a very wide variety of hard-to-understand bio-chemical phenomena such as molecular recognition mechanisms, water memory, and homeopathy and leads to a generalization of genetic code explaining the mystery of introns. The same model generalizes to a model of paranormal phenomena such as psychokinesis, remote sensing, remote healing, telepathy, communications with deceased, and instrumental transcommunications. The basic difference is that magnetic body receives information and controls "foreign" biological (or even magnetic) body or "dead" matter system.

The basic notions of the model are magnetic body as an intentional agent controlling biological body and receiving data from living body or even "dead" matter system with massless extremals (MEs) mediating these communications, zero energy ontology and the related notion of causal diamond (CD) serving as an embedding space correlate of self and assigning to elementary particles fundamental macroscopic time and length scales as those of CD, the hierarchy of Planck constants making possible macroscopic quantum phases and zoom-ups of quantum systems, and the vision about living matter as something residing in the intersection of real and p-adic worlds and the closely related notion of negentropic entanglement crucial for the functioning of living matter and conscious intelligence in TGD Universe.

Negentropic entanglement, which can be both space-like and time-like in zero energy ontology, makes possible quantum superposition of macroscopically different configurations of the target system correlated with the states of operator system. The operator should be able to achieve the negentropic entanglement and intentionally increase the amplitude of the desired outcome in this superposition. Negentropic entanglement need not involve binding energy and I have proposed this as a deeper level explanation for the nebulous notion of high energy phosphate bond crucial for metabolism in living matter. Quite generally, negentropic entanglement would make possible for the operator to transfer metabolic energy and momentum to the target. The hierarchy of values of Planck constant would make possible this process in long time and length scales.

1. Magnetic mirrors (ME-magnetic flux tube pairs) connecting the sender and receiver make possible a universal mechanism for the transfer of intent and action. The pair of flux tubes forms a kind of sensory-motor loop. In biology the fundamental realization could be by a pair of flux sheets going through the strands of DNA with passive strand sending sensory data to the magnetic body and active strand receiving control commands leading to various forms of gene expresion. MEs are ideal for the transfer of both classical information and momentum.

2. p-Adic MEs represent the transfer of a mere intent and real MEs represent a transfer of action. p-Adic ME can be transformed to real ME either by receiver or some higher level magnetic self. This makes sense only in the intersection of real and p-adic worlds.

3. The transfer of intent gives rise to mechanism of remote interaction which can act both endo- and exogenously. Magnetic mirrors characterized by their fundamental frequencies make possible bridges between sender and receiver (say healer and healee) and allow a resonant interaction in which healer can initiate various control commands acting as 4-dimensional

templates represented as holograms. Also smaller MEs can be send along the MEs serving as bridges (this is like throwing balls with light velocity!).

4. The ME-magnetic flux tube pair connecting sender and receiver can act as a reference wave which can initiate an arbitrarily complex hologram representing biological program. Sender has the ability to generate and amplify the frequencies which induce holograms representing the control commands. In particular, in living matter sender can initiate complex biological programs without knowing anything about their functioning.

One can distinguish between psychokinesis applied to living matter and "dead" matter.

1. When the target consists of living matter the mechanisms would be same as in communications between magnetic and biological bodies making possible bio-control of biological body by magnetic body and the receival of sensory input from biological body by magnetic body. Hypnosis would be one example of this kind of interaction.

2. Remote mental interactions in the case "dead" could use simpler variants of the fundamental mechanisms utilized in living matter. For instance, zero energy ontology assigns with the CD of electron and quarks time scales .1 s and 1 ms defining fundamental biorhythms. The CD assignable to elementary particles could be involved also with psychokinesis. Negentropic entanglement could be essential for the transfer of metabolic energy (say in simple psychokinesis moving an object) and for control actions -say in intentional change of sequences of binary digits produced by random number generator. Target system would not be completely "dead". Thermodynamical restrictions favor large values of Planck constant.

The basic problem in many remote mental interactions such as the intentional effect on random number generator is "Who knows how?". How the mere intent can be transformed to action without any knowledge about the details of the action? The attempt to understand how neuro-feedback affect the behavior of single neuron leads to the same question.

1. Magnetic mirrors make possible also feedback and this feedback could make possible learning. For instance, in psychokinesis (especially so in micro PK), this learning would be crucial and analogous to that what occurs when we learn to drive a car. In healing this kind of feedback might help to find the healing frequency by trial and error.

2. It is quite possible that also multibrained and -bodied higher level colletive selves actively participate in the process as a third party such that the remote mental interactions would act as a relay states. I have suggested similar explanation for Sheldrake's findings about learning at the lelel of species and Tiller's findings about the "transfer of intent". This could make possible coherent amplification effects (TEM, prayer groups) and could make available information resources of all brains involved with the group. This could for instance explain the ability of a remote viewer to see an object on basis of data which need not have any meaning for her.

3. A fast amplitude modulation of alpha waves introducing higher harmonics to the carrier wave is a good candidate for mediating communication between brains and higher level multibrained selves. Mesoscopic "features" in brain involve precisely this kind of amplitude modulation and might represent just this kind of messages. Interestingly, also speech is produced by a fast amplitude modulation of 10 Hz basic vibration frequency of speech organs (assignable to electron CD as a fundamental frequency) and kHz (quarks) frequency is a special frequency from the point of view of hearing.

TGD Based Model for OBEs

Out-of-body experiences (OBEs) are often understood as experience of seeing oneself from a position outside of the body. OBEs are poorly understood in the framework of neuro science and pose a challenge for the reductionistic world view.

In TGD framework the notion of magnetic body provides an attractive starting point in attempts to understand what OBEs and related experiences are. The basic idea is that magnetic

body serves effectively as a mirror defining a third person view as a cognitive representation also in ordinary wake-up state and that during OBEs this representation becomes sensory representation. Magnetic body need not always be a personal magnetic body but could correspond to a magnetic body receiving information from several brains (collective consciousness), magnetic body of another person, or be even associated with "dead" matter.

The progress in identifying dark matter as a phase of matter with large value of Planck constant making possible macroscopic quantum coherence has led to the vision about dark matter at magnetic flux quanta as quantum controller of ordinary matter in living systems. The Bose-Einstein condensates of dark photons decaying via decoherence to ordinary photons mediate interactions between ordinary and dark matter and the hypothesis is that dark photon "laser" beams from body and brain reflected at magnetic flux quanta give rise to third person aspect of consciousness which in OBEs and related experiences are realized as sensory representations. The identification of bio-photons as end products of the de-coherence of dark photon beams is natural.

Zero energy ontology and the notion of causal diamond (or CD defined roughly as the intersection of future and past directed light-cones) brings additional quantitative ingredients to the model. Sub-CDs define embedding space ($M^4 \times CP_2$) correlates for selves and by holography the 2-D partonic 2-surfaces at the light-like future and past boundaries of CDs are the ultimate space-time correlates for mental images. The moduli space for CDs makes possible a more detailed view about sensory representations.

A further new element is the vision about life as something in the intersection of real and p-adic worlds. The most important outcome is that the notion of number theoretic entanglement negentropy making sense in this situation is positive so that entanglement carries conscious information. The fusion of selves (in particular mental image) by negentropic entanglement is experienced as expansion of consciousness. It is negentropic entanglement between parts of biological body and corresponding parts of the magnetic body and biological body which makes living system living. This negentropic entanglement between magnetic body and biological body is important also for OBEs.

The model leads also to a model for dreams, hallucinations, sensory feedback from brain to sensory organs, and directed attention. Concrete models for how dark photons can give rise to experiences in various sensory modalities such as vision, hearing, olfaction, and tactile senses, are proposed.

Part I

BASIC IDEAS OF TGD INSPIRED THEORY OF CONSCIOUSNESS

Chapter 2

Topological Geometrodynamics: Basic Visions

2.1 Introduction

Originally Topological Geometrodynamics (TGD) was proposed as a solution of the problems related to the definition of conserved four-momentum in General Relativity. It was assumed that physical space-times are representable as 4-D surfaces in certain higher-dimensional space-time having symmetries of the empty Minkowski space of Special Relativity. This is guaranteed by the decomposition $H = M^4 \times S$, where S is some compact internal space. It turned out that the choice $S = CP_2$ is unique in the sense that it predicts the symmetries of the standard model and provides a realization for Einstein's dream of geometrizing of fundamental interactions at classical level. TGD can be also regarded as a generalization of super string models obtained by replacing strings with light-like 3-surfaces or equivalently with space-like 3-surfaces: the equivalence of these identification implies quantum holography.

The construction of quantum TGD turned out to be much more than mere technical problem of deriving S-matrix from path integral formalism. A new ontology of physics (many-sheeted space-time, zero energy ontology, generalization of the notion of number, and generalization of quantum theory based on spectrum of Planck constants giving hopes to understand what dark matter and dark energy are) and also a generalization of quantum measurement theory leading to a theory of consciousness and model for quantum biology providing new insights to the mysterious ability of living matter to circumvent the constraints posed by the second law of thermodynamics were needed. The construction of quantum TGD involves a handful of different approaches consistent with a similar overall view, and one can say that the construction of M-matrix, which generalizes the S-matrix of quantum field theories, is understood to a satisfactory degree although it is not possible to write even in principle explicit Feynman rules except at quantum field theory limit [**?**].

In this article I will discuss three basic visions about quantum Topological Geometrodynamics (TGD). It is somewhat matter of taste which idea one should call a vision and the selection of these three in a special role is what I feel natural just now.

1. The first vision is generalization of Einstein's geometrization program based on the idea that the Kähler geometry of the world of classical worlds (WCW) with physical states identified as classical spinor fields on this space would provide the ultimate formulation of physics [K127].

2. Second vision is number theoretical [K83] and involves three threads.

   (a) The first thread [K119] relies on the idea that it should be possible to fuse real number based physics and physics associated with various p-adic number fields to single coherent whole by a proper generalization of number concept.

   (b) Second thread [K120] is based on the hypothesis that classical number fields could allow to understand the fundamental symmetries of physics and and imply quantum TGD from purely number theoretical premises with associativity defining the fundamental dynamical principle both classically and quantum mechanically.

(c) The third thread [K118] relies on the notion of infinite primes whose construction has amazing structural similarities with second quantization of super-symmetric quantum field theories. In particular, the hierarchy of infinite primes and integers allows to generalize the notion of numbers so that given real number has infinitely rich number theoretic anatomy based on the existence of infinite number of real units. This implies number theoretical Brahman=Atman identity or number theoretical holography when one consider hyper-octonionic infinite primes.

(d) The third vision is based on TGD inspired theory of consciousness [K124], which can be regarded as an extension of quantum measurement theory to a theory of consciousness raising observer from an outsider to a key actor of quantum physics. The basic notions at quantum jump identified as as a moment of consciousness and self. Negentropy Maximization Principle (NMP) defines the fundamental variational principle and reproduces standard quantum measurement theory and predicts second law but also some totally new physics in the intersection of real and p-adic worlds where it is possible to define a hierarchy of number theoretical variants of Shannon entropy which can be also negative. In this case NMP favors the generation of entanglement and state function reduction does not mean generation of randomness anymore. This vision has obvious almost applications to biological self-organization.

My aim is to provide a bird's eye of view and my hope is that reader would take the attitude that details which cannot be explained in this kind of representation are not essential for the purpose of getting a feeling about the great dream behind TGD. I have also commented various ideas from the point of view of Quantum Mind program.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

2.2 Quantum Physics As Infinite-Dimensional Geometry

The first vision in its original form is a the generalization of Einstein's program for the geometrization of physics by replacing space-time with the WCW identified roughly as the space of 4-surfaces in $H = M^4 \times CP_2$. Later generalization due to replacement of H with book like structures from by real and p-adic variants of H emerged. A further book like structure of embedding space emerged via the introduction of the hierarchy of Planck constants. These generalizations do not however add anything new to the basic geometric vision.

2.2.1 Geometrization Of Fermionic Statistics In Terms Of WCW Spinor Structure

The great vision has been that the second quantization of the induced spinor fields can be understood geometrically in terms of the WCW spinor structure in the sense that the anti-commutation relations for WCW gamma matrices require anti-commutation relations for the oscillator operators for free second quantized induced spinor fields defined at space-time surface.

1. One must identify the counterparts of second quantized fermion fields as objects closely related to the configuration space spinor structure. Ramond model [B21] has as its basic field the anti-commuting field $\Gamma^k(x)$, whose Fourier components are analogous to the gamma matrices of the configuration space and which behaves like a spin 3/2 fermionic field rather than a vector field. This suggests that the are analogous to spin 3/2 fields and therefore expressible in terms of the fermionic oscillator operators so that their naturally derives from the anti-commutativity of the fermionic oscillator operators.

   WCW spinor fields can have arbitrary fermion number and there are good hopes of describing the whole physics in terms of WCW spinor field. Clearly, fermionic oscillator operators would act in degrees of freedom analogous to the spin degrees of freedom of the ordinary spinor and bosonic oscillator operators would act in degrees of freedom analogous to the "orbital" degrees of freedom of the ordinary spinor field. One non-trivial implication is bosonic

emergence: elementary bosons correspond to fermion anti-fermion bound states associated with the wormhole contacts (pieces of CP_2 type vacuum extremals) with throats carrying fermion and anti-fermion numbers. Fermions correspond to single throats associated with topologically condensed CP_2 type vacuum extremals.

2. The classical theory for the bosonic fields is an essential part of WCW geometry. It would be very nice if the classical theory for the spinor fields would be contained in the definition of the WCW spinor structure somehow. The properties of the associated with the induced spinor structure are indeed very physical. The modified massless Dirac equation for the induced spinors predicts a separate conservation of baryon and lepton numbers. The differences between quarks and leptons result from the different couplings to the CP_2 Kähler potential. In fact, these properties are shared by the solutions of massless Dirac equation of the embedding space.

3. Since TGD should have a close relationship to the ordinary quantum field theories it would be highly desirable that the second quantized free induced spinor field would somehow appear in the definition of the WCW geometry. This is indeed true if the complexified WCW gamma matrices are linearly related to the oscillator operators associated with the second quantized induced spinor field on the space-time surface and its boundaries. There is actually no deep reason forbidding the gamma matrices of WCW to be spin half odd-integer objects whereas in the finite-dimensional case this is not possible in general. In fact, in the finite-dimensional case the equivalence of the spinorial and vectorial vielbeins forces the spinor and vector representations of the vielbein group $SO(D)$ to have same dimension and this is possible for $D = 8$-dimensional Euclidian space only. This coincidence might explain the success of 10-dimensional super string models for which the physical degrees of freedom effectively correspond to an 8-dimensional Euclidian space.

4. It took a long time to realize that the ordinary definition of the gamma matrix algebra in terms of the anti-commutators $\{\gamma_A, \gamma_B\} = 2g_{AB}$ must in TGD context be replaced with

$$\{\gamma_A^\dagger, \gamma_B\} = iJ_{AB} \ ,$$

where J_{AB} denotes the matrix elements of the Kähler form of WCW. The presence of the Hermitian conjugation is necessary because WCW gamma matrices carry fermion number. This definition is numerically equivalent with the standard one in the complex coordinates. The realization of this delicacy is necessary in order to understand how the square of the WCW Dirac operator comes out correctly.

2.2.2 Construction Of WCW Clifford Algebra In Terms Of Second Quantized Induced Spinor Fields

The construction of WCW spinor structure must have a direct relationship to quantum physics as it is usually understood. The second quantization of the space-time spinor fields is needed to define the anti-commutative gamma matrices of WCW: this means a geometrization of Fermi statistics [K139] in the sense that free fermionic quantum fields at space-time surface correspond to purely classical Clifford algebra of WCW. This is in accordance with the idea that physics at WCW level is purely classical apart from the notion of quantum jump.

The identification of the correct variational principle for the dynamics of space-time spinor fields identified as induced spinor fields has involved many trials and errors. Ironically, the final outcome was almost the most obvious guess: the so called Kähler-Dirac action. What was difficult to discover was that the well-definedness of em charge requires that the modes of K-D equation are localized at 2-D string world sheets. The same condition results also from the condition that octonionic and ordinary spinor structures are equivalent for the modes of the induced spinor field and also from the condition that quantum deformations of fermionic oscillator operator algebra requiring 2-dimensionality can be realized as realization of finite measurement resolution. Fermionic string model therefore emerges from TGD.

The notion of measurement resolution realized in terms of the inclusions of hyper-finite factors of type II_1 and having discretization using rationals or algebraic extensions of rationals

have been one of the key challenges of quantum TGD. Quantum classical correspondence suggests with measurement interaction term defined as Lagrange multiplier terms stating that classical charges belonging to Cartan algebra are equal to their quantal counterparts after state function reduction for space-time surfaces appearing in quantum superposition [K139]. This makes sense if classical charges parametrize zero modes. State function reduction would mean state function collapse in zero modes.

Kähler function equals to the real part of Kähler action coming from Euclidian space-time regions for a preferred extremal whereas Minkowski regions give an exponent of phase factor responsible for quantum interferences effects. The conjecture is that preferred extremals by internal consistency conditions are critical in the sense that they allows infinite number of vanishing second variations having interpretation as conformal deformations respecting light-likeness of the partonic orbits. Criticality is realize classically as vanishing of the super-symplectic charges for sub-algebra of the entire super-symplectic algebra. This realizes the notion of quantum criticality-one of guiding principles of quantum TGD-at space-time level.

Recently this idea has become very concrete.

1. There is an infinite hierarchy of quantum criticalities identified as a hierarchy of breakings of conformal symmetry in the sense that the gauge symmetry for the super-symplectic algebra having natural conformal structure is broken to a dynamical symmetry: gauge degrees of freedom are transformed to physical ones.

2. The sub-algebras of the supersymplectic algebra isomorphic with the algebra itself are parametrized by integer n: the conformal weights for the sub-algebra are n-multiples for those of the entire algebra. This predicts an infinite number of infinite hierarchies characterized by sequences of integers $n_{i+1} = \prod_{k \leq i} m_k$. The integer n_i characterizes the effective value of Planck constant $h_{eff} = n_i$ for a given level of hierarchy and the interpretation is in terms of dark matter. The increase of n_i takes place spontaneously since it means reduction of criticality. Both the value of n_i and the numbers of string world sheets associated with 3-surfaces at the ends of CD and connecting partonic 2-surfaces characterize measurement resolution.

3. The symplectic hierarchies correspond to hierarchies of inclusions for HFFs [K138] and finite measurement resolution is a property of both zero energy state and space-time surface. The original idea about addition of measurement interaction terms to the Kähler action does not seem to be needed.

Number theoretical approach in turn leads to the conclusion that space-time surfaces are either associative or co-associative in the sense that the induced gamma matrices at each point of space-time surface in their octonionic representation define a quaternionic or co-quaternionic algebra and therefore have matrix representation. The conjecture is that these identifications of space-time dynamics are consistent or even equivalent. The string sheets at which spinor modes are localized can be regarded as commutative surfaces.

The recent understanding of the Kähler-Dirac action has emerged through a painful process and has strong physical implications.

1. Kähler-Dirac equation at string world sheets can be solved exactly just as in string models. At the light-like boundaries the limit of K-D equation holds true and gives rise to the analog of massless Dirac equation but for K-D gamma matrices. One could have a 1-D boundary term defined by the induced Dirac equation at the light-like boundaries of string world sheet. If it is there, the modes are solutions with light-like 8-momentum which has light-like projection to space-time surface. This would give rise to a fermionic propagator in the construction of scattering amplitudes mimicking Feynman diagrammatics: note that the M^4 projection of the momentum need not be light-like.

2. The space-time super-symmetry generalizes to what might be called $\mathcal{N} = \infty$ supersymmetry whose least broken sub-symmetry reduces to $\mathcal{N} = 2$ broken super-symmetry generated by right-handed neutrino and ant-ineutrino [**?**] . The generators of the super-symmetry correspond to the oscillator operators of the induced spinor field at space-time sheet and to the super-symplectic charges. Bosonic emergence means dramatic simplifications in the formulation of quantum TGD.

3. It is also possible to generalize the twistor program to TGD framework if one accepts the use of octonionic representation of the gamma matrices of embedding space and hyper-quaternionicity of space-time surfaces [K126]: what one obtains is 8-D generalization of the twistor Grassmann approach allowing non-light-like M^4 momenta. Essential condition is that octonionic and ordinary spinor structures are equivalent at string world sheets.

2.2.3 ZEO And WCW Geometry

In the ZEO quantum states have vanishing net values of conserved quantum numbers and decompose to superposition of pairs of positive and negative energy states defining counterparts of initial and final states of a physical event in standard ontology.

ZEO

ZEO was forced by the interpretational problems created by the vacuum extremal property of Robertson-Walker cosmologies imbedded as 4-surfaces in $M^4 \times CP_2$ meaning that the density of inertial mass (but not gravitational mass) for these cosmologies was vanishing meaning a conflict with Equivalence Principle. The most feasible resolution of the conflict comes from the realization that GRT space-time is obtained by lumping the sheets of many-sheeted space-time to M^4 endowed with effective metric. Vacuum extremals could however serve as models for GRT space-times such that the effective metric is identified with the induced metric [K132]. This is true if space-time is genuinely single-sheeted. In the models of astrophysical objects and cosmology vacuum extremals have been used [K113].

In zero energy ontology physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds defined as pairs of future and past directed light-cones ($\delta M^4_{\pm} \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology. It is possible to speak about the energy of the system if one identifies it as the average positive energy for the positive energy part of the system. Same applies to other quantum numbers.

The matrix ("M-matrix") representing time-like entanglement coefficients between positive and negative energy states unifies the notions of S-matrix and density matrix since it can be regarded as a complex square root of density matrix expressible as a product of real squared of density matrix and unitary S-matrix. The system can be also in thermal equilibrium so that thermodynamics becomes a genuine part of quantum theory and thermodynamical ensembles cease to be practical fictions of the theorist. In this case M-matrix represents a superposition of zero energy states for which positive energy state has thermal density matrix.

ZEO combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of universe and about the values of conserved quantum numbers of the Universe can be avoided since everything is in principle creatable from vacuum. Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in zero energy ontology. ZEO leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II_1. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD.

Causal diamonds

The embedding space correlates for ZEO are causal diamonds (CDs) CD serves as the correlate zero energy state at embedding space-level whereas space-time sheets having their ends at the light-like boundaries of CD are the correlates of the system at the level of 4-D space-time. Zero energy state can be regarded as a quantum superposition of space-time sheets with fermionic and other quantum numbers assignable to the partonic 2-surfaces at the ends of the space-time sheets.

1. The basic construct in the ZEO is the space $CD \times CP_2$, where the causal diamond CD is defined as an intersection of future and past directed light-cones with time-like separation between their tips regarded as points of the underlying universal Minkowski space M^4. In

ZEO physical states correspond to pairs of positive and negative energy states located at the boundaries of the future and past directed light-cones of a particular CD.

2. CDs form a fractal hierarchy and one can glue smaller CDs within larger CDs. Also unions of CDs are possible.

3. Without any restrictions CDs would be parametrized by the position of say lower tip of CD and by the relative M^4 coordinates of the upper tip with respect to the lower one so that the moduli space would be $M^4 \times M^4_+$. p-Adic length scale hypothesis follows if the values of temporal distance T between tips of CD come in powers of 2^n: $T = 2^n T_0$. This would reduce the future light-cone M^4_+ reduces to a union of hyperboloids with quantized value of light-cone proper time. A possible interpretation of this distance is as a quantized cosmic time. Also the quantization of the hyperboloids to a lattices of discrete points classified by discrete sub-groups of Lorentz group is an attractive proposal and the quantization of cosmic redshifts provides some support for it.

ZEO forces to replaced the original WCW by a union of WCWs associated with CDs and their unions. This does not however mean any problems of principle since Clifford algebras are simply tensor products of the Clifford algebras of CDs for the unions of CDs.

Generalization of S-matrix in ZEO

ZEO forces the generalization of S-matrix with a triplet formed by U-matrix, M-matrix, and S-matrix. The basic vision is that quantum theory is at mathematical level a complex square root of thermodynamics. What happens in quantum jump was already discussed.

1. M-matrices are matrices between positive and negative energy parts of the zero energy state and correspond to the ordinary S-matrix. M-matrix is a product of a hermitian square root - call it H - of density matrix ρ and universal S-matrix S. There is infinite number of different Hermitian square roots H_i of density matrices assumed to define orthogonal matrices with respect to the inner product defined by the trace: $Tr(H_i H_j) = 0$. One can interpret square roots of the density matrices as a Lie algebra acting as symmetries of the S-matrix. The most natural identification is in terms of super-symplectic algebra or as its sub-algebra. Since these operators should not change the vanishing quantum number of zero energy states, a natural identification would be as bilinears of the generators of super-symplectic generators associated with the opposite boundaries of CD and having vanishing net quantum numbers.

2. One can consider a generalization of M-matrices so that they would be analogous to the elements of Kac-Moody algebra. These M-matrices would involve all powers of S.

   (a) The orthogonality with respect to the inner product defined by $\langle A|B\rangle = Tr(AB)$ requires the conditions $Tr(H_1 H_2 S^n) = 0$ for $n \neq 0$ and H_i are Hermitian matrices appearing as square root of density matrix. $H_1 H_2$ is hermitian if the commutator $[H_1, H_2]$ vanishes. It would be natural to assign n:th power of S to the CD for which the scale is n times the CP_2 scale.

   (b) Trace - possibly quantum trace for hyper-finite factors of type II_1) is the analog of integration and the formula would be a non-commutative analog of the identity $\int_{S^1} exp(in\phi)d\phi = 0$ and pose an additional condition to the algebra of M-matrices.

   (c) It might be that one must restrict M matrices to a Cartan algebra and also this choice would be a process analogous to state function reduction. Since density matrix becomes an observable in TGD Universe, this choice could be seen as a direct counterpart for the choice of a maximal number of commuting observables which would be now hermitian square roots of density matrices. Therefore ZEO gives good hopes of reducing basic quantum measurement theory to infinite-dimensional Lie-algebra.

The collections of M-matrices defined as time reversals of each other define the sought for two natural state basis.

1. As for ordinary S-matrix, one can construct the states in such a way that either positive or negative energy part of the state has well defined particle numbers, spin, etc... resulting in state function preparation. Therefore one has two kinds of M-matrices: $M_K^{\pm}$ and for both of these the above orthogonality relations hold true. This implies also two kinds of U-matrices call them $U^{\pm}$. The natural assumption is that the two M-matrices differ only by Hermitian conjugation so that one would have $M_K^- = (M_K^+)^\dagger$.

   One can assign opposite arrows of geometric time to these states and the proposal is that the arrow of time is a result of a process analogous to spontaneous magnetization. The possibility that the arrow of geometric time could change in quantum jump has been already discussed.

2. Unitary U-matrix $U^{\pm}$ is induced from a projector to the zero energy state basis $|K^{\pm}\rangle$ acting on the state basis $|K^{\mp}\rangle$ and the matrix elements of U-matrix are obtained by acting with the representation of identity matrix in the space of zero energy states as $I = \sum_K |K^+\rangle\langle K^+|$ on the zero energy state $|K^-\rangle$ (the action on K^+ is trivial!) and gives

   $$U^+_{KL} = Tr(M_K^+ M_L^+) \ .$$

   Note that finite measurement resolution requires that the trace operation is q-trace rather than ordinary trace.

3. As the detailed discussion of the anatomy of quantum jump demonstrated, the first step in state function reduction is the choice of $M_K^{\pm}$ meaning the choice of the hermitian square root of a density matrix. A quantal selection of the measured observable takes place. This step is followed by a choice of "initial" state analogous to state function preparation and a choice of the "final state" analogous to state function reduction. The net outcome is the transition $|K^{\pm}\rangle \to |L^{\pm}\rangle$. It could also happen that instead of state function reduction as third step unitary process $U^{\mp}$ (note the change of the sign factor!) takes place and induces the change of the arrow of geometric time.

4. As noticed, one can imagine even higher level choices and this would correspond to the choice of the commuting set of hermitian matrices H defining the allowed square roots of density matrices as a set of mutually commuting observables.

5. The original naïve belief that the unitary U-matrix has as its rows orthonormal M-matrices turned out to be wrong. One can deduce the general structure of U-matrix from first principles by identifying it as a time evolution operator in the space of moduli of causal diamonds relating to each other M-matrices. Inner product for M-matrices gives the matrix elements of U-matrix. S-matrix can be identified as a representation for the exponential of the Virasoro generator L_{-1} for the super-symplectic algebra. The detailed construction of U-matrix in terms of M-matrices and S-matrices depending on CD moduli is discussed in [K78].

2.2.4 Quantum Criticality, Strong Form Form of Holography, and WCW Geometry

Quantum TGD and WCW geometry in particular can be understood in terms of two principles: Quantum Criticality (QC) and Strong form of Holography (SH).

Quantum Criticality

In its original form QC stated that the Kähler couplings strength appearing in the exponent of vacuum functional identifiable uniquely as the exponent of Kähler function defining the Kähler metric of WCW defines the analog of partition function of a thermodynamical system. Later it became clear that Kähler action in Minkowskian space-time regions is imaginary (by $\sqrt{g}$ factor) so that the exponent become that of complex number. The interpretation in ZEO is in terms of quantum TGD as "square root of thermodynamics" vision. Minkowskian Kähler action is the analog of action of quantum field theories.

TGD should be unique. The analogy with thermodynamics implies that Kähler coupling strength α_K is analogous to temperature. The natural guess is that it corresponds to a critical

temperature at which a phase transition between two phases occurs. It is of course possible that there are several critical values of α_K.

QC is physically very attractive since it would give maximally complex Universe. At quantum criticality long range fluctuations would be present and make possible macroscopic quantum coherence especially relevant for life.

In 2-D critical systems conformal symmetry provides the mathematical description of criticality and in TGD something similar but based on a huge generalization of the conformal symmetries is expected. Ordinary conformal symmetries are indeed replaced by super-symplectic isometries, by the generalized conformal symmetries acting on light-cone boundary and on light-like orbits of partonic 2-surfaces, and by the ordinary conformal symmetries at partonic 2-surfaces and string world sheets carrying spinors. Even a quaternionic generalization of conformal symmetries must be considered.

Strong Form of Holography

Strong form of holography (SH) is the second big principle. It is strongly suggested by the strong form of general coordinate invariance (SGCI) stating that the fundamental objects can be taken to be either the light-like orbits of partonic 2-surfaces or space-like 3-surfaces at the ends of causal diamonds (CDs). This would imply that partonic 2-surfaces at their intersection at the boundaries of CDs carry the data about quantum states.

As a matter fact, one must include also string world sheets at which fermions are localized - this for instance by the condition that em charge is well-defined. String world sheets carry vanishing induced W boson fields (they would mix different charge states) and the Kähler-Dirac gamma matrices are parallel to them. These conditions give powerful integrability conditions and it remains to be seen whether solutions to them indeed exist.

The best manner to proceed is to construct preferred extremals using SH - that is by assuming just string world sheets and partonic 2-surfaces intersecting by discrete point set as given, and finding the preferred extremals of Kähler action containing them and satisfying the boundary conditions at string world sheets and partonic 2-surfaces.

If this construction works, it must involve boundary conditions fixing the space-time surfaces to very high degree. Due to the non-determinism of Kähler action implied by its huge vacuum degeneracies, one however expects a gauge degeneracy. QC indeed suggests non-determinism. By 2-D analogy one expects the analogs of conformal symmetries acting as gauge symmetries. The proposal is that the fractal hierarchy of mutually isomorphic sub-algebras of super-symplectic algebra (and possibly of all conformal algebras involved) having conformal weights, which are n-ples of those for the entire algebra act as gauge symmetries so that the Noether charges for this sub-algebra would vanish. This would be the case at the ends of preferred extremals at both boundaries of CDs. This almost eliminates the classical degrees of freedom outside string world sheets and partonic 2-surfaces, and thus realizes the strong form of holography. In the fermionic sector the fermionic super-symplectic charges in the sub-algebra annihilate the physical states: this is a generalization of Super-Virasoro and Super Kac-Moody conditions.

In the phase transitions increasing the value of n the sub-algebra of gauge symmetries is reduced and gauge degrees of freedom become physical ones. By QC this transition occurs spontaneously. TGD Universe is like ball at the top of hill at the top of ....: ad infinitum and its evolution is endless dropping down. In TGD inspired theory of consciousness, one can understand living systems as systems fighting to stay at given level of criticality.

One could say that the conformal subalgebra is analogous to that defined by functions of $w = z^n$ act as conformal symmetries. One can also see the space-time surfaces at the level n as analogous to Riemann surface for function $f(z) = z^{1/n}$ conformal gauge symmetries as those defined by functions of z. This brings in n sheets not connected by conformal gauge symmetries. Hence the conformal equivalence classes of sheets give rise n-fold physical degeneracy. An effective description for this would be in terms of n-fold singular covering of the embedding space introduced originally but this is only an auxiliary concept.

A natural interpretation of the hierarchy of conformal criticalities is as a hierarchy of Planck constants $h_{eff} = n \times h$. The identification is suggested by the interpretation of n as the number of sheets in the singular covering of the space-time surface for which the sheets at the ends of

space-time surface (the 3-surfaces at boundaries of CD) coincide. The n sheets increase the action by a factor n and this is equivalent with the replacement $h \to h_{eff} = n \times h$.

The hierarchy of Planck constants allows to consider several interpretations.

1. If one regards the sheets of the covering as distinct, one has single critical value of g_K^2 and of h. This is the fundamental interpretation and justifies the subscript "$_{eff}$" in $h_{eff} = n \times h$.

2. If the sheets of the covering are are lumped to a single sheet (this is done for all sheets of the many-sheeted space-time in General Relativity approximation), there are two possible interpretations. There is single critical value of g_K^2 and a hierarchy of Planck constants $h_{eff} = n \times h$ giving rise to $\alpha_K(n) = g_K^2/2h_{eff}$. Alternatively, there is single value of Planck constant and a hierarchy of critical values $\alpha_K(n) = (g_K^2/2h)/n$ having an accumulation point at origin (zero temperature).

Non-commutative embedding space and strong form of holography

The precise formulation of strong form of holography (SH) is one of the technical problems in TGD. A comment in FB page of Gareth Lee Meredith led to the observation that besides the purely number theoretical formulation based on commutativity also a symplectic formulation in the spirit of non-commutativity of embedding space coordinates can be considered. One can however use only the notion of Lagrangian manifold and avoids making coordinates operators leading to a loss of General Coordinate Invariance (GCI).

Quantum group theorists have studied the idea that space-time coordinates are non-commutative and tried to construct quantum field theories with non-commutative space-time coordinates (see `http://tinyurl.com/z3m8sny`). My impression is that this approach has not been very successful. In Minkowski space one introduces antisymmetry tensor J_{kl} and uncertainty relation in linear M^4 coordinates m^k would look something like $[m^k, m^l] = l_P^2 J^{kl}$, where l_P is Planck length. This would be a direct generalization of non-commutativity for momenta and coordinates expressed in terms of symplectic form J^{kl}.

1+1-D case serves as a simple example. The non-commutativity of p and q forces to use either p or q. Non-commutativity condition reads as $[p, q] = \hbar J^{pq}$ and is quantum counterpart for classical Poisson bracket. Non-commutativity forces the restriction of the wave function to be a function of p or of q but not both. More geometrically: one selects Lagrangian sub-manifold to which the projection of J_{pq} vanishes: coordinates become commutative in this sub-manifold. This condition can be formulated purely classically: wave function is defined in Lagrangian sub-manifolds to which the projection of J vanishes. Lagrangian manifolds are however not unique and this leads to problems in this kind of quantization. In TGD framework the notion of "World of Classical Worlds" (WCW) allows to circumvent this kind of problems and one can say that quantum theory is purely classical field theory for WCW spinor fields. "Quantization without quantization" would have Wheeler stated it.

GCI poses however a problem if one wants to generalize quantum group approach from M^4 to general space-time: linear M^4 coordinates assignable to Lie-algebra of translations as isometries do not generalize. In TGD space-time is surface in embedding space $H = M^4 \times CP_2$: this changes the situation since one can use 4 embedding space coordinates (preferred by isometries of H) also as space-time coordinates. The analog of symplectic structure J for M^4 makes sense and number theoretic vision involving octonions and quaternions leads to its introduction. Note that CP_2 has naturally symplectic form.

Could it be that the coordinates for space-time surface are in some sense analogous to symplectic coordinates (p_1, p_2, q_1, q_2) so that one must use either (p_1, p_2) or (q_1, q_2) providing coordinates for a Lagrangian sub-manifold. This would mean selecting a Lagrangian sub-manifold of space-time surface? Could one require that the sum $J_{\mu\nu}(M^4) + J_{\mu\nu}(CP_2)$ for the projections of symplectic forms vanishes and forces in the generic case localization to string world sheets and partonic 2-surfaces. In special case also higher-D surfaces - even 4-D surfaces as products of Lagrangian 2-manifolds for M^4 and CP_2 are possible: they would correspond to homologically trivial cosmic strings $X^2 \times Y^2 \subset M^4 \times CP_2$, which are not anymore vacuum extremals but minimal surfaces if the action contains besides Käction also volume term.

But why this kind of restriction? In TGD one has strong form of holography (SH): 2-D string world sheets and partonic 2-surfaces code for data determining classical and quantum evolution.

Could this projection of $M^4 \times CP_2$ symplectic structure to space-time surface allow an elegant mathematical realization of SH and bring in the Planck length l_P defining the radius of twistor sphere associated with the twistor space of M^4 in twistor lift of TGD? Note that this can be done without introducing embedding space coordinates as operators so that one avoids the problems with general coordinate invariance. Note also that the non-uniqueness would not be a problem as in quantization since it would correspond to the dynamics of 2-D surfaces.

The analog of brane hierarchy for the localization of spinors - space-time surfaces; string world sheets and partonic 2-surfaces; boundaries of string world sheets - is suggestive. Could this hierarchy correspond to a hierarchy of Lagrangian sub-manifolds of space-time in the sense that $J(M^4) + J(CP_2) = 0$ is true at them? Boundaries of string world sheets would be trivially Lagrangian manifolds. String world sheets allowing spinor modes should have $J(M^4)+J(CP_2) = 0$ at them. The vanishing of induced W boson fields is needed to guarantee well-defined em charge at string world sheets and that also this condition allow also 4-D solutions besides 2-D generic solutions.

This condition is physically obvious but mathematically not well-understood: could the condition $J(M^4) + J(CP_2) = 0$ force the vanishing of induced W boson fields? Lagrangian cosmic string type minimal surfaces $X^2 \times Y^2$ would allow 4-D spinor modes. If the light-like 3-surface defining boundary between Minkowskian and Euclidian space-time regions is Lagrangian surface, the total induced Kähler form Chern-Simons term would vanish. The 4-D canonical momentum currents would however have non-vanishing normal component at these surfaces. I have considered the possibility that TGD counterparts of space-time super-symmetries could be interpreted as addition of higher-D right-handed neutrino modes to the 1-fermion states assigned with the boundaries of string world sheets [K110].

Induced spinor fields at string world sheets could obey the "dynamics of avoidance" in the sense that *both* the induced weak gauge fields W, Z^0 and induced Kähler form (to achieve this U(1) gauge potential must be sum of M^4 and CP_2 parts) would vanish for the regions carrying induced spinor fields. They would couple only to the *induced em field (!)* given by the R_{12} part of CP_2 spinor curvature [L2] for $D = 2, 4$. For $D = 1$ at boundaries of string world sheets the coupling to gauge potentials would be non-trivial since gauge potentials need *not* vanish there. Spinorial dynamics would be extremely simple and would conform with the vision about symmetry breaking of weak group to electromagnetic gauge group.

An alternative - but of course not necessarily equivalent - attempt to formulate SH would be in terms of number theoretic vision. Space-time surfaces would be associative or co-associative depending on whether tangent space or normal space in embedding space is associative - that is quaternionic. These two conditions would reduce space-time dynamics to associativity and commutativity conditions. String world sheets and partonic 2-surfaces would correspond to maximal commutative or co-commutative sub-manifolds of embedding space. Commutativity (co-commutativity) would mean that tangent space (normal space as a sub-manifold of space-time surface) has complex tangent space at each point and that these tangent spaces integrate to 2-surface. SH would mean that data at these 2-surfaces would be enough to construct quantum states. String world sheet boundaries would in turn correspond to real curves of the complex 2-surfaces intersecting partonic 2-surfaces at points so that the hierarchy of classical number fields would have nice realization at the level of the classical dynamics of quantum TGD. The analogy with branes and super-symmetry force to consider two options.

Two options for fundamental variational principle

One ends up to two options for the fundamental variational principle.

Option I: The *fundamental* action principle for space-time surfaces contains besides 4-D action also 2-D action assignable to string world sheets, whose topological part (magnetic flux) gives rise to a coupling term to Kähler gauge potentials assignable to the 1-D boundaries of string world sheets containing also geodesic length part. Super-symplectic symmetry demands that modified Dirac action has 1-, 2-, and 4-D parts: spinor modes would exist at both string boundaries, string world sheets, and space-time interior. A possible interpretation for the interior modes would be as generators of space-time super-symmetries [K110].

This option is not quite in the spirit of SH and string tension appears as an additional parameter. Also the conservation of em charge forces 2-D string world sheets carrying vanishing

induced W fields and this is in conflict with the existence of 4-D spinor modes unless they satisfy the same condition. This looks strange.

Option II: Stringy action and its fermionic counterpart are effective actions only and justified by SH. In this case there are no problems of interpretation. SH requires only that the induced spinor fields at string world sheets determine them in the interior much like the values of analytic function at curve determine it in an open set of complex plane. At the level of quantum theory the scattering amplitudes should be determined by the data at string world sheets. If the induced W fields at string world sheets are vanishing, the mixing of different charge states in the interior of X^4 would not make itself visible at the level of scattering amplitudes!

If string world sheets are generalized Lagrangian sub-manifolds, only the induced em field would be non-vanishing and electroweak symmetry breaking would be a fundamental prediction. This however requires that M^4 has the analog of symplectic structure suggested also by twistorialization. This in turn provides a possible explanation of CP breaking and matter-antimatter asymmetry. In this case 4-D spinor modes do not define space-time super-symmetries.

The latter option conforms with SH and would mean that the theory is amazingly simple. String world sheets together with number theoretical space-time discretization meaning small breaking of SH would provide the basic data determining classical and quantum dynamics. The Galois group of the extension of rationals defining the number-theoretic space-time discretization would act as a covering group of the covering defined by the discretization of the space-time surface, and the value of $h_{eff}/h = n$ would correspond to the dimension of the extension dividing the order of its Galois group. The phase transitions reducing n would correspond to spontaneous symmetry breaking leading from Galois group to a subgroup and the transition would replace n with its factor.

The ramified primes of the extension would be preferred primes of given extension. The extensions for which the number of p-adic space-time surfaces representable also as a real algebraic continuation of string world sheets to preferred extrenal is especially large would be physically favored as also corresponding ramified primes. In other words, maximal number of p-adic imaginations would be realizable so that these extensions and corresponding ramified primes would be winners in the number-theoretic fight for survival. Whether this conforms with p-adic length scale hypothesis, remains an open question.

Consequences

The outcome is a precise identification of preferred extremals and therefore also a precise definition of Kähler function as Kähler action in Euclidian space-time regions: the Kähler action in Minkowskian regions takes the role of action in quantum field theories and emerges because one has complex square root of thermodynamics. The outcome is a vision combining several big ideas thought earlier to be independent.

1. Effective 2-dimensionality, which was already 30 years ago realized to be unavoidable but meant a catastrophe with the physical understanding that I had at that time. Now it is the outcome of SH implied by SGCI.

2. QC is very naturally realized in terms of generalized conformal symmetries and implies a fractal hierarchy of quantum criticalities, and gives as a side product the hierarchy of Planck constants, which emerged originally from purely physical considerations rather than from TGD. Also the hierarchy of inclusions of hyper-finite factors is a natural outcome as well as the interpretation in terms of measurement resolutions (increasing when n increases by integer factor).

3. The reduction of quantum TGD proper by SH so that only data at partonic 2-surfaces and string world sheets are used to construct the scattering amplitudes. This allows to realized number theoretical universality both at the level of space-time and WCW using algebraic continuation of the physics from an algebraic extension of rationals to real and p-adic number fields. This adelic picture together with Negentropy Maximization Principle (NMP) allows to understand the preferred p-adic primes and deduce a generalization of p-adic length scale hypothesis.

2.2.5 Hyper-Finite Factors And The Notion Of Measurement Resolution

The work with TGD inspired model [K4, K3] for topological quantum computation [B15] led to the realization that von Neumann algebras [A33], in particular so called hyper-finite factors of type II_1 [A25], seem to provide the mathematics needed to develop a more explicit view about the construction of S-matrix. Later came the realization that the Clifford algebra of WCW defines a canonical representation of hyper-finite factors of type II_1 and that WCW spinor fields give rise to HFFs of type III_1 encountered also in relativistically invariant quantum field theories [K138].

Philosophical ideas behind von Neumann algebras

The goal of von Neumann was to generalize the algebra of quantum mechanical observables. The basic ideas behind the von Neumann algebra are dictated by physics. The algebra elements allow Hermitian conjugation * and observables correspond to Hermitian operators. Any measurable function $f(A)$ of operator A belongs to the algebra and one can say that non-commutative measure theory is in question.

The predictions of quantum theory are expressible in terms of traces of observables. Density matrix defining expectations of observables in ensemble is the basic example. The highly non-trivial requirement of von Neumann was that identical a priori probabilities for a detection of states of infinite state system must make sense. Since quantum mechanical expectation values are expressible in terms of operator traces, this requires that unit operator has unit trace: $tr(Id) = 1$.

In the finite-dimensional case it is easy to build observables out of minimal projections to 1-dimensional eigen spaces of observables. For infinite-dimensional case the probably of projection to 1-dimensional sub-space vanishes if each state is equally probable. The notion of observable must thus be modified by excluding 1-dimensional minimal projections, and allow only projections for which the trace would be infinite using the straightforward generalization of the matrix algebra trace as the dimension of the projection.

The non-trivial implication of the fact that traces of projections are never larger than one is that the eigen spaces of the density matrix must be infinite-dimensional for non-vanishing projection probabilities. Quantum measurements can lead with a finite probability only to mixed states with a density matrix which is projection operator to infinite-dimensional subspace. The simple von Neumann algebras for which unit operator has unit trace are known as factors of type II_1 [A25].

The definitions of adopted by von Neumann allow however more general algebras. Type I_n algebras correspond to finite-dimensional matrix algebras with finite traces whereas I_∞ associated with a separable infinite-dimensional Hilbert space does not allow bounded traces. For algebras of type III non-trivial traces are always infinite and the notion of trace becomes useless being replaced by the notion of state which is generalization of the notion of thermodynamical state. The fascinating feature of this notion of state is that it defines a unique modular automorphism of the factor defined apart from unitary inner automorphism and the question is whether this notion or its generalization might be relevant for the construction of M-matrix in TGD.

Von Neumann, Dirac, and Feynman

The association of algebras of type I with the standard quantum mechanics allowed to unify matrix mechanism with wave mechanics. Note however that the assumption about continuous momentum state basis is in conflict with separability but the particle-in-box idealization allows to circumvent this problem (the notion of space-time sheet brings the box in physics as something completely real).

Because of the finiteness of traces von Neumann regarded the factors of type II_1 as fundamental and factors of type III as pathological. The highly pragmatic and successful approach of Dirac [K139] based on the notion of delta function, plus the emergence of generalized Feynman graphs [K48], the possibility to formulate the notion of delta function rigorously in terms of distributions [A36, A26], and the emergence of path integral approach [A42] meant that von Neumann approach was forgotten by particle physicists.

Algebras of type II_1 have emerged only much later in conformal and topological quantum field theories [A20, A44] allowing to deduce invariants of knots, links and 3-manifolds. Also al-

gebraic structures known as bi-algebras, Hopf algebras, and ribbon algebras [A16, A45] relate closely to type II_1 factors. In topological quantum computation [B15] based on braid groups [A48] modular S-matrices they play an especially important role.

In algebraic quantum field theory [A28] defined in Minkowski space the algebras of observables associated with bounded space-time regions correspond quite generally to the type III_1 hyper-finite factor [A8, A31].

Hyper-finite factors in quantum TGD

The following argument suggests that von Neumann algebras known as hyper-finite factors (HFFs) of type II_1 and III_1- the latter appearing in relativistic quantum field theories provide also the proper mathematical framework for quantum TGD.

1. The Clifford algebra of the infinite-dimensional Hilbert space is a von Neumann algebra known as HFF of type II_1. There also the Clifford algebra at a given point (light-like 3-surface) of WCW is therefore HFF of type II_1. If the fermionic Fock algebra defined by the fermionic oscillator operators assignable to the induced spinor fields (this is actually not obvious!) is infinite-dimensional it defines a representation for HFF of type II_1. Super-conformal symmetry suggests that the extension of the Clifford algebra defining the fermionic part of a super-conformal algebra by adding bosonic super-generators representing symmetries of WCW respects the HFF property. It could however occur that HFF of type II_∞ results.

2. WCW is a union of sub-WCWs associated with causal diamonds (CD) defined as intersections of future and past directed light-cones. One can allow also unions of CDs and the proposal is that CDs within CDs are possible. Whether CDs can intersect is not clear.

3. The assumption that the M^4 proper distance a between the tips of CD is quantized in powers of 2 reproduces p-adic length scale hypothesis but one must also consider the possibility that a can have all possible values. Since $SO(3)$ is the isotropy group of CD, the CDs associated with a given value of a and with fixed lower tip are parameterized by the Lobatchevski space $L(a) = SO(3,1)/SO(3)$. Therefore the CDs with a free position of lower tip are parameterized by $M^4 \times L(a)$. A possible interpretation is in terms of quantum cosmology with a identified as cosmic time [K113]. Since Lorentz boosts define a non-compact group, the generalization of so called crossed product construction strongly suggests that the local Clifford algebra of WCW is HFF of type III_1. If one allows all values of a, one ends up with $M^4 \times M^4_+$ as the space of moduli for WCW.

Hyper-finite factors and M-matrix

HFFs of type III_1 provide a general vision about M-matrix [K138].

1. The factors of type III allow unique modular automorphism Δ^{it} (fixed apart from unitary inner automorphism). This raises the question whether the modular automorphism could be used to define the M-matrix of quantum TGD. This is not the case as is obvious already from the fact that unitary time evolution is not a sensible concept in ZEO.

2. Concerning the identification of M-matrix the notion of state as it is used in theory of factors is a more appropriate starting point than the notion modular automorphism but as a generalization of thermodynamical state is certainly not enough for the purposes of quantum TGD and quantum field theories (algebraic quantum field theorists might disagree!). ZEO requires that the notion of thermodynamical state should be replaced with its "complex square root" abstracting the idea about M-matrix as a product of positive square root of a diagonal density matrix and a unitary S-matrix. This generalization of thermodynamical state -if it exists- would provide a firm mathematical basis for the notion of M-matrix and for the fuzzy notion of path integral.

3. The existence of the modular automorphisms relies on Tomita-Takesaki theorem [A39], which assumes that the Hilbert space in which HFF acts allows cyclic and separable vector serving as ground state for both HFF and its commutant. The translation to the language of physicists

states that the vacuum is a tensor product of two vacua annihilated by annihilation oscillator type algebra elements of HFF and creation operator type algebra elements of its commutant isomorphic to it. Note however that these algebras commute so that the two algebras are not hermitian conjugates of each other. This kind of situation is exactly what emerges in ZEO: the two vacua can be assigned with the positive and negative energy parts of the zero energy states entangled by M-matrix.

4. There exists infinite number of thermodynamical states related by modular automorphisms. This must be true also for their possibly existing "complex square roots". Physically they would correspond to different measurement interactions giving rise to Kähler functions of WCW differing only by a real part of holomorphic function of complex coordinates of WCW and arbitrary function of zero mode coordinates and giving rise to the same Kähler metric of WCW.

The concrete construction of M-matrix utilizing the idea of bosonic emergence (bosons as fermion anti-fermion pairs at opposite throats of wormhole contact) meaning that bosonic propagators reduce to fermionic loops identifiable as wormhole contacts leads to generalized Feynman rules for M-matrix in which Kähler-Dirac action containing measurement interaction term defines stringy propagators [K28]. This M-matrix should be consistent with the above proposal.

Connes tensor product as a realization of finite measurement resolution

The inclusions $\mathcal{N} \subset \mathcal{M}$ of factors allow an attractive mathematical description of finite measurement resolution in terms of Connes tensor product [A18] but do not fix M-matrix as was the original optimistic belief.

1. In ZEO $\mathcal{N}$ would create states experimentally indistinguishable from the original one. Therefore $\mathcal{N}$ takes the role of complex numbers in non-commutative quantum theory. The space $\mathcal{M}/\mathcal{N}$ would correspond to the operators creating physical states modulo measurement resolution and has typically fractal dimension given as the index of the inclusion. The corresponding spinor spaces have an identification as quantum spaces with non-commutative $\mathcal{N}$-valued coordinates.

2. This leads to an elegant description of finite measurement resolution. Suppose that a universal M-matrix describing the situation for an ideal measurement resolution exists as the idea about square root of state encourages to think. Finite measurement resolution forces to replace the probabilities defined by the M-matrix with their $\mathcal{N}$ averaged counterparts. The "averaging" would be in terms of the complex square root of $\mathcal{N}$-state and a direct analog of functionally or path integral over the degrees of freedom below measurement resolution defined by (say) length scale cutoff.

3. One can construct also directly M-matrices satisfying the measurement resolution constraint. The condition that $\mathcal{N}$ acts like complex numbers on M-matrix elements as far as $\mathcal{N}$ averaged probabilities are considered is satisfied if M-matrix is a tensor product of M-matrix in $\mathcal{M}(\mathcal{N}$ interpreted as finite-dimensional space with a projection operator to $\mathcal{N}$. The condition that $\mathcal{N}$ averaging in terms of a complex square root of $\mathcal{N}$ state produces this kind of M-matrix poses a very strong constraint on M-matrix if it is assumed to be universal (apart from variants corresponding to different measurement interactions).

Number theoretical braids as space-time correlates for finite measurement resolution

Finite measurement resolution has discretization as a space-time counterpart. In the intersection of real and p-adic worlds defines as partonic 2-surfaces with a mathematical representation allowing interpretation in terms of real or p-adic number fields one can identify points common to real and p-adic worlds as rational points and common algebraic points (in preferred coordinates dictated by symmetries of embedding space). Quite generally, one can identify rational points and algebraic points in some extension of rationals as points defining the initial points of what might be called number theoretical braid beginning from the partonic 2-surface at the past boundary of CD and

connecting it with the future boundary of CD. The detailed definition of the braid inside light-like 3-surface is not relevant if only the information at partonic 2-surface is relevant for quantum physics.

Number theoretical braids are especially relevant for topological QFT aspect of quantum TGD. The topological QFT associated with braids accompanying light-like 3-surfaces having interpretation as lines of generalied Feynman diagrams should be important part of the definition of amplitudes assigned to generalized Feynman diagrams. The number theoretic braids relate also closely to a symplectic variant of conformal field theory emerges very naturally in TGD framework (symplectic symmetries acting on $\delta M^4_{\pm} \times CP_2$ are in question) and this leads to a concrete proposal for how to construct n-point functions needed to calculate M-matrix [K28]. The mechanism guaranteeing the predicted absence of divergences in M-matrix elements can be understood in terms of vanishing of symplectic invariants as two arguments of n-point function coincide.

Quantum spinors and fuzzy quantum mechanics

The notion of quantum spinor leads to a quantum mechanical description of fuzzy probabilities [K138]. For quantum spinors state function reduction to spin eigenstates cannot be performed unless quantum deformation parameter $q = exp(i2\pi/n)$ equals to $q = 1$. The reason is that the components of quantum spinor do not commute: it is however possible to measure the commuting operators representing moduli squared of the components giving the probabilities associated with "true" and "false". Therefore the probability for either spin state becomes a quantized observable. The universal eigenvalue spectrum for probabilities does not in general contain (1,0) so that quantum qbits are inherently fuzzy. State function reduction would occur only after a transition to q=1 phase and de-coherence is not a problem as long as it does not induce this transition.

Concrete realization of finite measurement resolution

The recent view about the realization of finite measurement resolution is surprisingly concrete.

1. The hierarchy of Planck constants $h_{eff} = n \times h$ relates to a hierarchy of criticalities and hierarchy of measurement resolutions since each breaking of symplectic conformal symmetries transforms some gauge degrees of freedom to physical ones making possible improved resolution. For the conformal symmetries associated with the spinor modes the identification as unbroken gauge symmetries is the natural one and conforms with the interpretation as counterparts of gauge symmetries. The hierarchies of conformal symmetry breakings can be identified as hierarchies of inclusions of HFFs. Criticality would generate dark matter phase characterized by n.

   The conformal sub-algebra realized as gauge transformations corresponds to the included algebra gets smaller as n increases so that the measurement resolution improves. The integer n would naturally characterize the inclusions of hyperfinite factors of type II_1 characterized by quantum phase $exp(2\pi/n)$. Finite measurement resolution is expected to give rise to the quantum group representations of symmetries, q-special functions, and q-derivative replacing ordinary derivative and reflecting the presence of discretization.

   In p-adic context representation of angle by phases coming as roots of unity corresponds to this as also the hierarchy of effective p-adic topologies reflecting the fact that finite measurement resolution makes well-orderedness of real numbers as un-necessary luxury and one can use much simpler p-adic mathematics. An excellent example is provided by p-adic mass calculations where number theoretical existence arguments fix the predictions of the model based on p-adic thermodynamics to a high degree.

2. Also the numbers of partonic 2-surfaces and string world sheets connecting them give rise to a physical realization of the finite measurement resolution since fermions at string world sheets represent the space-time geometry physically in finite measurement resolution realized also as a hierarchy of geometries for WCW (via the representation of WCW Kähler metric in terms of anti-commutators of super charges). Finite measurement resolution is a property of physical system formed by the observer and system studied: the system studied changes when the resolution changes.

3. This representation is automatically discrete at the level of partonic 2-surfaces, 1-D at their light-like orbits and 4-D in space-time interior. The discretization can be induced from discretization at the level of embedding space as is done in the definition of p-adic variants of space-time surfaces [K140].

   For $D > 0$ the discretization could also take place more abstractly for the parameters characterizing the functions (say coefficients of polynomials) characterizing string boundaries, string world sheets and partonic 2-surfaces, 3-surfaces, and 4-D space-time surfaces. Clearly, an abstraction hierarchy is involved. Similar discretization applied to the parameters characterizing the functions defining the 3-surfaces makes sense at the level of WCW. The discretization is obviously analogous to a choice of gauge and p-adicization suggests that rational numbers and their algebraic extensions give rise to a natural discretization allowing easy algebraic continuation of scattering amplitudes between different number fields.

2.3 Physics As A Generalized Number Theory

Physics as a generalized number theory vision involves actually three threads: p-adic ideas [K119], the ideas related to classical number fields [K120], and the ideas related to the notion of infinite prime [K118].

2.3.1 Fusion Of Real And P-Adic Physics To A Coherent Whole

p-Adic number fields were not present in the original approach to TGD. The success of the p-adic mass calculations (summarized in the first part of [K79]) made however clear that one must generalize the notion of topology also at the infinitesimal level from that defined by real numbers so that the attribute "topological" in TGD gains much more profound meaning than intended originally. It took a decade to get convinced that the identification of p-adic physics as a correlate of cognition is the most plausible interpretation [K81].

Another idea has been that that p-adic topology of p-adic space-time sheets somehow induces the effective p-adic topology of real space-time sheets. This idea could make physical sense but is not necessary in the recent adelic vision.

The discovery of the properties of number theoretic variants of Shannon entropy led to the idea that living matter could be seen as as something in the intersection of real and p-adic worlds and gave additional support for this interpretation. If even elementary particles reside in this intersection and effective p-adic topology applies for real partonic 2-surfaces, the success of p-adic mass calculations can be understood. The precise identification of this intersection has been a long-standing problem and only quite recently a definite progress has taken place [K137].

The original view about physics as the geometry of WCW is not enough to meet the challenge of unifying real and p-adic physics to a single coherent whole. This inspired "physics as a generalized number theory" approach [K83].

1. The first element is a generalization of the notion of number obtained by "gluing" reals and various p-adic number fields and their algebraic extensions along common rationals and algebraics to form a larger adelic structure (see **Fig. ??** in the appendix of this book).

2. At the level of embedding space this gluing could be seen as a gluing of real and p-adic variants of the embedding space together along common points in an algebraic extension of rationals inducing those for p-adic fields to what could be seen as a book like structure. General Coordinate Invariance (GCI) restricted to rationals or their extension requires preferred coordinates for $CD \times CP_2$ and this kind coordinates can be fixed by isometries of H. The coordinates are however not completely unique since non-rational isometries produce new equally good choices.

3. The manner to get rid of these problems is a more abstract formulation at the level of WCW: a discrete collection of space-time surface instead of a discrete collection of points of space-time surface. In the recent formulation based on strong form of holography identifying the back of the book as string world sheets and partonic 2-surfaces with parameters in some algebraic extension of rationals, the problems with GCI seem to disappear since the equations for the

2-surfaces in the intersection can be interpreted in any number field. One also gets rid of the ugly discretization at space-time level needed in the notion of p-adic manifold [K140] since it is performed at the level of parameters characterizing 2-D surfaces. By conformal invariance these parameters could be conformal moduli so that infinite-D WCW would effectively reduce to finite-D spaces.

4. The possibility to assign a p-adic prime to the real space-time sheets is required by the success of the elementary particle mass calculations and various applications of the p-adic length scale hypothesis. The original idea was that the non-determinism of Kähler action corresponds to p-adic non-determinism for some primes. It has been however difficult to make this more concrete.

   Rational numbers are common to reals and all p-adic number fields. One can actually assign to any algebraic extension of rationals extensions of p-adic numbers and construct corresponding adeles. These extensions can be arranged according to the complexity and I have already earlier proposed that this hierarchy gives rie to an evolutionary hierarchy.

   How the existence of preferred p-adic primes characterizing space-time surfaces emerge was solved only quite recently [K137]. The solution relies on p-adicization based on strong holography motivating the idea the idea that string world sheets and partonic surfaces with parameters in algebraic extensions of rationals define the intersection of reality and various p-adicities. The algebraic extension possesses preferred primes as primes, which are ramified meaning that their decomposition to a product of primes of the extension contains higher than first powers of its primes (prime ideals is the more precise notion).

   These primes are obviously natural candidates for the primes characterizing string world sheets number theoretically and it might even happen that strong form of holography is possible only for these primes. The weak form of NMP [K73] allows also to justify a generalization of p-adic length scale hypothesis. Primes near but below powers of primes are favoured since they allow exceptionally large negentropy gain so that state function reductions to tend to select them. Therefore the adelic approach combined with strong form of holography seems to be a rather promising approach.

   p-Adic continuations of 2-surfaces to 4-surfaces identifiable as imaginations would be due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K81]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes.

The interpretation for discretization the level of partonic 2-surfaces could be in terms of cognitive, sensory, and measurement resolutions rather than fundamental discreteness of the space-time. At the level of partonic 2-surface the discretization reduces to the naïvely expected one: the corners of string world sheets at partonic 2-surface defined the end points of string and orbits of string ends carrying fermion number. This discretization has concrete physical interpretation. Clearly a co-dimension rule holds. Discretization of n-D object consist of n-2-D objects.

What looks rather counter intuitive first is that transcendental points of p-adic space-time sheets are at spatiotemporal infinity in real sense so that the correlates of cognition cannot be localized to any finite spatiotemporal volume unlike those of sensory experience. The description of cognition in this manner predicts p-adic fractality of real physics meaning chaos in short scales combined with long range correlations: p-adic mass calculations represent one example of p-adic fractality.

The realization of this program at the level of WCW is far from trivial. Kähler-Dirac equation and classical field equations make sense but quantities expressible as space-time integrals - in particular Kähler action- do not make sense p-adically. Therefore one can ask whether only the partonic surfaces in the intersection of real and p-adic worlds should be allowed. Also this restricted theory would be highly non-trivial physically.

2.3.2 Classical Number Fields And Associativity And Commutativity As Fundamental Law Of Physics

The dimensions of classical number fields appear as dimensions of basic objects in quantum TGD. Embedding space has dimension 8, space-time has dimension 4, light-like 3-surfaces are orbits of 2-D partonic surfaces. If conformal QFT applies to 2-surfaces (this is questionable), one-dimensional structures would be the basic objects. The lowest level would correspond to discrete sets of points identifiable as intersections of real and p-adic space-time sheets. This suggests that besides p-adic number fields also classical number fields (reals, complex numbers, quaternions, octonions [A35]) are involved [K120] and the notion of geometry generalizes considerably. In the recent view about quantum TGD the dimensional hierarchy defined by classical number field indeed plays a key role. $H = M^4 \times CP_2$ has a number theoretic interpretation and standard model symmetries can be understood number theoretically as symmetries of hyper-quaternionic planes of hyper-octonionic space.

The associativity condition $A(BC) = (AB)C$ suggests itself as a fundamental physical law of both classical and quantum physics. Commutativity can be considered as an additional condition. In conformal field theories associativity condition indeed fixes the n-point functions of the theory. At the level of classical TGD space-time surfaces could be identified as maximal associative (hyper-quaternionic) sub-manifolds of the embedding space whose points contain a preferred hyper-complex plane M^2 in their tangent space and the hierarchy finite fields-rationals-reals-complex numbers-quaternions-octonions could have direct quantum physical counterpart [K120]. This leads to the notion of number theoretic compactification analogous to the dualities of M-theory: one can interpret space-time surfaces either as hyper-quaternionic 4-surfaces of M^8 or as 4-surfaces in $M^4 \times CP_2$. As a matter fact, commutativity in number theoretic sense is a further natural condition and leads to the notion of number theoretic braid naturally as also to direct connection with super string models.

At the level of Kähler-Dirac action the identification of space-time surface as a hyper-quaternionic sub-manifold of H means that the modified gamma matrices of the space-time surface defined in terms of canonical momentum currents of Kähler action using octonionic representation for the gamma matrices of H span a hyper-quaternionic sub-space of hyper-octonions at each point of space-time surface (hyper-octonions are the subspace of complexified octonions for which imaginary units are octonionic imaginary units multiplied by commutating imaginary unit). Hyper-octonionic representation leads to a proposal for how to extend twistor program to TGD framework [K139, K126].

How to achieve associativity in the fermionic sector?

In the fermionic sector an additional complication emerges. The associativity of the tangent- or normal space of the space-time surface need not be enough to guarantee the associativity at the level of Kähler-Dirac or Dirac equation. The reason is the presence of spinor connection. A possible cure could be the vanishing of the components of spinor connection for two conjugates of quaternionic coordinates combined with holomorphy of the modes.

1. The induced spinor connection involves sigma matrices in CP_2 degrees of freedom, which for the octonionic representation of gamma matrices are proportional to octonion units in Minkowski degrees of freedom. This corresponds to a reduction of tangent space group $SO(1,7)$ to G_2. Therefore octonionic Dirac equation identifying Dirac spinors as complexified octonions can lead to non-associativity even when space-time surface is associative or co-associative.

2. The simplest manner to overcome these problems is to assume that spinors are localized at 2-D string world sheets with 1-D CP_2 projection and thus possible only in Minkowskian regions. Induced gauge fields would vanish. String world sheets would be minimal surfaces in $M^4 \times D^1 \subset M^4 \times CP_2$ and the theory would simplify enormously. String area would give rise to an additional term in the action assigned to the Minkowskian space-time regions and for vacuum extremals one would have only strings in the first approximation, which conforms with the success of string models and with the intuitive view that vacuum extremals of Kähler

action are basic building bricks of many-sheeted space-time. Note that string world sheets would be also symplectic covariants.

Without further conditions gauge potentials would be non-vanishing but one can hope that one can gauge transform them away in associative manner. If not, one can also consider the possibility that CP_2 projection is geodesic circle S^1: symplectic invariance is considerably reduces for this option since symplectic transformations must reduce to rotations in S^1.

3. The fist heavy objection is that action would contain Newton's constant G as a fundamental dynamical parameter: this is a standard recipe for building a non-renormalizable theory. The very idea of TGD indeed is that there is only single dimensionless parameter analogous to critical temperature. One can of coure argue that the dimensionless parameter is $\hbar G/R^2$, R CP_2 "radius".

   Second heavy objection is that the Euclidian variant of string action exponentially damps out all string world sheets with area larger than $\hbar G$. Note also that the classical energy of Minkowskian string would be gigantic unless the length of string is of order Planck length. For Minkowskian signature the exponent is oscillatory and one can argue that wild oscillations have the same effect.

   The hierarchy of Planck constants would allow the replacement $\hbar \to \hbar_{eff}$ but this is not enough. The area of typical string world sheet would scale as h_{eff} and the size of CD and gravitational Compton lengths of gravitationally bound objects would scale as $\sqrt{h_{eff}}$ rather than $\hbar_{eff} = GMm/v_0$, which one wants. The only way out of problem is to assume $T \propto (\hbar/h_{eff})^2 \times (1/h_{bar}G)$. This is however un-natural for genuine area action. Hence it seems that the visit of the basic assumption of superstring theory to TGD remains very short.

Is super-symmetrized Kähler-Dirac action enough?

Could one do without string area in the action and use only K-D action, which is in any case forced by the super-conformal symmetry? This option I have indeed considered hitherto. K-D Dirac equation indeed tends to reduce to a lower-dimensional one: for massless extremals the K-D operator is effectively 1-dimensional. For cosmic strings this reduction does not however take place. In any case, this leads to ask whether in some cases the solutions of Kähler-Dirac equation are localized at lower-dimensional surfaces of space-time surface.

1. The proposal has indeed been that string world sheets carry vanishing W and possibly even Z fields: in this manner the electromagnetic charge of spinor mode could be well-defined. The vanishing conditions force in the generic case 2-dimensionality.

   Besides this the canonical momentum currents for Kähler action defining 4 embedding space vector fields must define an integrable distribution of two planes to give string world sheet. The four canonical momentum currents $\Pi_k \alpha = \partial L_K/\partial_{\partial_\alpha h^k}$ identified as embedding 1-forms can have only two linearly independent components parallel to the string world sheet. Also the Frobenius conditions stating that the two 1-forms are proportional to gradients of two embedding space coordinates Φ_i defining also coordinates at string world sheet, must be satisfied. These conditions are rather strong and are expected to select some discrete set of string world sheets.

2. To construct preferred extremal one should fix the partonic 2-surfaces, their light-like orbits defining boundaries of Euclidian and Minkowskian space-time regions, and string world sheets. At string world sheets the boundary condition would be that the normal components of canonical momentum currents for Kähler action vanish. This picture brings in mind strong form of holography and this suggests that might make sense and also solution of Einstein equations with point like sources.

3. The localization of spinor modes at 2-D surfaces would would follow from the well-definedness of em charge and one could have situation is which the localization does not occur. For instance, covariantly constant right-handed neutrinos spinor modes at cosmic strings are completely de-localized and one can wonder whether one could give up the localization inside wormhole contacts.

4. String tension is dynamical and physical intuition suggests that induced metric at string world sheet is replaced by the anti-commutator of the K-D gamma matrices and by conformal invariance only the conformal equivalence class of this metric would matter and it could be even equivalent with the induced metric. A possible interpretation is that the energy density of Kähler action has a singularity localized at the string world sheet.

   Another interpretation that I proposed for years ago but gave up is that in spirit with the TGD analog of AdS/CFT duality the Noether charges for Kähler action can be reduced to integrals over string world sheet having interpretation as area in effective metric. In the case of magnetic flux tubes carrying monopole fluxes and containing a string connecting partonic 2-surfaces at its ends this interpretation would be very natural, and string tension would characterize the density of Kähler magnetic energy. String model with dynamical string tension would certainly be a good approximation and string tension would depend on scale of CD.

5. There is also an objection. For M^4 type vacuum extremals one would not obtain any non-vacuum string world sheets carrying fermions but the successes of string model strongly suggest that string world sheets are there. String world sheets would represent a deformation of the vacuum extremal and far from string world sheets one would have vacuum extremal in an excellent approximation. Situation would be analogous to that in general relativity with point particles.

6. The hierarchy of conformal symmetry breakings for K-D action should make string tension proportional to $1/h_{eff}^2$ with $h_{eff} = h_{gr}$ giving correct gravitational Compton length $\Lambda_{gr} = GM/v_0$ defining the minimal size of CD associated with the system. Why the effective string tension of string world sheet should behave like $(\hbar/\hbar_{eff})^2$?

   The first point to notice is that the effective metric $G^{\alpha\beta}$ defined as $h^{kl}\Pi_k^\alpha\Pi_l^\beta$, where the canonical momentum current $\Pi_k\alpha = \partial L_K/\partial_{\partial_\alpha h^k}$ has dimension $1/L^2$ as required. Kähler action density must be dimensionless and since the induced Kähler form is dimensionless the canonical momentum currents are proportional to $1/\alpha_K$.

   Should one assume that α_K is fundamental coupling strength fixed by quantum criticality to $\alpha_K = 1/137$? Or should one regard g_K^2 as fundamental parameter so that one would have $1/\alpha_K = \hbar_{eff}/4\pi g_K^2$ having spectrum coming as integer multiples (recall the analogy with inverse of critical temperature)?

   The latter option is the in spirit with the original idea stating that the increase of h_{eff} reduces the values of the gauge coupling strengths proportional to α_K so that perturbation series converges (Universe is theoretician friendly). The non-perturbative states would be critical states. The non-determinism of Kähler action implying that the 3-surfaces at the boundaries of CD can be connected by large number of space-time sheets forming n conformal equivalence classes. The latter option would give $G^{\alpha\beta} \propto h_{eff}^2$ and $det(G) \propto 1/h_{eff}^2$ as required.

7. It must be emphasized that the string tension has interpretation in terms of gravitational coupling on only at the GRT limit of TGD involving the replacement of many-sheeted space-time with single sheeted one. It can have also interpretation as hadronic string tension or effective string tension associated with magnetic flux tubes and telling the density of Kähler magnetic energy per unit length.

   Superstring models would describe only the perturbative Planck scale dynamics for emission and absorption of $h_{eff}/h = 1$ on mass shell gravitons whereas the quantum description of bound states would require $h_{eff}/n > 1$ when the masses. Also the effective gravitational constant associated with the strings would differ from G.

   The natural condition is that the size scale of string world sheet associated with the flux tube mediating gravitational binding is $G(M+m)/v_0$, By expressing string tension in the form $1/T = n^2\hbar G_1$, $n = h_{eff}/h$, this condition gives $\hbar G_1 = \hbar^2/M_{red}^2$, $M_{red} = Mm/(M+m)$. The effective Planck length defined by the effective Newton's constant G_1 analogous to that appearing in string tension is just the Compton length associated with the reduced mass of the system and string tension equals to $T = [v_0/G(M+m)]^2$ apart from a numerical constant ($2G(M+m)$ is Schwartschild radius for the entire system). Hence the macroscopic

stringy description of gravitation in terms of string differs dramatically from the perturbative one. Note that one can also understand why in the Bohr orbit model of Nottale [E1] for the planetary system and in its TGD version [K112] v_0 must be by a factor 1/5 smaller for outer planets rather than inner planets.

Are 4-D spinor modes consistent with associativity?

The condition that octonionic spinors are equivalent with ordinary spinors looks rather natural but in the case of Kähler-Dirac action the non-associativity could leak in. One could of course give up the condition that octonionic and ordinary K-D equation are equivalent in 4-D case. If so, one could see K-D action as related to non-commutative and maybe even non-associative fermion dynamics. Suppose that one does not.

1. K-D action vanishes by K-D equation. Could this save from non-associativity? If the spinors are localized to string world sheets, one obtains just the standard stringy construction of conformal modes of spinor field. The induce spinor connection would have only the holomorphic component A_z. Spinor mode would depend only on z but K-D gamma matrix Γ^z would annihilate the spinor mode so that K-D equation would be satisfied. There are good hopes that the octonionic variant of K-D equation is equivalent with that based on ordinary gamma matrices since quaternionic coordinated reduces to complex coordinate, octonionic quaternionic gamma matrices reduce to complex gamma matrices, sigma matrices are effectively absent by holomorphy.

2. One can consider also 4-D situation (maybe inside wormhole contacts). Could some form of quaternion holomorphy [A47] [K126] allow to realize the K-D equation just as in the case of super string models by replacing complex coordinate and its conjugate with quaternion and its 3 conjugates. Only two quaternion conjugates would appear in the spinor mode and the corresponding quaternionic gamma matrices would annihilate the spinor mode. It is essential that in a suitable gauge the spinor connection has non-vanishing components only for two quaternion conjugate coordinates. As a special case one would have a situation in which only one quaternion coordinate appears in the solution. Depending on the character of quaternionion holomorphy the modes would be labelled by one or two integers identifiable as conformal weights.

   Even if these octonionic 4-D modes exists (as one expects in the case of cosmic strings), it is far from clear whether the description in terms of them is equivalent with the description using K-D equation based ordinary gamma matrices. The algebraic structure however raises hopes about this. The quaternion coordinate can be represented as sum of two complex coordinates as $q = z_1 + Jz_2$ and the dependence on two quaternion conjugates corresponds to the dependence on two complex coordinates z_1, z_2. The condition that two quaternion complexified gammas annihilate the spinors is equivalent with the corresponding condition for Dirac equation formulated using 2 complex coordinates. This for wormhole contacts. The possible generalization of this condition to Minkowskian regions would be in terms Hamilton-Jacobi structure.

   Note that for cosmic strings of form $X^2 \times Y^2 \subset M^4 \times CP_2$ the associativity condition for S^2 sigma matrix and without assuming localization demands that the commutator of Y^2 imaginary units is proportional to the imaginary unit assignable to X^2 which however depends on point of X^2. This condition seems to imply correlation between Y^2 and S^2 which does not look physical.

To summarize, the minimal and mathematically most optimistic conclusion is that Kähler-Dirac action is indeed enough to understand gravitational binding without giving up the associativity of the fermionic dynamics. Conformal spinor dynamics would be associative if the spinor modes are localized at string world sheets with vanishing W (and maybe also Z) fields guaranteeing well-definedness of em charge and carrying canonical momentum currents parallel to them. It is not quite clear whether string world sheets are present also inside wormhole contacts: for CP_2 type vacuum extremals the Dirac equation would give only right-handed neutrino as a solution (could they give rise to $N = 2$ SUSY?).

The construction of preferred extremals would realize strong form of holography. By conformal symmetry the effective metric at string world sheet could be conformally equivalent with the induced metric at string world sheets.

Dynamical string tension would be proportional to $\hbar/h_{eff}^2$ due to the proportionality $\alpha_K \propto 1/h_{eff}$ and predict correctly the size scales of gravitationally bound states for $\hbar_{gr} = \hbar_{eff} = GMm/v_0$. Gravitational constant would be a prediction of the theory and be expressible in terms of α_K and R^2 and $\hbar_{eff}$ ($G \propto R^2/g_K^2$).

In fact, all bound states - elementary particles as pairs of wormhole contacts, hadronic strings, nuclei [L3], molecules, etc. - are described in the same manner quantum mechanically. This is of course nothing new since magnetic flux tubes associated with the strings provide a universal model for interactions in TGD Universe. This also conforms with the TGD counterpart of AdS/CFT duality.

2.3.3 Infinite Primes And Quantum Physics

The hierarchy of infinite primes (and of integers and rationals) [K118] was the first mathematical notion stimulated by TGD inspired theory of consciousness. The construction recipe is equivalent with a repeated second quantization of a super-symmetric arithmetic quantum field theory with bosons and fermions labeled by primes such that the many-particle states of previous level become the elementary particles of new level. At a given level there are free many particles states plus counterparts of many particle states. There is a strong structural analogy with polynomial primes. For polynomials with rational coefficients free many-particle states would correspond to products of first order polynomials and bound states to irreducible polynomials with non-rational roots.

The hierarchy of space-time sheets with many particle states of space-time sheet becoming elementary particles at the next level of hierarchy. For instance, the description of proton as an elementary fermion would be in a well defined sense exact in TGD Universe. Also the hierarchy of n:th order logics are possible correlates for this hierarchy.

This construction leads also to a number theoretic generalization of space-time point since a given real number has infinitely rich number theoretical structure not visible at the level of the real norm of the number a due to the existence of real units expressible in terms of ratios of infinite integers. This number theoretical anatomy suggest a kind of number theoretical Brahman=Atman identity stating that the set consisting of number theoretic variants of single point of the embedding space (equivalent in real sense) is able to represent the points of WCW or maybe even quantum states assignable to causal diamond. One could also speak about algebraic holography.

The hierarchy of algebraic extensions of rationals is becoming a fundamental element of quantum TGD. This hierarchy would correspond to the hierarchy of quantum criticalities labelled by integer $n = h_{eff}/h$, and n could be interpreted as the product of ramified primes of the algebraic extension or its power so that number theoretic criticality would correspond to quantum criticality. The idea is that ramified primes are analogous to multiple roots of polynomial and criticality indeed corresponds to this kind of situation.

Infinite primes at the n:th level of hierarchy representing analogs of bound states correspond to irreducible polynomials of n-variables identifiable as polynomials of z_n with coefficients, which are polynomials of $z_1, .., z_{n-1}$. At the first level of hierarchy one has irreducible polynomials of single variable and their roots define irreducible algebraic extensions of rationals. Infinite integers in turn correspond to products of reducible polynomials defining reducible extensions. The infinite integers at the first level of hierarchy would define the hierarchy of algebraic extensions of rationals in turn defining a hierarchy of quantum criticalities. This observation could generalize to the higher levels of hierarchy of infinite primes so that infinite primes would be part of quantum TGD although in much more abstract sense as thought originally.

2.4 Physics As Extension Of Quantum Measurement Theory To A Theory Of Consciousness

TGD inspired theory of consciousness could be seen as a generalization of quantum measurement theory to make observer, which in standard quantum measurement theory remains an outsider, a genuine part of physical system subject to laws of quantum physics. The basic notions are quantum

jump identified as moment of consciousness and the notion of self [K68]: in zero energy ontology these notions might however reduce to each other. Negentropy Maximization Principle [K73] defines the dynamics of consciousness and as a special case reproduces standard quantum measurement theory.

2.4.1 Quantum Jump As Moment Of Consciousness

TGD suggests that the quantum jump between quantum histories could identified as moment of consciousness and could therefore be for consciousness theory what elementary particle is for physics [K68].

This means that subjective time evolution corresponds to the sequence of quantum jumps $\Psi_i \to U\Psi_i \to \Psi_f$ consisting of unitary process followed by state function process. Originally U was thought to be the TGD counterpart of the unitary time evolution operator $U(-t,t)$, $t \to \infty$, associated with the scattering solutions of Schrödinger equation. It seems however impossible to assign any real Schrödinger time evolution with U. In zero energy ontology U defines a unitary matrix between zero energy states and is naturally assignable to intentional actions whereas the ordinary S-matrix telling what happens in particle physics experiment (for instance) generalizes to M-matrix defining time-like entanglement between positive and negative energy parts of zero energy states. One might say that U process corresponds to a fundamental act of creation creating a quantum superposition of possibilities and the remaining steps generalizing state function reduction process select between them.

2.4.2 Negentropy Maximization Principle And The Notion Of Self

Negentropy Maximization Principle (NMP [K73]) defines the variational principle of TGD inspired theory of consciousness. It has developed considerably during years. The notion of negentropic entanglement (NE) and Zero Energy Ontology (ZEO) have been main stimuli in this process.

1. U-process is followed by a sequence of state function reductions. Negentropy Maximization Principle (NMP [K73]) in its original form stated that in a given quantum state the most quantum entangled subsystem-complement pair can perform the quantum jump to a state with vanishing entanglement. More precisely: the reduction of the entanglement entropy in the quantum jump is as large as possible. This selects the pair in question and in case of ordinary entanglement entropy leads the selected pair to a product state. The interpretation of the reduction of the entanglement entropy as a conscious information gain makes sense. The sequence of state function reductions decomposes at first step the entire system to two parts in such a way that the reduction entanglement entropy is maximal. This process repeats itself for subsystems. If the subsystem in question cannot be divided into a pair of entangled free system the process stops since energy conservation does not allow it to occur (binding energy).

   The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible.

2. The existence of number theoretical entanglement entropies in the intersection of real and various p-adic worlds forced to modify this picture. These entropies can be negative and therefore are actually positive negentropies representing conscious or potentially conscious information.

   The reduction process can stop also if the self in question allows only decompositions to pairs of systems with negentropic entanglement (NE). This does not require that the system forms a bound state for any pair of subsystems so that the systems decomposing it can be free (no binding energy). This defines a new kind of bound state not describable as a jail defined by the bottom of a potential well. Subsystems are free but remain correlated by NE (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book).

   The consistency with quantum measurement theory demands that quantum measurement leads to an eigen-space of the density matrix so that the outcome of the state function

reduction would be characterized by a possibly higher-dimensional projection operator. This would define strong form of NMP. The condition that negentropy gain (rather than final state negentropy) is maximal fixed the sub-system complement pair for which the reduction occurs.

3. Strong form of NMP would mean very restricted form of free will: we would live in the best possible world. The weak form of NMP allows the outcome of state function reduction to be a lower-dimensional subspace of the space defined by the projector. This form of NMP allows free will, event also ethics and moral can be understood if one assumes that NE means experience with positive emotional coloring and has interpretation as information (Akashic records) [K133]. Weak form of NMP allows also to predict generalization of p-adic length scale hypothesis [K137]. Hence weak NMP is much more feasible than strong form of NMP.

It is not at all obvious that NMP is consistent with the second law and it is quite possible that second law holds true only if one restricts the consideration to the visible matter sector with ordinary value of Planck constant.

1. The ordinary state function reductions - as opposed to those generating negentropic entanglement - imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of an iteration like process leading to the asympotic self-organization patterns. One could regard dissipation as a Darwinian selector as in standard theories of self-organization. NMP thus predicts that self organization and hence presumably also fractalization can occur inside selves. NMP would favor the generation of negentropic entanglement. This notion is highly attractive since it could allow to understand how quantum self-organization generates larger coherent structures.

2. State function reduction for NE is not deterministic for the weak form of NMP but on the average sense negentropy assignable to dark matter sectors increases. This could allow to understand how living matter is able to develop almost deterministic cellular automaton like behaviors.

3. A further implication of NMP is that Universe generates information about itself represented in terms of NE: if one is not afraid of esoteric associations one could call this information Akashic records. This ia not in obvious conflict with second law since the entropy in the case of second law is ensemble entropy assignable to single particle in thermodynamical description.

   The simplest assumption is that the information measured by number theoretic negentropy is experienced during the state function reduction sequence at fixed boundary of CD defining self.

Weak NMP provides an understanding of life, which is the mirror image of that believed to be provided by the second law. Life in the standard Universe would be a thermodynamical fluctuation - the needed size of this fluctuation has been steadily increasing and it seems that it will eventually fill the entire Universe! Life in TGD Universe is a necessity implied by NMP and the attribute "weak" makes possible the analogs of thermodynamical fluctuations in opposite effects meaning that the world is not the best possible one. On the other hand, weak form of NMP implies evolution as selection of preferred p-adic primes since the free will allows also larger negentropy gains than strong form of NMP.

2.4.3 Life As Islands Of Rational/Algebraic Numbers In The Seas Of Real And P-Adic Continua?

NMP and negentropic entanglement demanding entanglement probabilities which are equal to inverse of integer, is the starting point. Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that in some sense life and conscious intelligence reside in the intersection of the real and p-adic worlds.

What could be this intersection of realities and p-adicities?

1. The facts that fermionic oscillator operators are correlates for Boolean cognition and that induced spinor fields are restricted to string world sheets and partonic 2-surfaces suggests that the intersection consists of these 2-surfaces.

2. Strong form of holography allows a rather elegant adelization of TGD by a construction of space-time surfaces by algebraic continuations of these 2-surfaces defined by parameters in algebraic extension of rationals inducing that for various p-adic number fields to real or p-adic number fields. Scattering amplitudes could be defined also by a similar algebraic contination. By conformal invariance the conformal moduli characterizing the 2-surfaces would defined the parameters.

This suggests a rather concrete view about the fundamental quantum correlates of life and intelligence.

1. For the minimal option life would be effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world sheets partonic two-surfaces appears in U-matrix so that the data localizable to strings connecting partonic 2-surfaces would dictate the scattering amplitudes.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K3]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K103].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and also hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

2.4.4 Two Times

The basic implication of the proposed view is that subjective time and geometric time of physicist are not the same [K68]. This is not a news actually. Geometric time is reversible, subjective time irreversible. Geometric future and past are in completely democratic position, subjective future does not exist at all yet. One can say that the non-determinism of quantum jump is completely outside space-time and Hilbert space since quantum jumps replaces entire 4-D time evolution (or

rather, their quantum superposition) with a new one, re-creates it. Also conscious existence defies any geometric description. This new view resolves the basic problem of quantum measurement theory due to the conflict between determinism of Schrödinger equation and randomness of quantum jump. The challenge is to understand how these two times correlate so closely as to lead to their erratic identification.

With respect to geometric time the contents of conscious experience is naturally determined by the space-time region inside CD in zero energy ontology. This geometro-temporal integration should have subjecto-temporal counterpart. The experiences of self are determined partially by the mental images assignable to sub-selves (having sub-CDs as embedding space correlates) and the quantum jump sequences associated with sub-selves define a sequence of mental images.

The view about the experience of time has changed.

1. The original hypothesis was that self experiences these sequences of mental images as a continuous time flow. If the mental images define the contents fo consciousness completely, self would experience in absence of mental images experience of "timelessness". This could be seen to be in accordance with the reports of practitioners of various spiritual practices. One must be however extremely cautious and try to avoid naïve interpretations.

2. ZEO forces to modify this view: the experience about the flow of time and its arrow corresponds to a sequence of repeated state function reductions leaving the state at fixed boundary of CD invariant: in standard quantum theory the entire state would remain invariant but now the position of the upper boundary of CD and state at it changes. Perhaps the experiences of meditators are such that the upper boundary of CD is more or less stationary during them.

What happens when consciousness is lost?

1. The original vision was that self loses consciousness in quantum jump generating entropic entanglement and experience an expansion of consciousness if the resulting entanglement is negentropic.

2. The recent vision is that the first state function reduction to the opposite boundary of CD means for self death followed by re-incarnation at the opposite boundary.

The assumption that the integration of experiences of self involves a kind of averaging over sub-selves of sub-selves guarantees that the sensory experiences are reliable despite the fact that quantum nondeterminism is involved with each quantum jump.

The measurement of density matrix defined by the $MM^\dagger$, where M is the M-matrix between positive and negative energy parts of the zero energy state would correspond to the passive aspects of consciousness such as sensory experiencing. U would represent at the fundamental level volition as a creation of a quantum superposition of possibilities. What follows it would be a selection between them. The volitional choice between macroscopically differing space-time sheets representing different maxima of Kähler function could be basically responsible for the active aspect of consciousness. The fundamental perception-reaction feedback loop of biosystems would result from the combination of the active and passive aspects of consciousness represented by U and M.

2.4.5 How Experienced Time And The Geometric Time Of Physicist Relate To Each Other?

The relationship between experienced time and time of physicist is one of the basic puzzles of modern physics. In the proposed framework they are certainly two different things and the challenge is to understand why the correlation between them is so strong that it has led to their identification. One can imagine several alternative views explaining this correlation [K133, K10] and it is better to keep mind open.

Basic questions

The flow of subjective time corresponds to quantum jump sequences for sub-selves of self having interpretation as mental images. If mind is completely empty of mental images subjectively experienced time ceases to exists. This leaves however several questions to be answered.

1. Why the contents of conscious of self comes from a finite space-time region looks like an easy question. If the contents of consciousness for sub-selves representing mental images is localized to the sub-CDs with indeed have defined temporal position inside CD assigned with the self the contents of consciousness is indeed from a finite space-time volume. This implies a new view about memory. There is no need to store again and again memories to the "brain now" since the communications with the geometric past by negative energy signals and also time-like negentropic quantum entanglement allow the sharing of the mental images of the geometric past.

2. There are also more difficult questions. Subjective time has arrow and has only the recent and possibly also past. The subjective past could in principle reduce to subjective now if conscious experience is about 4-D space-time region so that memories would be always geometric memories. How these properties of subjective time are transferred to apparent properties of geometric time? How the arrow of geometric time is induced? How it is possible that the locus for the contents of conscious experience shifts or at least seems to be shifted quantum jump by quantum jump to the direction of geometric future? Why the sensory mental images are located in a narrow time interval of about .1 seconds in the usual states of consciousness (not that sensory memories are possible: scent memories and phantom pain in leg could be seen as examples of vivid sensory memory)?

The recent view about arrow of time

The basic intuitive idea about the explanation for the arrow of psychological time has been the same from the beginning - diffusion inside light-cone - but its detailed realization has required understanding of what quantum TGD really is. The replacement of ordinary positive energy ontology with zero energy ontology (ZEO) has played a crucial role in this development. The TGD based vision about how the arrow of geometric time is by no means fully developed and final. It however seems that the most essential aspects have been understood now.

1. What seems clear now is the decisive role of ZEO and hierarchy of CDs, and the fact that the quantum arrow of geometric time is coded into the structure of zero energy states to a high extent. The still questionable but attractively simple hypothesis is that U matrix two basis with opposite quantum arrows of geometric time: is this assumption really consistent with what we know about the arrow of time? If this is the case, the question is how the relatively well-defined quantum arrow of geometric time implies the experienced arrow of geometric time. Should one assume the arrow of geometric time separately as a basic property of the state function reduction cascade or more economically- does it follow from the arrow of time for zero energy states or only correlate with it?

2. The state function reductions can occur at both boundaries of CD. If the reduction occurs at given boundary is immediately followed by a reduction at the opposite boundary, the arrow of time alternates: this does not conform with intuitive expectations: for instance, this would imply that there are two selves assignable to the opposite boundaries!

   Zero energy states are however de-localized in the moduli space CDs (size of CD plus discrete subgroup of Lorentz group defining boosts of CD leaving second tip invariant). One has quantum superposition of CDs with difference scales but with fixed upper or lower boundary belonging to the same light-cone boundary after state function reduction. In standard quantum measurement theory the repetition of state function reduction does not change the state but now it would give rise to the experienced flow of time. Zeno effect indeed requires that state function reductions can occur repeatedly at the same boundary. In these reductions the wave function in moduli degrees of freedom of CD changes. This implies "dispersion" in the moduli space of CDs experienced as flow of time with definite arrow. This view lead to a precise definition of self as sequence of quantum jumps to the reducing to the same boundary of CD.

3. This approach codes also the arrow of time at the space-time level: the average space-time sheet in quantum superposition increases in size as the average position of the "upper boundaries" of CDs drift towards future state function reduction by state function reduction.

4. In principle the arrow of time can temporarily change but it would seem that this can occur in very special circumstances and probably takes place in living matter routinely. Phase conjugate laser beam is a non-biological example about reversal of the arrow of time. The act of volition would correspond to the first state function reduction to the opposite boundary so that the reversal of time arrow at some level of the hierarchy of selves would take place in the act of volition.

Usually it is thought that the increase of ensemble entropy implied by second law gives rise to the arrow of observed time. In TGD framework NMP replaces second law as a fundamental principle and at the level of ensembles implies it. The negentropy assignable to entanglement increases by NMP if one accept the number of number theoretic Shannon entropy.

Could the increase of entanglement negentropy define the arrow of time? Negentropy is assignable to the fixed boundary of CD and characterizes self. The sequence of repeated state function reductions cannot therefore increase negentropy. Negentropy would increase only in the state function reduction a the opposite boundary of CD and the increased negentropy would be associated the re-incarnated self. The increase of negentropy would be forced by NMP and also the size scale of CD would increase.

This would be certainly consistent with evolution. The prediction is that a given CD corresponds to an entire family CDs coming integer multiples $n = h_{eff}/h$ of a minimal size. During state function reduction sequence to fixed boundary of CD the average size defined by average value of n and p-adic length scale involved would increase in statistical sense. One can consider also the possibility that there is sharp localization to given value of n.

The periods of repeated state function reductions would be periods of coherence (sustained mental image, subself) and decoherence would be implied by the first state function to the opposite boundary of CD forced by NMP to eventually to occur. At the level of action principle the increase of h_{eff} means gradual reduction of string tension $T \propto 1/\hbar_{eff}G$ and generation of gravitationally bound states of increasing size with binding realized in terms of strings connecting the partonic 2-surfaces. Gravitation, biology, and evolution would be very intimately related.

2.5 Implications Of Quantum Classical Correspondence

Quantum Classical Correspondence has been of the guiding principles in the construction of Quantum TGD. Recall that at the level of WCW Quantum TGD is a theory of purely classical spinor fields. In ZEO the modes of sub- WCW spinor fields associated with a given CD have by effective 2-dimensionality as their arguments collections of partonic 2-surfaces and their 4-D tangent space data. U-matrix, M-matrices, and S-matrix are in principle reducible to the properties of the basis of WCW spinor fields [K78].

Quantum classical correspondence assumes that classical dynamics defined by the preferred extremals of Kähler action define an exact part of Quantum TGD. More generally, all quantum notions - even the quantum jump sequence characterizing the contents of consciousness - must have space-time counterpart: this representation is analogous to written language.

The notion of WCW Kähler geometry combined with GCI allows to identify classical space-time surfaces as analogs of Bohr orbits as preferred extremals of Kähler action. What "preferred" means is of course a highly non-trivial question. Assuming that light-like 3-surfaces and space-like 3-surfaces at the ends of CDs give rise to same theory implies effective 2-dimensionality and strong form of holography having dramatic implications for the theory.

2.5.1 Strong Form Of Holography And Effective 2-Dimensionality

Strong form of holography reduces to strong form of General Coordinate Invariance.

1. The starting point is the vision about geometrization of quantum physics in terms of the geometry of WCW , the space of 3-surfaces of H. Quantum states correspond to classical WCW spinor fields and WCW spinors (spinor field at given point of WVW, which is 3-surface!). No quantization occurs at WCW level: spinor fields are classical. WCW spinor corresponds to fermionic Fock states with fermionic oscillator operators associated with free second quantized induced spinor fields (spinor fields of H) at 3-surfaces and extended to

4-surfaces. This "second quantization" has purely geometric meaning and makes possible WCW spinor geometry.

2. General Coordinate Invariance is one of the fundamental symmetries and states that 4-D general coordinate transformations act as gauge symmetries. This requires that the definition of WCW metric assigns to 3-D surface a 4-D space-time surface. This space-time surface is analogous to Bohr orbit and defines the "classical physics" associated with the 3-surface but satisfying the analogs of Bohr quantization rules. This space-time surface is a preferred extremal of Kähler action and the value of Kähler action for the Euclidian regions of space-time surface defines Kähler function defining the Kähler metric of WCW .

   The value of Kähler action for Minkowskian regions of space-time surface defines a complex phase in vacuum functional and plays a role of Morse function and is also analogous to the action in ordinary quantum field theory: in particular it makes possible interference effects at the level of vacuum functional central in quantum field theories.

   Obviously the effective reduction of 4-D theory to 3-D theory corresponds to holography. In ordinary QFT approach to TGD this would not take place since one performs path integral over all space-time surfaces. In fact, the total failure of this approach led to the generalization of Einstein's geometrization program of classical physics to a geometrization of quantum physics in terms of WCW geometry.

   Characterizing the mathematical conditions satisfied by the preferred extremals of Kähler action precisely is still one of the basic mathematical challenges and several conjectures have been made during years.

3. GCI makes possible to fix the gauge by choosing the 3-surfaces in some especially convenient manner. One choice is as unions of space-like 3-surfaces at the light-like boundaries of CDs. Second choice is as wormhole throats which are light-like 3-surfaces at which the signature of the induced metric changes from Euclidian to Minkowskian and behaving in many respects like causal horizons and black hole horizons. Which of the choices is correct or are both correct? If both choices are correct one ends up with the strong form of GCI: the intersections of 3-D light-like wormhole throats with the 3-D space-like ends of space-time surface defining partonic 2-surfaces and their 4-D tangent space data carry information about quantum states.

   Strong form of GCI implies strong form of holography. Already partonic 2-surfaces and their 4-D tangent space data are enough. This does not mean genuine 2-dimensionality and reduction to a string theory since tangent space data are needed. Also the breaking of strict determinism for Kähler action implies that the effective 2-dimensionality is true only in some length scales.

2.5.2 Weak Form Of Electric Magnetic Duality

The notion of electric-magnetic duality [B2] was proposed first by Olive and Montonen and is central in $\mathcal{N} = 4$ supersymmetric gauge theories. It states that magnetic monopoles and ordinary particles are two different phases of theory and that the description in terms of monopoles can be applied at the limit when the running gauge coupling constant becomes very large and perturbation theory fails to converge. The notion of electric-magnetic self-duality is more natural since for CP_2 geometry Kähler form is self-dual and Kähler magnetic monopoles are also Kähler electric monopoles and Kähler coupling strength is by quantum criticality renormalization group invariant rather than running coupling constant. The notion of electric-magnetic (self-)duality emerged already two decades ago in the attempts to formulate the Kähler geometric of WCW . Quite recently a considerable step of progress took place in the understanding of this notion [K30]. What seems to be essential is that one adopts a weaker form of the self-duality applying at partonic 2-surfaces [K28].

Every new idea must be of course taken with a grain of salt but the good sign is that this concept leads to precise predictions. The point is that elementary particles do not generate monopole fields in macroscopic length scales: at least when one considers visible matter. The first question is whether elementary particles could have vanishing magnetic charges: this turns out to be impossible. The next question is how the screening of the magnetic charges could take place and

leads to an identification of the physical particles as string like objects identified as pairs magnetic charged wormhole throats connected by magnetic flux tubes.

1. The first implication is a new view about electro-weak massivation reducing it to weak confinement in TGD framework. The second end of the string contains particle having electroweak isospin neutralizing that of elementary fermion and the size scale of the string is electro-weak scale would be in question. Hence the screening of electro-weak force takes place via weak confinement realized in terms of magnetic confinement.

2. This picture generalizes to the case of color confinement. Also quarks correspond to pairs of magnetic monopoles but the charges need not vanish now. Rather, valence quarks would be connected by flux tubes of length of order hadron size such that magnetic charges sum up to zero. For instance, for baryonic valence quarks these charges could be $(2, -1, -1)$ and could be proportional to color hyper charge.

3. The highly non-trivial prediction making more precise the earlier stringy vision is that elementary particles are string like objects in the length scale defined by their Compton length. Since the other end of flux tube carries neutrino pair it is however essentially invisible at low energies so that there is no obvious conflict with experimental facts.

The hierarchy of Planck constants means that the Compton lengths of dark elementary particles can be macroscopic so that their character as magnetic flux tubes with monopoles at ends could make itself manifest in condensed and living matter.

2.5.3 TGD As Almost Topological QFT

TGD as almost topological QFT is one of those idea that one cannot be sure of. I think it emerged around 2005. I have been even ready to give it up but it experienced re-incarnation as I discovered the weak form of electric-magnetic duality.

1. Holography in the sense that data at 3-D surfaces code for the quantum state is an idea which emerged already at 1990 or so since 3-surfaces are indeed basic objects in quantum TGD. General Coordinate Invariance indeed implies this and the highly non-trivial implication is that space-time surface associated with a given 3-surface is analogous to Bohr orbit. Therefore semiclassical quantization is an exact part of quantum TGD.

2. The question is whether it is light-like 3-surfaces or space-like 3-surfaces at the ends of space-time sheet defined by CD can be identified as the 3-surfaces that carry the data. Strong form of General Coordinate Invariance states that both choices are equally good. Only the intersections of these surfaces at the boundaries of CDs and their 4-D tangent spaces carry the data. This implies effective 2-dimensionality and strongly suggests conformal invariance and coset representation meaning that the actions of conformal generators of light-like 3-surface and those associated with the boundary of CD cancel each other. This implies EP in generalized form.

3. Already effective 3-dimensionality suggests but does not imply that the Kähler action reduces to 3-D Chern-Simons term. If this occurs, the theory simplifies enormously calculationally and there are good hopes of calculating even without knowing details about preferred extremals. Chern-Simons action defines a topological QFT for braids and braids indeed replaced the 3-D light-like orbits of partonic 2-surfaces in TGD Universe in finite measurement resolution.

The reduction of Kähler action to 3-D integrals

To achieve reduction to Chern-Simons term the Kähler action for preferred extremals must reduce to a total divergence. This is achieved if in the decomposition of action to a total divergence and term $j \cdot A$, where j is Kähler current the latter term vanishes: $j \cdot A = 0$. This takes place in the following situations.

1. Empty space Maxwell equations $j = 0$ stating the vanishing of Kähler current hold true.

2. j and A are light-like and in the same direction so that their product vanishes. This is true for so called "massless extremals" (topological light rays).

3. j is proportional to the instanton current $j = \Phi j_I$, $j_I = \epsilon^{\alpha\beta\gamma\delta} A_\beta J_{\gamma\delta}$ so that $j \cdot A$ vanishes identically. Conservation of the Kähler current requires that the proportional factor Φ must satisfy $d\Phi \cdot j_I + \Phi I = 0$ where I is instanton density. $d\Phi$ is either orthogonal to j_I or both $d\Phi$ and j_I are light-like and have same direction.

   This kind of proportionality might hold true also for other isometry currents and would mean "topologicalization" of conserved currents in accordance with the idea about almost topological QFT.

One also ends up with the proposal that preferred extremals are such that the flow lines of isometry currents integrate to coordinate lines globally. This kind of flow is known as Beltrami flow. This would mean that they define the analog of hydrodynamic flow in which the orbits of particles do not cross each other and there are no collisions. The analog of quantum flow (no collisions - no dissipation) would be in question and one could assign to the flow an order parameter of a supra phase varying only along the flow lines. The basic condition for a flow J to define Beltrami flow read as $J \wedge dJ = 0$, where J is the 1-form defined by the current (covariant form of current depending on induced metric).

Reduction to Chern-Simons term by the weak form of electric-magnetic duality

The proportionality of Kähler current to instanton current implies the reduction of action to 3-D terms but not yet a reduction to Chern-Simons terms implying almost topological QFT property.

1. This is guaranteed if one assumed what I have called weak form of electric-magnetic duality. This duality generalizes the Montonen-Olive electric-magnetic duality and would hold at wormhole throats and space-like 3-surfaces at the ends of space-time sheets but not necessarily elsewhere. It would imply that Kähler flux equals to magnetic flux so that Kähler electric charge is quantized. There are good reasons to assume that this charge corresponds to fermion number so that all wormhole throats carrying fermion number would be magnetic monopoles carrying Kähler magnetic charge equal to fermion number. Physical particles would correspond to multi-monopole states with vanishing total Kähler magnetic charge.

2. It is important to notice that the weak form of electric-magnetic duality at the space-like 3-surfaces and wormhole throats involves the induced metric of the space-time sheet so that metric does not disappear from the theory although Kähler action reduces to Chern-Simons term. This gives a precise content to the attribute "almost". The reduction to Chern-Simons terms would mean enormous calculational simplification of the theory and raises the hope that the theory could be calculable.

3. This also fixes to a high degree the view about leptons and hadrons. For instance, leptons should be string like objects formed by Kähler magnetically charged wormhole throats connected by magnetic flux tubes. Analogous picture applies to gauge bosons consisting of wormhole contacts with throats carrying fermion and anti-fermion numbers respectively. Hadrons could correspond multimonopole states.

Morse, Kähler, and me

First year physics student would immediately say that $\sqrt{g_4}$ is imaginary in the space-time regions with Minkowskian signature of the induced metric and real otherwise. For me it took 33 years to finally accept this trivial fact as a fact but finally I had to give up! This simple fact implies that Minkowskian regions give imaginary exponent of Chern-Simons term and Euclidian regions real exponent of Chern-Simons term [K72]. Under rather natural assumptions the two Chern-Simons terms are identical and would be obtained as an exponent of Chern-Simons term multiplied by complex number.

The imaginary exponent gives rise to interference effects typical for gauge theories and defining the core mechanism of quantum field theories and implies that stationary phase approximation

makes sense. Stationary phase approximation is important also in topological QFTs and Chern-Simons term plays the role of Morse function in topological QFTs classifying the topological of 4-manifolds. The real exponent defines Kähler function and guarantees the convergence of the functional integral and guarantees that it exists as a genuine mathematical object.

Could Kähler action reduce to a 2-D integral?

Effective 2-dimensionality suggests a further dimensional reduction in the sense that Chern-Simons terms might allow expression as 2-dimensional integrals. If this idea is accepted, the only natural option is a reduction to a sum of areas of string world sheets with dynamical string tension. I have indeed developed a detailed proposal concerning the identification of this string world sheet [K126]. String world sheets indeed emerge naturally in quantum TGD and have as their boundary the space-like braid strands at the ends of space-time surfaces and light-like braid strands at the light-like 3-surfaces. Knotting of string world sheets is possible in 4-D space-time whereas braid strands link and knot at 3-surfaces so that quantum TGD would provide a theory of ordinary knots and 2-knots. This adds additional aspect to the statement that TGD is almost topological QFT.

2.5.4 Generalized Feynman Diagrams And Braids

The notion of generalized Feynman diagram [K56, K126, K48] has been developing rapidly during last five years. This progress has been boosted by several developments. The basic observation is that the regions of space-time surface with Euclidian signature of induced metric can be identified as generalized Feynman diagrams. Same interpretation applies by holography also to the light-like 3-surfaces at which the signature of the induced metric changes from Euclidian to Minkowskian. Additional boosts are due to ZEO allowing to interpreted the Feynman diagrams as a characterization of zero energy states. Also strong form of holography, bosonic energence, finite measurement resolution realized as discretization allows to replaced space-time sheets with string world sheets with the ends of string world sheets realized as braid strands, the realization that knotting of these strings is possible and could play a key role, and the connection with twistor approach have been important stimuli. The special role of 10 Hz frequency assignable to electron suggests that generalized Feynman diagrams could be relevant also for TGD inspired biology.

ZEO together with the notion of bosonic emergence leads to a new view about Feynman diagrams. The new element is that all physical states consist basically of wormhole throats which carry light-like four-momentum. Even virtual momenta are light-like and space-like four-momenta are obtained for wormhole contacts for which the energies of light-like states are of opposite sign. This leads to very powerful constraints on loop diagrams and there are good reasons to believe that both UV and IR divergences are absent.

Finite measurement resolution allows to assign braid strands to the light-like 3-surfaces and string world sheets to the 4-surfaces and one can also identify the braid strands as lines of generalized Feynman diagrams. It is possible to distinguish between light-like braids assignable to the light-like 3-surfaces and space-like braids connecting different partonic 2-surfaces at the ends of the space-time surface at the boundary of CD. Braids have also direct biological significance. DNA as topological quantum computer [K3] utilizes both kinds of braidings.

2.5.5 The Superposition Of Classical Fields In TGD Universe

Living system as conscious hologram is one of the basic visions. What one means with classical fields, their interference, and their interaction with elementary particles is an very essential aspect of what it is to be a hologram and a clarification to this issued emerged only during last year. As a matter fact, basic objection against TGD is that the interference of classical fields in the usual sense is not possible in TGD Universe!

In TGD Universe gauge fields are replaced with topological field quanta. Examples are topological light rays, magnetic/electric flux tubes and sheets, and flux quanta carrying both magnetic and electric fields. Flux quanta form a fractal hierarchy in the sense that there are flux quanta inside flux quanta. It is natural to assume quantization of Kähler magnetic flux. Braiding and reconnection are the basic topological operations for flux quanta.

The basic question is how the basic notions assigned with the classical gauge and gravitational fields understood in standard sense generalize in TGD framework.

1. Superposition and interference of the classical fields is very natural in Maxwell electrodynamics and certainly experimentally verified phenomena. Also the notion of hologram relies crucially on the notion of interference. How can one describe the effects explained in terms of superposition of fields in a situation in which the theory is extremely non-linear and all classical gauge fields are expressible in terms of CP_2 coordinates and their gradients? It is also rather clear that the preferred extremals for Kähler action decompose to space-time regions representing space-time correlates for quanta. The superposition of classical fields in Maxwellian sense is impossible.

2. How can one cope with this situation? The answer is based on simple observation: only the *effects* of the classical fields superpose. There is no need for the fields to superpose. Together with the notion of many-sheeted space-time this leads to elegant description of interference effects without any need to assume that linearization is a good approximation.

3. Topological quantization brings in also braiding and reconnection of magnetic flux tubes as basic operations for classical fields. These operations for flux tubes have also Maxwellian counterparts at the level of field lines. Braiding and reconnection are in a central role in TGD Universe and especially so in in TGD inspired theory of consciousness and quantum biology. The challenge is to build a coherent overall phenomenological view about the role of topologically quantized classical fields in biology and neuroscience. For instance, one can ask what is the precise formulation for the notion of conscious hologram and whether magnetic flux tubes could serve as correlates of entanglement (or at least negentropic entanglement suggested by the number theoretic vision and identified as a basic signature of living matter).

4. Topological quantization and the notion of magnetic body are especially important in TGD inspired model of EEG. The attempt to understand the findings of Persinger from the study of what is known as God helmet leads to a considerable progress in the understanding the possible role of topologically quantized classical fields in biology and neuro-science.

The replacement of superposition of fields with superposition of their effects allows to understand also how the many-sheeted space-time of TGD relates to the space-time of general relativity. GRT space-time seen as an effective space-time obtained by replacing Minkowskian regions of many-sheeted space-time with a region of Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrics of space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical form of Equivalence Principle realized in terms of Einstein's equation for the GRT limit in long length scales at least.

One can consider also other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with very large cosmological constant in Einstein-Maxwell theory. Also the gauge potentials of the standard model correspond classically to superpositions of induced gauge potentials over space-time sheets and standard model follows naturally at the QFT limit of TGD. TGD can be seen as a microscopic theory with space-time sheets carrying extremely simple "archetypal" field patterns and arranged in complex manner to many-sheeted space-time topologies whereas GRT and QFT represents long length scale limit with topological complexity replaced with the complexity of fields patterns.

For the induced gauge fields coupling constants are absorbed into the definition of gauge potentials so that coupling constant evolution does not make sense in TGD space-time. Coupling constant evolution characterizing quantum field theories makes in TGD framework sense as the dependence of various vertices on the size scale of causal diamond (CD). This discrete coupling constant evolution becomes at QFT and GRT limits continuous coupling constant evolution.

Chapter 3

Quantum Mind in TGD Universe

3.1 Introduction

The notion of Quantum Mind [J129] has become a respected branch of science during thirty years since Esalem conference. The basic vision is that quantum superposition, quantum entanglement and state function reduction (or some of its interpretational equivalents) are somehow highly relevant for the understanding of consciousness. Whether quantum entanglement or quantum jump or something else is identified as a correlate for consciousness depends on theorist.

The basic objections against Quantum Mind is that standard quantum physics - at least wave mechanics- leaves no room for quantum mind. Decoherence leading to a loss of entanglement is the basic enemy of quantum mind [J134]. Experimental work however suggests that macroscopic quantum coherence prevails in cell length scale: the findings about photosynthesis provide an example of this [I18]. There is also a growing evidence for macro-entanglement between different brains correlating closely with electromagnetic fields [J148, J88].

Of course, the idea that wave mechanics is enough to describe living matter and also the belief that quantum theory - as we know it - is something final are only beliefs. There are many other similar beliefs: the belief on reductionism coded to the statement that everything above intermediate boson length scale is understood in recent day physics; the belief that living matter differs from inanimate matter only because it is very complex; the belief that experienced time and the geometric time of physicist are one and the same thing; the pragmatic belief that the problems of quantum measurement theory can be forgotten by saying that quantum theory is just a calculational recipe;...

One could add one further not quite obvious item to the list. Dark matter and dark energy are one of the most notorious problems of recent day physics and it is just a belief that dark matter is nothing but some exotic X-ino having very weak interactions with visible matter and therefore does not have any relevance for the understanding of living matter.

The basic message of this article is that standard quantum theory is not enough if one wants to construct a theory of Quantum Mind. A profound re-evaluation of the belief system underlying the ontology of the recent day quantum physics is needed. My own proposal is following.

- The reductionistic dogma is replaced with fractality meaning infinite hierarchies both at the level of matter and mind. Consciousness is everywhere in a form of self hierarchy so that Quantum Mind involves more than brain. Biological bodies, cells, biomolecules, and even elementary particles correspond to the levels of the self hierarchy. Also higher collective levels are present.

- Topological field structures implied by the new fractal view about space-time - I speak about many-sheeeted space-time- are essential parts of this hierarchy. The notion of field (or magnetic) body is one aspect of the many-sheeted space-time and one could even say that magnetic body is the intentional agent using biological body as a motor instrument and sensory receptor. EEG and its various fractal analogs can be seen as communication and control tools of of the magnetic body in this conceptual framework. The explanation for the strange time delays associated the passive aspects of consciousness discovered by Libet [J87] and

the good hopes about understanding of fundamental biorhythms in terms of cyclotron frequencies of biologically important and Josephson frequencies assignable to cell membrane Josephson junctions [K37] provide support for this vision. This conforms with the proposals that spin and more generally angular momentum are central for understanding consciousness and living matter [J106, J148]. Biological evolution becomes evolution of consciousness and one cannot restrict Quantum Mind to microtubules, brain, or even biological body.

- Self hierarchy has two physical correlates: the hierarchy of p-adic length scales and the hierarchy of Planck constants: both hierarchies have experimental support. A number theoretical miracle occurs: the length scale range 10 nm-2.5 μm involves as many as four electron Compton scales assignable to Gaussian Mersennes. The effects of ELF em fields on vertebrate brain [J57] and the strange behavior of cell membrane and cell interior suggesting strongly quantal ionic currents [I39] provide physical support for both the hierarchy of Planck constants and p-adic length scale hypothesis.

- In TGD Universe zero energy ontology (ZEO) replaces the positive energy ontology of standard physics. The motivation comes both certain philosophical dilemma which is very frustrating for a theoretician, and the crossing symmetry of quantum field theory justifies ZEO. ZEO assigns new macroscopic time scale to each elementary particle. For electron and quarks these time scale coincide with fundamental biological time scales (for instance, the.1 second time scale predicted for electron corresponds to 10 Hz fundamental biorhythm). Elementary particle physics and biology are therefore strongly interrelated in ZEO.

- The identification of quantum jump as moment of consciousness and the notion of self emerge from a generalization of quantum measurement theory to a theory of consciousness. In this framework the experienced time identified as a sequence of quantum jumps and the geometric time of physicist cannot be identified [**?**]

  The fact that the contents of conscious experience is about a four-dimensional region of space-time implies a new interpretation of memories [K101]. Quantum jump replacing the entire geometric future and past with a new one: Libet's strange findings about active aspects of consciousness [J44] forcing in positive energy ontology the conclusion that free will is illusion provide support for this view. The challenge is to understand the arrow of time and why the contents of sensory experience is localized to a rather short time interval of about.1 second: this suggests a rather dramatic radical idea about how the arrow of subjective time emerges as a consequence of Negentropy Maximization Principle [K73] defining the basic variational principle of TGD inspired theory of consciousness.

- p-Adic physics extending reality to include also various p-adic levels is highly relevant for the understanding of the difference between living and inanimate matter. Negentropic entanglement is possible for p-adic variant of Shannon entropy making sense if entanglement probabilities are algebraic. One can say that this entanglement is possible in the intersection of real and p-adic worlds in which intentions could transform to actions by quantum jumps replacing p-adic space-time sheets with real ones (this makes sense only in ZEO!). Maybe this is the mathematical and information theoretical quintessence of life.

Before continuing a comment about the notion of consciousness is in order. This notion as also the notion of awareness implicitly codes for the assumption that consciousness is a property of a physical system- something mathematically analogous to mass or charge. The greek world "nous" and finnish word "tajunta" refer to activity rather than property and this meaning is more appropriate in TGD framework. Since it would sound rather artificial to talk about "TGD inspired theory of nous", I will will use the standard term in the sequel although it is misleading. It should be also emphasize that I represent only those aspects of a rather extensive work documented in the books at my homepage, which seem to be especially interesting just now. In the following representation I am forced to leave out all details. They can be found in the books about TGD inspired theory of consciousness at my homepage [K124, K20, K91, K51, K19, K63, K67, K114]. I have also summarized TGD inspired theory of consciousness in an issue of tgd [L12, L10, L8] but from different view point.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

3.2 What Are The Problems Of Quantum Mind Theories?

In the following I list briefly the basic problems of physics and quantum mind theories using a classification which is rather natural from the point of view of physics.

3.2.1 Some Philosophical Problems Of Quantum Physics

"Monism, dualism, or something else?" is the first basic question. Monism appears as two variants which are mirror images. Materialism has the problem that consciousness becomes something totally reducible to the state of material system so that free will must be an illusion if one believes in the deterministic laws of physics. This is in a sharp contrast to what we directly experience. In the idealistic framework one loses completely physics. The difficulty of dualism- pointed out very clearly by Chalmers [J59] - is that it is very difficult to achieve consistency with the basic laws of physics which do not allow free will. It seems that one must have something new allowing to achieve consistency of the determinism of field equations with (partially) free will.

"Reductionism or not?" is second key question. For me personally the realization that reductionism is a mere dogma was a painful process although it was from the beginning clear that TGD based view about space-time forces to challenge this belief. It was especially painful to take seriously the fact that even the reduction of chemical bond to wave mechanics alone is nothing but a belief since it it is not yet testable by performing numerical calculations. Gradually I became conscious about the many non-existing bridges of reductionism: the bridge from quarks and gluons to hadrons; the bridge from nucleons to nuclei; the bridge from atoms to molecules; the bridges from inorganic chemistry to organic chemistry to biochemistry: all these bridges are just figments of wishful thinking and implications of the reductionistic dogma rather than support for it. Also the widely accepted argument about living matter as something which is just complex fails to be distinguishable from a rhetoric trick.

"Determinism or not?" is the third question. Also here it took time to realize that the belief that free will is an illusion does not reflect the reality but our limited tools for describing it. The physicists of previous centuries did not have any conceptual and mathematical tools to describe free will without giving up the idea about laws of physics. Most importantly, they did not know anything about quantum non-determinism. Perhaps it is some kind of cognitive inertia that physicists have been ready to give up even the very notion of objective reality instead of accepting the fact that non-determinism is real and concluding that one should find an ontology consistent with both quantum non-determinism and Schrödinger equation.

- The notion of time is highly problematic.

  - The relationship between experienced time and the geometric time of physicist is poorly understood. Subjective time is irreversible and has only recent moment and past, geometric time is reversible and spans entire eternity. The assignment of experienced time with a 3-D wave front shifting in the direction of geometric time direction is in conflict with Lorentz symmetry and general coordinate invariance, which do not allow to identify a unique time coordinate as the subjective time. The natural basic object in general relativity is 4-dimensional space-time region, not time=constant snapshot.

  - In physics conceptual difficulties are encountered already in the phenomenological description of dissipation by adding to the reversible field equations phenomenological dissipation terms. Rather remarkably, the quantum mechanical formulas for the reaction rates in terms used to calculated dissipation coefficients involve integral over entire space-time so that quantum events have at least formally an infinite duration.

Finite duration is certainly necessary by Uncertainty Principle. Somehow quantum jump seems to involve entire geometric eternity: as if it would take place between two geometric eternities.

– There is also the problem of initial state. If the dynamics is deterministic and conservation laws hold, only a single solution of field equations is realized in classical physics and theoretical physics becomes useless waste of time since it cannot be tested. If quantum non-determinism is allowed, conservation laws still restrict the physical states to those having fixed net values. "What was the initial state at the moment of Big Bang?" is the question which cannot be answered in the framework of physics alone and one ends up doing metaphysics. Indeed, the recent crisis of M-theory- meant to be the final jewel in the crown of materialistic and reductionistic science- has led to the landscape problem, and many colleagues have given up the hope that ultimate theory could predict anything so that anthropic principle would be the only manner to connect theory with experiment.

3.2.2 Basic Philosophical Problems Of Quantum Mind Theories

At least the following problems could be seen as basic philosophical problems of quantum mind theories.

- What are the quantum correlates for consciousness? Entanglement has been proposed as a correlate of consciousness. For instance, in the orchestrated reduction approach of Hameroff and Penrose the period of consciousness ends with a state function reduction and quantum gravitation is believed to play a fundamental role in the understanding of consciousness. The believer in free will could see state function reduction or its generalization as as a natural quantum correlate for a moment of consciousness. The basic objection is that the randomness of state function reduction does not allow genuine goal directed free will. One could also argue that state function reduction generates entropy at least at the level of ensemble whereas intentional action should do just the opposite. Here one must however remember that entropy generation at the level of aspect need not mean entropy generation at the level of the member of ensemble.

- How the determinism of field equations and Schrödinger equation can be consistent with the non-determinism of the state function reduction? This question must be answered unless one is ready to give up the notion of objective reality completely or to believe in multiverse interpretation. These ways to circumvent the basic problem do not however leave much room for quantum consciousness theorizing. The closely related question about the relationship between experienced time and time of physicist has been already mentioned.

- What is the quantum correlate for the notion of self? The quantum notion of self should be a generalization of the notion of observer which in quantum measurement theory still remains a structureless outsider.

- What conscious information is? Can one give it a mathematical measure? Can one measure physically the amount of conscious information? Unfortunately the recent day physics can only provide measure for dis-information as Shannon entropy and the best that subsystem can achieve is no information at all if this picture is accepted.

- There is a bundle of questions about the quantum correlates of various aspects of conscious experience. For instance, what is the quantum correlate of mental image, and what are the quantum correlates of cognition, Boolean mind, sensory qualia, memory, and of emotions?

- An especially challenging question relates to the quantum correlate for the self referentiality of consciousness making possible reflective levels of consciousness. What it means physically to be conscious about what one is (or perhaps only "was") conscious? Jack Sarfatti was well aware about this problem and in his dualistic approach talked about feedback loop but still used a trick in which one divides various fields to matter-like and mind-like.

3.2.3 Basic Problems Of Quantum Biology And Quantum Neuroscience

The basic problems of quantum biology and neuroscience are closely related unless one is ready to believe that consciousness reduces to one particular function assignable to some particular part of brain ("consciousness module"). This kind of assignment can be imagined in engineerish neuroscience identifying brain as electric circuitry but does not have much sense in quantum mind approach.

The first list of first principle questions includes at least the following ones.

- What distinguishes between living and dead matter is certainly the fundamental question. In standard biology based on materialistic philosophy one tries to reduce the distinction to a list of properties which as such can be possessed by inanimate matter. Ability to replicate, to process information, to communicate, to form representations about the external world, the ability to self-organize to increasingly complex configurations, intentional behavior, ability to co-operate, ... could be properties of this kind. Up to self-organization the reduction seems plausible. It is easy to model self-organization (by say cell automatons) but it this dynamics is like the dynamics of traffic rules and neither classical nor quantum dynamics resembles it. Intentional behavior is impossible to understand in classical physics unless one claims that it is a mere illusion. This is the case also in quantum physics as we understand it since the randomness of the outcome of state function reduction seems to be in conflict with intentional behavior. Here one must however keep in mind that the individual subsystem performing a state function reduction could quite well experience it as an intentional action. In any case, standard view about state function reduction makes it difficult to co-operative behavior.

- What distinguishes between biochemistry and organic chemistry? For instance, how biomolecules can find themselves in the dense soup of biomolecules and how can one understand the effectiveness of bio-catalysts? One might think that these problems are well-understood since we have learned what happens in DNA replication, transcription, and translation and we know the complex reaction pathways. The dynamics involved is very much like the symbolic dynamics of society (one can predict the day of practicizing professional from knowing his profession but not from the knowledge of initial data of every possible elementary particle in his body). But what makes the soup of biomolecules a molecular society obeying a dynamics based on symbols? The description of biochemistry in terms of kinematics allows to construct complex reaction pathways based on the idea that each step of the reaction pathway requires a key which fits to a lock of a room containing a key to the lock to the next room [I43] but can one really deduce this kind of kinematics from standard quantum theory?

- Both biology and neuroscience characterizes subsystems of biological systems and brain in terms of functions they possess and one should also understand whether and how the quantum counterparts of functions emerge. The identification of various functions as time evolution of standard self-organization patterns is certainly a part of the answer. But what self-organization means? Conscious information is certainly the key notion but is the existing quantum theory able to characterize it?

- At the level of brain one of the key questions concerns EEG. Since EEG correlates strongly with the contents of consciousness it is difficult to believe that it is random side product of neural activity. What is then the real role of neuronal activity and EEG and its variants? Why EEG is needed? Signalling related to communication and control is what comes first in mind. But why this kind of signalling would be needed. Brain sends (receives) information but who receives (sends) it?

- How macroscopic quantum coherence is achieved allowing quantum super-positions in long time scales? How stable quantum entanglement is achieved? These are difficult problems if one wants to understand quantum mind without generalizing quantum theory itself. Planck constant is simply too small so that dissipation rates are too high and coherence times and lengths are too short. Should physicists adopt a humbler attitude and consider seriously the possibility that the existing physics is not enough and try to learn from biology instead of saying that living systems are just complex?

3.2.4 Could Anomalies Help?

Anomalies are the best way to end up with a discovery of something new. Of course, living matter as such is a gigantic anomaly but this does not help much. One should pick up the anomalies which are in sharp conflict with the existing physics and give a clear hint about what is wrong with our cherished assumptions.

- In quantum mind approach EEG should be a quantal phenomenon since it correlates with consciousness. From the basic formula $E = hf$ of quantum mechanics the energies of EEG photons are however ridiculously small as compared to the thermal energy at physiological temperatures. The strange quantal looking effects of ELF photons on vertebrate (why just vertebrate?!) brain at frequencies which correspond to cyclotron frequencies of biologically important ions such as Ca^{++} are however an experimental fact (see for instance [J57]). The effects of magnetic field patterns on brain studied by Persinger and collaborators represent also an example of this kind of strange effects [J132]. The strange findings about the behavior of cell membrane [I39] suggest that ionic currents do not dissipate much. The recently discovered burning of water when irradiated by radio wave photons [D11, D1] suggests that energetically these photons behave like photons of visible light. The recent findings about photosynthesis [I18] suggest quantum coherence in cellular length scale.

  Is standard quantum theory able to explain these findings? Should one challenge the belief that Planck constant is just a conversion factor between units which can be put equal one with a suitable choice of units? Could Planck constant have a spectrum of discrete values? This would explain the strange findings since by $E = hf$ relation low frequencies could correspond to high energies and dissipation rates -in the first guess inversely proportional to $\hbar$- could be very small. Large values of Planck constant would also increase the spatial and time scales of quantum coherence and might solve the basic technical problem of quantum consciousness theories.

- Also bio-photons [I34] correlate with the state of living system but are poorly understood in the existing theoretical framework.

- Libet's findings about strange time delays associated with the passive aspects of consciousness serve also as a hint. Our sensory data has age which is a fraction of second and corresponds to a photon wavelength $\lambda = cT$ to a length scale, which is of order of Earth size. As if sensory data would be communicated somewhere. Where?

- Cyclotron frequencies of biologically important ions in a magnetic field.2 Gauss (smaller than the nominal value of.5 Gauss of the Earth's magnetic field) are involved with the effects of ELF radiation on vertebrate brain. Also Schumann resonances are reported to have effects on brain. Are some kind of magnetic field structures involved? Earth's magnetic field and perhaps also the magnetic field patterns associated with biological system itself with $B = 2B_E/5$ for one important level in the hierarchy? As noticed in [J148], the cyclotron energy scale of electron in pT range is in EEG range and pT range indeed characterizes the magnetic field associated with brain activity. Do also these magnetic structures carry Cooper pairs of electrons?

- ADP-ATP machinery is the core of energy metabolism and its description involves the problematic notion of high energy phosphate bond [I10]. Does this notion really reduce to standard quantum theory?

- The chiral selection of biomolecules in living matter [I4, I73] means a large parity breaking. This is a complete mystery in standard model which predicts extremely small parity breaking effects. Therefore chiral selection is extremely valuable anomaly helping to guess what kind of new physics might be involved with living matter. Somehow it seems that the parity breaking effects which are large in electro-weak scale appear in immensely zoomed up scales (scaling factors of order 10^{10} would be involved)

3.3 Some Aspects Of Quantum TGD

In the following I summarize very briefly those basic notions of TGD which are especially relevant for TGD inspired consciousness theory and quantum biology. The representation will be practically formula free. The article series published in Prespace-time Journal [L14, L15, L18, L19, L16, L13, L17, L20] describes the mathematical theory behind TGD. The seven books about TGD [K135, K127, K24, K79, K83, K102, K115] provide a detailed summary about the recent state of TGD.

3.3.1 New Space-Time Concept

The physical motivation for TGD was what I have christened the energy problem of General Relativity. The notion of energy is ill-defined because the basic symmetries of empty space-time are lost in the presence of gravity. The way out is based on assumption that space-times are imbeddable as 4-surfaces to certain 8-dimensional space by replacing the points of 4-D empty Minkowski space with 4-D very small internal space. This space -call it S- is unique from the requirement that the theory has the symmetries of standard model: $S = CP_2$, where CP_2 is complex projective space with 4 real dimensions [L20], is the unique choice.

The replacement of the abstract manifold geometry of general relativity with the geometry of surfaces brings the shape of surface as seen from the perspective of 8-D space-time and this means additional degrees of freedom giving excellent hopes of realizing the dream of Einstein about geometrization of fundamental interactions.

The work with the generic solutions of the field equations assignable to almost any general coordinate invariant variational principle led soon to the realization that the space-time in this framework is much more richer than in general relativity.

1. Space-time decomposes into space-time sheets with finite size: this lead to the identification of physical objects that we perceive around us as space-time sheets. For instance, the outer boundary of the table is where that particular space-time sheet ends. Besides sheets also string like objects and elementary particle like objects appear so that TGD can be regarded also as a generalization of string models obtained by replacing strings with 3-D surfaces.

2. Elementary particles are identified as topological inhomogenuities glued to these space-time sheets. In this conceptual framework material structures and shapes are not due to some mysterious substance in slightly curved space-time but reduce to space-time topology just as energy- momentum currents reduce to space-time curvature in general relativity.

3. Also the view about classical fields changes. One can assign to each material system a field identity since electromagnetic and other fields decompose to topological field quanta. Examples are magnetic and electric flux tubes and flux sheets and topological light rays representing light propagating along tube like structure without dispersion and dissipation making em ideal tool for communications [K85]. One can speak about field body or magnetic body of the system.

Field body indeed becomes the key notion distinguishing TGD inspired model of quantum biology from competitors. The magnetic body inherits from the biological body an onion-like fractal structure. Each part of the magnetic body can be seen as an intentional agent using the corresponding part of the biological body as a motor instrument and sensory receptor. The size scale of the magnetic body is in general much larger than that of biological body. Cyclotron frequency identified as frequency of photons able to exist as oscillations at magnetic body gives an estimate for the size of the magnetic body corresponding to a particular magnetic field strength. For 10 Hz frequency the size scale is of order Earth size. In this framework a fractal generalization of EEG and its variants provides a communication and control tool for magnetic body. The findings of Libet about time delays associated with the passive aspects and meaning that sensory data is a fraction of second old [J87] could be understood as delays due to the finite velocity of light: it takes finite time for the signal to propagate from biological body to the magnetic body.

This obviously means a profound modification of the views about what we are. The identification with the biological body could be understood as an illusion: a child looking a movie

assimilates completely with the hero. There is a rich variety of illusions related to this identification of observer with the region of space from which the dominating contribution to consciousness comes from.

3.3.2 Zero Energy Ontology

In standard ontology of quantum physics physical states are assumed to have positive energy. In zero energy ontology physical states decompose to pairs of positive and negative energy states such that all net values of the conserved quantum numbers vanish. The interpretation of these states in ordinary ontology would be as transitions between initial and final states, physical events. By quantum classical correspondences zero energy states must have space-time and embedding space correlates.

1. Positive and negative energy parts reside at future and past light-like boundaries of causal diamond (CD) defined as intersection of future and past directed light-cones and visualizable as double cone. The analog of CD in cosmology is big bang followed by big crunch. CDs for a fractal hierarchy containing CDs within CDs. Disjoint CDs are possible and CDs can also intersect.

2. p-Adic length scale hypothesis [**?**]otivates the hypothesis that the temporal distances between the tips of the intersecting light-cones come as octaves $T = 2^n T_0$ of a fundamental time scale T_0 defined by CP_2 size R as $T_0 = R/c$. One prediction is that in the case of electron this time scale is.1 seconds defining the fundamental biorhythm. Also in the case u and d quarks the time scales correspond to biologically important time scales given by 10 ms for u quark and by and 2.5 ms for d quark [K12]. This means a direct coupling between microscopic and macroscopic scales.

Zero energy ontology conforms with the crossing symmetry of quantum field theories meaning that the final states of the quantum scattering event are effectively negative energy states. As long as one can restrict the consideration to either positive or negative energy part of the state ZEO is consistent with positive energy ontology. This is the case when the observer characterized by a particular CD studies the physics in the time scale of much larger CD containing observer's CD as a sub-CD. When the time scale sub-CD of the studied system is much shorter that the time scale of sub-CD characterizing the observer, the interpretation of states associated with sub-CD is in terms of quantum fluctuations.

ZEO solves the problem of initial state since in principle any zero energy state is obtained from any other state by a sequence of quantum jumps without breaking of conservation laws. The fact that energy is not conserved in general relativity based cosmologies can be also understood since each CD is characterized by its own conserved quantities. As a matter fact, one must be speak about average values of conserved quantities since one can have a quantum superposition of zero energy states with the quantum numbers of the positive energy part varying over some range.

For thermodynamical states this is indeed the case and this leads to the idea that quantum theory in ZEO can be regarded as a "complex square root" of thermodynamics obtained as a product of positive diagonal square root of density matrix and unitary S-matrix. M-matrix defines time-like entanglement coefficients between positive and negative energy parts of the zero energy state and replaces S-matrix as the fundamental observable. In standard quantum measurement theory this time-like entanglement would be reduced in quantum measurement and regenerated in the next quantum jump if one accepts Negentropy Maximization Principle (NMP) [K73] as the fundamental variational principle. Various M-matrices define the rows of the unitary U matrix characterizing the unitary process part of quantum jump. From the point of view of consciousness theory the importance of ZEO is that conservation laws in principle pose no restrictions for the new realities created in quantum jumps: free will is maximal.

3.3.3 The Hierarchy Of Planck Constants

The motivations for the hierarchy of Planck constants come from both astrophysics and biology. The biological motivations have been already discussed. In astrophysics the observation of Nottale [E1] that planetary orbits in solar system seem to correspond to Bohr orbits with a gigantic

gravitational Planck constant motivated the proposal that Planck constant might not be constant after all [K112, K87].

This led to the introduction of the quantization of Planck constant as an independent postulate. It has however turned that quantized Planck constant in effective sense could emerge from the basic structure of TGD alone. Canonical momentum densities and time derivatives of the embedding space coordinates are the field theory analogs of momenta and velocities in classical mechanics. The extreme non-linearity and vacuum degeneracy of Kähler action imply that the correspondence between canonical momentum densities and time derivatives of the embedding space coordinates is 1-to-many: for vacuum extremals themselves 1-to-infinite.

A convenient technical manner to treat the situation is to replace embedding space with its n-fold singular covering. Canonical momentum densities to which conserved quantities are proportional would be same at the sheets corresponding to different values of the time derivatives. At each sheet of the covering Planck constant is effectively $\hbar = n\hbar_0$. This splitting to multi-sheeted structure can be seen as a phase transition reducing the densities of various charges by factor $1/n$ and making it possible to have perturbative phase at each sheet (gauge coupling strengths are proportional to $1/\hbar$ and scaled down by $1/n$). The connection with fractional quantum Hall effect [D2] is almost obvious. At the more detailed level one finds that the spectrum of Planck constants would be given by $\hbar = n_a n_b \hbar_0$.

This has many profound implications, which are wellcome from Quantum Mind perspective.

1. Quantum coherence and quantum superposition become possible in arbitrary long length scales. One can speak about zoomed up variants of elementary particles and zoomed up sizes make it possible to satisfy the overlap condition for quantum length parameters used as a criterion for the presence of macroscopic quantum phases. In the case of quantum gravitation the length scale involved are astrophysical. This would conform with Penrose's intuition that quantum gravity is fundamental for the understanding of consciousness and also with the idea that consciousness cannot be localized to brain.

2. Photons with given frequency can in principle have arbitrarily high energies by $E = hf$ formula, and this would explain the strange anomalies associated with the interaction of ELF em fields with living matter [J57]. Quite generally the cyclotron frequencies which correspond to energies much below the thermal energy for ordinary value of Planck constant could correspond to energies above thermal threshold.

3. The value of Planck constant is a natural characterizer of the evolutionary level and biological evolution would mean a gradual increase of the largest Planck constant in the hierarchy characterizing given quantum system. Evolutionary leaps would have interpretation as phase transitions increasing the maximal value of Planck constant for evolving species. The space-time correlate would be the increase of both the number and the size of the sheets of the covering associated with the system so that its complexity would increase.

4. The phase transitions changing Planck constant change also the length of the magnetic flux tubes. The natural conjecture is that biomolecules form a kind of Indra's net connected by the flux tubes and $\hbar$ changing phase transitions are at the core of the quantum biodynamics. The contraction of the magnetic flux tube connecting distant biomolecules would force them near to each other making possible for the bio-catalysis to proceed. This mechanism could be central for DNA replication and other basic biological processes. Magnetic Indra's net could be also responsible for the coherence of gel phase and the phase transitions affecting flux tube lengths could induce the contractions and expansions of the intracellular gel phase. The reconnection of flux tubes would allow the restructuring of the signal pathways between biomolecules and other subsystems and would be also involved with ADP-ATP transformation inducing a transfer of negentropic entanglement [K45, K46] (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). The braiding of the magnetic flux tubes could make possible topological quantum computation like processes and analog of computer memory realized in terms of braiding patterns [K3].

5. p-Adic length scale hypothesis and hierarchy of Planck constants suggest entire hierarchy of zoomed up copies of standard model physics with range of weak interactions and color forces

scaling like $\hbar$. This is not conflict with the known physics for the simple reason that we know very little about dark matter (partly because we might be making misleading assumptions about its nature).

Dark matter would make possible the large parity breaking effects manifested as chiral selection of bio-molecules [I4]. What is required is that classical Z^0 and W fields responsible for parity breaking effects are present in cellular length scale. If the value of Planck constant is so large that weak scale is some biological length scale, weak fields are effectively massless below this scale and large parity breaking effects become possible.

For the solutions of field equations which are almost vacuum extremals Z^0 field is non-vanishing and proportional to electromagnetic field. The hypothesis that cell membrane corresponds to a space-time sheet near a vacuum extremal (this corresponds to criticality very natural if the cell membrane is to serve as an ideal sensory receptor) leads to a rather successful model for cell membrane as sensory receptor with lipids representing the pixels of sensory qualia chart. The surprising prediction is that bio-photons [I34] and bundles of EEG photons can be identified as different decay products of dark photons with energies of visible photons. Also the peak frequencies of sensitivity for photoreceptors are predicted correctly [K97].

3.3.4 P-Adic Physics And Number Theoretic Universality

p-Adic physics [K120, K79] has become gradually a key piece of TGD inspired biophysics. Basic quantitative predictions relate to p-adic length scale hypothesis and to the notion of number theoretic entropy. Basic ontological ideas are that life resides in the intersection of real and p-adic worlds and that p-adic space-time sheets serve as correlates for cognition.

p-Adic number fields

p-Adic number fields Q_p [A15] -one for each prime p- are analogous to reals in the sense that one can speak about p-adic continuum and that also p-adic numbers are obtained as completions of the field of rational numbers. One can say that rational numbers belong to the intersection of real and p-adic numbers. p-Adic number field Q_p allows also an infinite number of its algebraic extensions. Also transcendental extensions are possible. For reals the only extension is complex numbers.

p-Adic topology defining the notions of nearness and continuity differs dramatically from the real topology. An integer which is infinite as a real number can be completely well defined and finite as a p-adic number. In particular, powers p^n of prime p have p-adic norm (magnitude) equal to p^{-n} in Q_p so that at the limit of very large n real magnitude becomes infinite and p-adic magnitude vanishes.

p-Adic topology is rough since p-adic distance $d(x,y) = d(x-y)$ depends on the lowest pinary digit of $x-y$ only and is analogous to the distance between real points when approximated by taking into account only the lowest digit in the decimal expansion of $x-y$. A possible interpretation is in terms of a finite measurement resolution and resolution of sensory perception. p-Adic topology looks somewhat strange. For instance, p-adic spherical surface is not infinitely thin but has a finite thickness and p-adic surfaces possess no boundary in the topological sense. Ultra-metricity is the technical term characterizing the basic properties of p-adic topology and is coded by the inequality $d(x-y) \leq Min\{d(x), d(y)\}$. p-Adic topology brings in mind the decomposition of perceptive field to objects.

Physical and biological motivations for p-adic number fields

The physical motivations for p-adic physics came from the observation that p-adic thermodynamics -not for energy but infinitesimal scaling generator of so called super-conformal algebra [A4] acting as symmetries of quantum TGD [K127] - predicts elementary particle mass scales and also masses correctly under very general assumptions [K79]. In particular, the ratio of proton mass to Planck mass, the basic mystery number of physics, is predicted correctly. The basic assumption is that the preferred primes characterizing the p-adic number fields involved are near powers of two: $p \simeq 2^k$, k positive integer. Those nearest to power of two correspond to Mersenne primes $M_n = 2^n - 1$. One

can also consider complex primes known as Gaussian primes, in particular Gaussian Mersennes $M_{G,n} = (1+i)^n - 1$.

It turns out that Mersennes and Gaussian Mersennes are in a preferred position physically in TGD based world order. What is especially interesting is that the p-adic length scale range 10 nm-5 μm contains as many as four scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$ assignable to Gaussian Mersennes $M_k = (1+i)^k - 1$, $k = 151, 157, 163, 167$ [K97]. This number theoretical miracle supports the view that p-adic physics is especially important for the understanding of living matter.

p-Adic length scale hypothesis suggests the identification of metabolic energy currencies as energy quanta liberated as particle drops from space-time sheet to a larger one. These energy quanta correspond to increments of zero point kinetic energy. Metabolic energy currencies would be completely universal and exist already during the prebiotic era so that metabolic machinery would build up around this pre-existing structure. A simple (and also rough) model based on p-adic length scale hypothesis allows to estimate the increments of zero point kinetic energy. The quantum corresponding to about.5 eV has place in this hierarchy for which basic energies (those for which larger space-time sheet is very large) come as octaves of basic energy quantum [K12, K59]. These energy quanta do not have interpretation in terms of molecular transitions and there exist anomalous lines of radiation from interstellar space both in IR, visible, and UV region [K12].

Life as something in the intersection of real and p-adic worlds

The philosophical for p-adic numbers fields come from the question about the possible physical correlates of cognition [K81]. Cognition forms representations of the external world which have finite cognitive resolution and the decomposition of the perceptive field to objects is an essential element of these representations. Therefore p-adic space-time sheets could be seen as candidates of thought bubbles, the mind stuff of Descartes.

Rational numbers belong to the intersection of real and p-adic continua. An obvious generalization of this statement applies to real manifolds and their p-adic variants. When extensions of p-adic numbers are allowed, also some algebraic numbers can belong to the intersection of p-adic and real worlds. The notion of intersection of real and p-adic worlds has actually two meanings.

1. The intersection could consist of the rational and possibly some algebraic points in the intersection of real and p-adic partonic 2-surfaces at the ends of CD. This set is in general discrete. The interpretation could be as discrete cognitive representations.

2. The intersection could also have a more abstract meaning. For instance, the surfaces defined by rational functions with rational coefficients have a well-defined meaning in both real and p-adic context and could be interpreted as belonging to this intersection. There is strong temptation to assume that intentions are transformed to actions only in this intersection. One could say that life resides in the intersection of real and p-adic worlds in this abstract sense.

Additional support for the idea comes from the observation that Shannon entropy $S = -\sum p_n log(p_n)$ allows a p-adic generalization if the probabilities are rational numbers by replacing $log(p_n)$ with $-log(|p_n|_p)$, where $|x|_p$ is p-adic norm. Also algebraic numbers in some extension of p-adic numbers can be allowed. The unexpected property of the number theoretic Shannon entropy is that it can be negative and its unique minimum value as a function of the p-adic prime p it is always negative. Entropy transforms to information!

In the case of number theoretic entanglement entropy there is a natural interpretation for this. Number theoretic entanglement entropy would measure the information carried by the entanglement whereas ordinary entanglement entropy would characterize the uncertainty about the state of either entangled system. For instance, for p maximally entangled states both ordinary entanglement entropy and number theoretic entanglement negentropy are maximal with respect to R_p norm. Entanglement carries maximal information. The information would be about the relationship between the systems, a rule. Schrödinger cat would be dead enough to know that it is better to not open the bottle completely.

Negentropy Maximization Principle [K73] coding the basic rules of quantum measurement theory implies that negentropic entanglement can be stable against the effects of quantum jumps

unlike entropic entanglement. Therefore living matter could be distinguished from inanimate matter also by negentropic entanglement possible in the intersection of real and p-adic worlds. In consciousness theory negentropic entanglement could be seen as a correlate for the experience of understanding or any other positively colored experience, say love.

Negentropically entangled states are stable but binding energy and effective loss of relative translational degrees of freedom is not responsible for the stability. Therefore bound states are not in question. The distinction between negentropic and bound state entanglement could be compared to the difference between unhappy and happy marriage. The first one is a social jail but in the latter case both parties are free to leave but do not want to. The special characterics of negentropic entanglement raise the question whether the problematic notion of high energy phosphate bond citebbioHEP central for metabolism could be understood in terms of negentropic entanglement. This would also allow an information theoretic interpretation of metabolism since the transfer of metabolic energy would mean a transfer of negentropy [K45, K46].

3.4 Consciousness Theory As Extension Of Quantum Measurement Theory

TGD inspired theory of consciousness [K68] could be seen as a generalization of quantum measurement theory. The notions of quantum jump and self self are the key notions. Negentropy Maximization Principle (NMP) [K73] is the basic dynamical principle. NMP is mirror image for the second law of thermodynamics and states that the amount of conscious information gain in quantum jump is maximal. NMP reproduces standard quantum measurement theory for entropic entanglement and is in this case consistent with the second law since the non-determinism of state function reductions implies the increase of ensemble entropy.

3.4.1 Quantum Jumps As Moment Of Consciousness

The starting point of TGD inspired theory of consciousness was the identification of quantum jump as a moment of consciousness [K68].

1. Quantum jump has a complex anatomy which however simplifies in ZEO. Quantum jump involves unitary time evolution leading from a state resulting in state function reduction to a quantum superposition of states: one could speak of multiverse. This step is described by the counterpart of the unitary process of Penrose and is coded by a unitary matrix U in the state space formed by zero energy states. U is therefore not identifiable directly as S-matrix of quantum field theories but contains as its rows all possible M-matrices which are what particle physicist tries to measure in laboratory. State function reduction and state preparation can be assigned to the opposite light-like boundaries of CD.

   A good metaphor is Djinn in the bottle. In U-process bottle is opened and Djinn comes out and creates a quantum superposition of all possible worlds. The wish of the observer is fulfilled and leads to a state function reduction. Actually there is an entire cascade of state function reductions starting from the level of the entire universe which splits the entangleement subsystems already obtained in a step-wise manner to pairs un-entangled sub-systems. The splitting for a given sub-system occurs only if it is consisent with NMP.

   For the ordinary definition of entanglement entropy the process would lead to a completely unentangled situation. If the number theoretic entanglement entropy making sense for rational (and even algebraic) entanglement probabilities is allowed, the process stops unless the reduction of entanglement reduces the entanglement entropy. Therefore the number theoretic entanglement possible in the intersection of real and p-adic worlds can be stable and living systems are able to preserve their coherence.

2. Since the reduction cascade proceeds from top to bottom, one can speak about fractal formed by quantum jumps within quantum jumps. One cannot assign to the steps of this sequence any duration of geometric time. One can however associate to it an experienced duration and it is very tempting to assume that the experienced duration increases as one climbs up in the self hierarchy.

3. Quantum jump replaces the quantum superposition of classical histories (space-time surfaces, classical worlds) with a new one whereas ordinary state function reduction would do this for time=constant snapshot of Schrödinger evolution. Quantum jump does not spoil the determinism of classical dynamics or of Dirac equation since it occurs entirely outside space-time and Hilbert space. In quantum jump both the geometric future and past (defined only within measurement resolution) are replaced with new ones. The mysterious finding of Libet [J44] that intentional action is preceded by neural activity can be interpreted in this framework without giving up the notion of free will. This raises a fascinating question about time scales in which the geometric past can be affected in quantum jump. Also memories stored in the geometric past can be affected in quantum jumps and the fact that memories are highly unstable suggest that the time scale is measured in years.

   It must be added that the notion of classical determinism in its standard form fails due to the special properties of Kähler action (vacuum degeneracy mathematically analogous to a gauge degeneracy but physically analogous to 4-D spin glass degeneracy). This failure provides a space-time correlate for the non-determinism of the quantum jump sequence.

3.4.2 The Notion Of Self

The notion of self can be seen as a generalization of the notion of observer. The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of zero energy ontology (ZEO) only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant. The parts of zero energy states at second boundary of CD change even the position of opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self. Hence act of free will means change of the arrow of psychological time at some level of hierarchy of CDs.

This allows to understand the relationship between subject and geometric time and how the arrow of and flow of psychological time emerges. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

There exists an infinite hierarchy of number theoretical entropies [K73] making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that Negentropy Maximization principle (NMP) favors generation of negentropic entanglement, which need not be bound state entanglement in standard sense.

In the case of negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) a more natural interpretation is that expansion of consciousness rather than loss of it is experienced as self entangles with second system negentropically. Only entropic entanglement would lead to a loss of consciousness. Second condition would be that self is stable against splitting to unentangled subsystems. This criterion is satisfied if self corresponds to a system for which the entanglement between its subsystems is negentropic.

This leads to the vision that negentropic entanglement defines kind of Akashic records, kind of library storing conscious or potentially conscious information. According to the recent

view, Akashic records could define self as opposed to self model defined in terms of memory representations relying on bits. Consistency with standard quantum measurement theory [K73] requires that density matrix for negentropic entanglement is proportional to unit matrix associated to unitary entanglement matrix associated with quantum computation. "Akashic records" would define self and would be consciously experienced.

Self experiences its sub-selves as mental images and even we would represent mental images of some higher collective self. Everything would be conscious but consciousness could be only lost. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.

By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J148] could be understood as a sharing of mental images between brain hemispheres which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.

At the level of 8-dimensional embedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. As already noticed, .1 second time scale defining the duration of moment for sensory experience corresponds to that of electron's CD which suggests that Cooper pairs of electrons are essential for the sensory qualia.

3.4.3 How Experienced Time And The Geometric Time Of Physicist Relate To Each Other?

The relationship between experienced time and time of physicist is one of the basic puzzles of modern physics. In the proposed framework they are certainly two different things and the challenge is to understand why the correlation between them is so strong that it has led to their identification. One can imagine several alternative views explaining this correlation [K133, **?**, K10] and it is better to keep mind open.

Basic questions

The flow of subjective time corresponds to quantum jump sequences for sub-selves of self having interpretation as mental images. If mind is completely empty of mental images subjectively experienced time ceases to exists. This leaves however several questions to be answered.

1. Why the contents of conscious of self comes from a finite space-time region looks like an easy question. If the contents of consciousness for sub-selves representing mental images is localized to the sub-CDs with indeed have defined temporal position inside CD assigned with the self the contents of consciousness is indeed from a finite space-time volume. This implies a new view about memory. There is no need to store again and again memories to the "brain now" since the communications with the geometric past by negative energy signals and also time-like negentropic quantum entanglement allow the sharing of the mental images of the geometric past.

2. There are also more difficult questions. Subjective time has arrow and has only the recent and possibly also past. The subjective past could in principle reduce to subjective now if conscious experience is about 4-D space-time region so that memories would be always geometric memories. How these properties of subjective time are transferred to apparent properties of geometric time? How the arrow of geometric time is induced? How it is possible that the locus for the contents of conscious experience shifts or at least seems to be shifted quantum jump by quantum jump to the direction of geometric future? Why the sensory mental images are located in a narrow time interval of about .1 seconds in the usual states

of consciousness (not that sensory memories are possible: scent memories and phantom pain in leg could be seen as examples of vivid sensory memory)?

The recent view about arrow of time

The basic intuitive idea about the explanation for the arrow of psychological time has been the same from the beginning - diffusion inside light-cone - but its detailed realization has required understanding of what quantum TGD really is. The replacement of ordinary positive energy ontology with zero energy ontology (ZEO) has played a crucial role in this development. The TGD based vision about how the arrow of geometric time is by no means fully developed and final. It however seems that the most essential aspects have been understood now.

1. What seems clear now is the decisive role of ZEO and hierarchy of CDs, and the fact that the quantum arrow of geometric time is coded into the structure of zero energy states to a high extent. The still questionable but attractively simple hypothesis is that U matrix two basis with opposite quantum arrows of geometric time: is this assumption really consistent with what we know about the arrow of time? If this is the case, the question is how the relatively well-defined quantum arrow of geometric time implies the experienced arrow of geometric time. Should one assume the arrow of geometric time separately as a basic property of the state function reduction cascade or more economically- does it follow from the arrow of time for zero energy states or only correlate with it?

2. The state function reductions can occur both boundaries of CD. If the reduction occurs at given boundary is immediately followed by a reduction at the opposite boundary, the arrow of time alternates: this does not conform with intuitive expectations: for instance, this would imply that there are two selves assignable to the opposite boundaries!

   Zero energy states are however de-localized in the moduli space CDs (size of CD plus discrete subgroup of Lorentz group defining boosts of CD leaving second tip invariant). One has quantum superposition of CDs with difference scales but with fixed upper or lower boundary belonging to the same light-cone boundary after state function reduction. In standard quantum measurement theory the repetition of state function reduction does not change the state but now it would give rise to the experienced flow of time. Zeno effect indeed requires that state function reductions can occur repeatedly at the same boundary. In these reductions the wave function in moduli degrees of freedom of CD changes. This implies "dispersion" in the moduli space of CDs experienced as flow of time with definite arrow. This view lead to a precise definition of self as sequence of quantum jumps to the reducing to the same boundary of CD.

3. This approach codes also the arrow of time at the space-time level: the average space-time sheet in quantum superposition increases in size as the average position of the "upper boundaries" of CDs drift towards future state function reduction by state function reduction.

4. In principle the arrow of time can temporarily change but it would seem that this can occur in very special circumstances and probably takes place in living matter routinely. Phase conjugate laser beam is a non-biological example about reversal of the arrow of time. The act of volition would correspond to the first state function reduction to the opposite boundary so that the reversal of time arrow at some level of the hierarchy of selves would take place in the act of volition.

3.4.4 Quantum Correlates For Various Aspects Of Conscious Experience

The identification of quantum correlates of cognition and intentionality, of sensory qualia, Boolean mind, and of emotions [K50] represents one challenge for Quantum Mind theories. As already explained, p-adic physics, the vision about life as something residing in the intersection of real and p-adic worlds, and the notion of number theoretic entropy provide a plausible starting point when one tries to say something about the geometric and quantum correlates of cognition and intentionality. Zero energy ontology makes possible the transitions transforming p-adic zero energy states to their real counterparts and having interpretation in terms of intentional action.

1. Quantum numbers characterize quantum states. Therefore the increments ΔQ of quantum numbers for a subsystem should characterize quantum jumps and it is attractive to assign classify fundamental qualia in terms of quantum number increments. "The increments of quantum numbers for a sub-system representing self" looks innocent but what it really means is surprisingly difficult to make precise. The following attempt relies on ZEO.

   (a) For the positive energy part of state located at "lower" boundary of CD self - subsystem S - and environment E are un-entangled. At the "upper" boundary there is entanglement between S and E, and it should be able to assign qualia as quantum number increments to this entanglement.

   (b) Consider increments of color quantum numbers identified in terms of visual colors as an example. In the positive energy state color quantum numbers for an unentangled subsystem S vanish by color confinement. In negative energy state they can be non-vanishing for S but vanish for $S \otimes E$. The experienced qualia for S are determined as quantum averages of color quantum numbers in the entangled state and expressible in terms of the sub-system density matrix. One can indeed assign to the zero energy state increments ΔQ_{ZEO} of color quantum numbers as difference of color quantum numbers for S at "upper" and "lower" boundaries of C. These increments characterize zero energy state rather than quantum jump.

   (c) In state function reduction the entanglement at upper boundary is reduced if the entanglement is entropic whereas negentropic entanglement can be stable. Quale is experienced sensorily as long as quantum jumps preserve negentropic entanglement. When entanglement is eventually reduced, the experience can be only a memory about the experienced quale. The increments ΔQ of color quantum numbers in quantum jump can be identified as $\Delta Q = \Delta Q_{ZEO}$. Hence this notion is indeed well-defined.

   (d) This interpretation allows to assign to the quantum jump also space-time evolution changing the quantum numbers in the same manner as they change in quantum jump. This is what quantum-classical correspondence indeed requires.

   One application is the identification of basic colors in terms of color quantum number increments of quantum states [K50]. This identification makes sense if one accepts the fractal hierarchy of QCD like dynamics allowed by p-adic length scale hierarchy and by the hierarchy of Planck constants. The original concrete model was provided by the capacitor model of sensory qualia in which a large number of particles which same quantum numbers flows to a subsystem during quantum jump inducing the analog of di-electric breakdown (note the analogy with nerve pulse). Bose-Einstein condensation provides one possible realization. In this case one can say that the quantum numbers of the particle in question represent the basic quale which is amplified.

   The above picture forces to modify this view by replacing a color capacitor with a fixed size with that of a variable size corresponding to the size of system S and $S \otimes E$: the second plate of capacitor either in S or environment. The flow of charges associated with the transition generating quale still makes sense and generates strong color polarization in the scale $S \otimes E$. In the model the increase of the size of the color capacitor means a formation of flux tubes between the sensory receptor and environment such that net color is non-vanishing only for these flux tubes. In state function reduction reducing entanglement the flux tubes are split and S become color neutral but can represent a memory about the quale as negentropic color neutral entanglement in the scale of S: some sub-system of S can now experience the color quale. This suggests a holographic memory in which quale eventually is represented in very small scale in terms of negentropic entanglement.

   The argument involves assumption about color confinement. In the case of qualia assignable to electromagnetic charges, spin, etc... similar assumption makes sense. Even in case of momentum and angular momentum this assumption makes sense and means that subsystem in the state of experiencing momentum or angular momentum increment as quale is in a real accelerated motion in the scale of CD. As a matter fact, the vanishing of quantum numbers of S in absence of entanglement might not be necessary for the interpretation.

2. One could also speak about Boolean qualia and fermions provide possible correlates for them. The 2^N many-fermion states of fermionic Fock space for N fermionic qubits define a basis of Boolean algebra. The entangled pairs of fermionic states associated with the positive and negative energy parts of zero energy states define quantal Boolean functions as sums over entangled pairs of many fermion states. Negentropic entanglement could define a representation of a rule with entangled pairs representing various instances of the rule. Time-like entanglement would define a representation for a "law of physics" and M-matrices would be fundamental representations of this kind. The increments of the fermionic quantum numbers could define Boolean qualia and one can imagine Boolean capacitor mechanism allowing to amplify a given Boolean statement.

One should be also able to say something about the quantum correlates of emotions. Here the notion of negentropic entanglement might be the key concept.

1. Emotions have a quale like character. For instance, psychological pleasure and pain resemble their physiological counterparts- and quite generally there is a tendency to assign to emotions the attributes of sensory experience. It would be attractive to assign this positive/negative dichotomy to the increase/reduction of entanglement negentropy. Emotion would represent Boolean bit as the sign of negentropy increment. The destruction of generation of negentropic entanglement would therefore be the core element of emotional quale. The character of entanglement involved would determine whether the emotion corresponds to pleasure or pain, joy or sorrow, pride or shame.

   In the case of physiological pain or pleasure it is easy to imagine that the cause of pain destroys/creates negentropic entanglement. Pain and pleasure at this level relates directly to what happens to metabolism. This is easy to understand if the basic function of energy metabolism is to transfer negentropic entanglement. For higher level emotions the negentropy reduction or increase could be produced artificially to give an emotional content for something regarded as important.

2. Very often emotions are characterized by good-bad/right-wrong dichotomy characterizable by single binary digit. Perhaps emotions provide a representation of a high level summary about large amounts information, a kind of Boolean function of very many qubits. The function of neural transmitters can be often interpreted in terms of reward or punishment. Information and emotions seem to be closely related: peptides are often regarded as both information molecules and molecules of emotion [J55]. This can be understood if the function of information molecule is to induce emotional response representing the information.

3. Comparison to a standard -be it moral rule, expected or desired behavior, or something else- is rather often an essential aspect of emotion. Comparison can in principle be represented as a quantal Boolean function involving the standard (say moral rule) represented in terms of negentropic entanglement. If the Boolean instance compared with the rule corresponds to an instance allowed by the rule, positive emotion results. Otherwise the emotion is negatively colored. One might also think that there is expectation for the result of comparison. If the outcome differs from expected- which corresponds to a flip of bit, positive or negative emotion results but could do so as a secondary representation. The above argument suggests that the outcome of comparison does not represent the emotion as such but there is a neural circuitry encoding the outcome to reward or punishment.

3.4.5 Self Referentiality Of Conscious Experience

Self referentiality of consciousness is one of its most mysterious looking aspects. In a loose formulation one could say that system is able to be conscious what it *is* conscious of. This formulation however leads to an infinite hierarchy of reflective levels and therefore to a paradox. One can however milden the formulation by saying that self-referential system is able to be conscious about what it *was* conscious of (with respect to subjective time of course!)

In this formulation quantum classical correspondence gives hopes about the understanding of self-referentiality. Quantum classical correspondence means in TGD framework that not only quantum states but also quantum jump sequences have space-time correlates. The failure of

classical determinism for Kähler action in standard sense of the word is responsible for this and relates directly to the basic properties distinguishing TGD Universe from that of standard model. This allows to imagine that quantum jump leading from a superposition of space-time surfaces to a new one also gives rise to a representation of the conscious experiences which preceded the last quantum jump at the level of space-time geometry. Reductio ad absurdum would transform to evolution of consciousness able to add to the existing hierarchy a new reflective level in each quantum jump.

I have proposed several correlates for the self-referentiality of consciousness. Many-sheeted space-time would provide the physical representation (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book).

Many-sheeted space-time and self-referentiality

The fractal hiearchy of magnetic flux tubes giving rise to braids, which in turn make possible topological quantum computation would be a rather realization of this representation, A possible concrete physical realization of self-referentiality is suggested by DNA as quantum computer model [K3]. One assumes that DNA nucleotides and lipids are connected by magnetic flux tubes. Since the lipid layer of the cell membrane is 2-dimensional liquid crystal, the lipids are in continual hydrodynamical motion and this means in time direction entanglement of the orbits. The events in nearby environment and also nerve pulses affect this flow. This braiding in time direction defines a topological quantum computation. This motion entangles also the flux tubes connecting the lipids to DNA nucleotides so that when the topological quantum computation halts it becomes stored into memory as space-like entanglement. In TGD framework also the time-like braiding provides a space-time representation of the quantum computation which also gives to a conscious experience at some level of the hierarchy.

Infinite primes and self-referentiality

The hierarchy of infinite primes (and of integers and rationals) [K118] was the first mathematical notion stimulated by TGD inspired theory of consciousness. The construction recipe is equivalent with a repeated second quantization of a super-symmetric arithmetic quantum field theory with bosons and fermions labeled by primes such that the many-particle states of previous level become the elementary particles of new level. At a given level there are free many particles states plus counterparts of many particle states. There is strong structural analogy with polynomial primes. For polynomials with rational coefficients free many-particle states would correspond to products of first order polynomials and bound states to irreducible polynomials with non-rational roots.

The hierarchy of space-time sheets with many particle states of space-time sheet becoming elementary particles at the next level of hierarchy. For instance, the description of proton as an elementary fermion would be in a well defined sense exact in TGD Universe. Also the hierarchy of n: th order logics are possible correlates for this hierarchy.

This construction leads also to a number theoretic generalization of space-time point since a given real number has infinitely rich number theoretical structure not visible at the level of the real norm of the number a due to the existence of real units expressible in terms of ratios of infinite integers. This number theoretical anatomy suggest a kind of number theoretical Brahman=Atman identity stating that the set consisting of number theoretic variants of single point of the embedding space (equivalent in real sense) is able to represent the points of WCW or maybe even quantum states assignable to causal diamond. One could also speak about algebraic holography.

The correspondence between the quantum states defined by WCW spinor fields and wave functions in the infinite-dimensional discrete space of hyper-octonionic units can be made more concrete [K118]. These wave functions must transforming irreducibly under discrete subgroup SU(3) of octonion automorpisms transforming ordinary hyper-octonionic prime to a new hyper-octonionic prime. SU(3) has interpretation as color group. One can assign standard model quantum numbers to these wave functions and prime property in principle fixes the spectrum of possible quantum states- in particular the spectrum of masses. Therefore the extremely esoteric looking notion of infinite prime might turn out to be very practical calculational tool.

Quantum Mathematics and self referentiality of consciousness

In Quantum Mathematics numbers are replaced with Hilbert spaces and the dimension of Hilbert space - in appropriately. generalized sense - characterizes the number.

1. This suggests a generalization of calculus for Hilbert spaces. Mathematical objects which are defined for numbers in various number fields become well defined when these numbers are replaced with Hilbert spaces. One can speak of the Hilbert space analogs of algebraic numbers, transcendentals, p-adic numbers and their extensions. Anything having as a building brick rationals, algebraic numbers, real or p-adic numbers or finite fields generalizes. Even the notions like matrix group, algebras, and ring generalize. Also the notion of manifold generalizes as well as the notion of calculus.

2. The Hilbert space in associated with the element of number field characterizes its number theoretic anatomy and therefore could be a correlate of cognition. The crucial step in the generalization of this process to the level of the Hibert space representing points. Points of Hilbert spaces can be replaced with Hilbert spaces and process can be repeated ad infinitum. This suggests that the self-referentiality at the deepest level corresponds to this fractal view about space-time based on assignment of quantum dynamics to numbers. Also a connection with the hierarchy of n: th order logics. A close relationship to infinite primes would not be surprising since in both cases one an infinite hierarchy of processes analogous to second quantization is involved. A natural question is whether many-sheeted space-time provides a dynamical representation in terms of space-time sheets for the number theoretic anatomy so that kind of Brahman=Atman identity or algebraic holography would hold true. This correspondence could be see as a cognitive representation of external world and one could also see the external world as symbolic representation of the world of cognition.

3. A connection with generalized Feynman diagrams and hierarchy of Planck constants is suggestive and the idea was originally inspired by the observation that the two vertices of generalized Feynman diagrams identifiable as generalizations of the basic stringy 3-vertex for closed strings and basic 3-vertex for Feynman diagrams correspond naturally to direct sum and tensor product in turn having natural correspondence with + and $\times$ of the usual arithmetics. This correspondence motivates the introduction of co-operations of direct sum and tensor product meaning that quantum dynamics is brought into the game through these vertices. This suggests that Quantum Mathematics is actually Quantum dynamics in which generalized Feynman diagrams define sequences of arithmetic or even more general algebraic operations.

   If so, the basic structures of Quantum Mechanics (QM) might reduce to fundamental mathematical and metamathematical structures, and that one even consider the possibility that Quantum Mechanics reduces to Quantum Mathematics with mathematician included or expressing it in a concise manner: QM=QM!

The fractal character of the Quantum Mathematics is what makes it a good candidate for understanding the self-referentiality of consciousness. The replacement of the Hilbert space with the direct sum of Hilbert spaces defined by its points would be the basic step and could be repeated endlessly corresponding to a hierarchy of statements about statements or hierarchy of n^{th} order logics. The construction of infinite primes leads to a similar structure.

What about the step leading to a deeper level in hierarchy and involving the replacement of each point of Hilbert space with Hilbert space characterizing it number theoretically? What could it correspond at the level of states?

1. Suppose that state function reduction selects one point for each Hilbert space $x_n \times p^n$. The key step is to replace this direct sum of points of these Hilbert spaces with direct sum of Hilbert spaces defined by the points of these Hilbert spaces. After this one would select point from this very big Hilbert space. Could this point be in some sense the image of the Hilbert space state at previous level? Should one imbed Hilbert space $x_n \times p^n$ isometrically to the Hilbert space defined by the preferred state $x_n \times p^n$ so that one would have a realization of holography: part would represent the whole at the new level. It seems that there is a

canonical manner to achieve this. The interpretation as the analog of second quantization suggest the identification of the embedding map as the identification of the many particle states of previous level as single particle states of the new level.

2. Could topological condensation be the counterpart of this process in many-sheeted space-time of TGD? The states of previous level would be assigned to the space-time sheets topologically condensed to a larger space-time sheet representing the new level and the many-particle states of previous level would be the elementary particles of the new level.

3. If this vision is correct, second quantization performed by theoreticians would not be a mere theoretical operation but a fundamental physical process necessary for cognition! The above proposed unitary embedding would imbed the states of the previous level as single particle states to the new level. It would seem that the process of second quantization, which is indeed very much like self-reference, is completely independent from state function reduction and unitary process. This picture would conform with the fact that in TGD Universe the theory about the Universe is the Universe and mathematician is in the quantum jumps between different solutions of this theory.

Chapter 4

Matter, Mind, Quantum

4.1 Introduction

Topological Geometro-Dynamics (TGD) is a unified theory of fundamental interactions. TGD involves a quite far-reaching generalization of the space-time concept and, apart from the notion of quantum jump, reduces quantum theory to infinite-dimensional geometry. Quantum TGD requires the introduction of several new mathematical tools and concepts, in particular p-adic numbers.

TGD based theory of consciousness has developed gradually during the last fifteen years side by side with TGD based quantum measurement theory. For a summary of TGD and p-adic aspects of TGD see [K135, K79].

The emergence of the notions of zero energy ontology (ZEO) and hierarchy of Planck constants together with the increased understanding of the special features of number theoretical universality have led to a considerable deepening of the understanding during last half decade. The basic concepts and ideas of TGD based theory of consciousness as I would have formulated them around 2005 are introduced first. After that the ideas that have appeared during the period 2005-2014 are briefly summarized.

4.1.1 Basic Ideas Of TGD Inspired Theory Of Consciousness

In the following basic ideas of TGD inspired theory of consciousness as they were formulate for about half decade ago are summarized.

Identification of quantum states as quantum histories and the notion of quantum jump

General coordinate invariance (GCI) forces the identification of the quantum states as quantum histories rather than time=constant snapshots of single quantum history. Quantum history can be regarded as a classical spinor field in the world of all classical worlds (WCW) so that rather abstract concept is in question. This identification has several important consequences.

1. The possibility to regard unitary process followed by state function collapse as a quantum jump between quantum histories solves the basic paradox posed by the determinism of the Schrödinger equation contra non-determinism of the state function collapse.

2. A radical reconsideration of the concepts of psychological time and observer becomes necessary and forces a profound generalization of the standard views about time.

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphoral sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies". Quantum jump would have actually a complex anatomy corresponding to unitary process U, state function reduction and state preparation at least.

Negentropy Maximization Principle (NMP) codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to maximal reduction of entanglement entropy at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

The notion of self

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that negentropy maximization principle (NMP) favors generation of negentropic entanglement, which need not be bound state entanglement in standard sense. This leads to the vision that negentropic entanglement defines kind of Akashic records, kind of library storing potentially conscious information becoming conscious in interaction free measurement. Akashic records could define self model as opposed to self. Consistency with standard quantum measurement theory requires that density matrix for negentropic entanglement is projector and thus equal to a unit matrix associated to a unitary entanglement matrix characterizing quantum computation.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-subselves) increases.

The sub-selves of two unentangled selves can entangle although selves remain unentangled. This is possible by the modification of the subsystem concept forced by the p-adic length scale cutoff. The entanglement of sub-selves means fusion and sharing of mental images providing a universal telepathy like quantum communication mechanism and presumably making possible both molecular, cellular, and human societies.

Generalization of quantum measurement theory to a theory of consciousness

One must reformulate quantum measurement theory. The hypothesis that each quantum jump involves localization in the so called zero modes having interpretation as classical variables characterizing the observable geometric properties of the space-time surface, and thus of external macroscopic observer, together with an additional condition guaranteing that the density matrix characterizing the entanglement between quantum fluctuating degrees of freedom and zero modes is diagonal, implies standard quantum measurement theory. Needless to emphasize, the reduction of the standard quantum measurement theory to fundamental quantum physics is a triumph of TGD approach.

This is however not the whole story. The standard quantum measurement is followed by a cascade self measurements inside self, which reduces entanglement between some subsystem and its complement in quantum fluctuating degrees of freedom: again a measurement of the density matrix is in question. This cascade is equivalent with the process of state preparation which is

a phenomenological notion in the standard quantum measurement theory. The dynamics of self measurement is governed by Negentropy Maximization Principle (NMP), which specifies which subsystems are subject to quantum measurement in a given quantum jump. NMP can be regarded as a basic law for the dynamics of quantum jumps and states that the information content of the conscious experience is maximized. In p-adic context NMP dictates the dynamics of cognition.

Zero energy ontology changes considerably the interpretation of the unitary process and state function reduction. In zero energy ontology quantum states are replaced with zero energy states defined as superpositions of pairs of positive and negative energy states identified as counterparts of initial and final states of a physical event such as particle scattering. Zero energy ontology is ideal from the point of view of consciousness and intentionality. Everything can be in principle be created from vacuum so that several frustrating paradoxes plaguing positive energy ontology disappear. Also the quantum jumps between p-adic and real quantum states suggested to correspond to intentional action are mathematically sensible in zero energy ontology.

The matrix defining entanglement between positive and negative - christened as M-matrix- is the counterpart of the ordinary S-matrix but need not be unitary. It can be identified as a "complex square root" of density matrix expressible as a product of positive square root of diagonal density matrix and unitary S-matrix. Quantum TGD can be seen as defining a "square root" of thermodynamics, which thus becomes an essential part of quantum theory.

U-matrix is defined between zero energy states and cannnot therefore be equated with the S-matrix used to describe particle scattering events. Unitary conditions however imply that U-matrix can be seen as a collection of M-matrices labelled by zero energy states so that the knowledge of U-matrix implies the knowledge of M-matrices. A natural guess is that U is directly related to consciousness and the description of intentional actions. For positive energy ontology state function reduction would serve as a state preparation for the next quantum jump. In zero energy ontology state function preparation and reduction can be assigned to the positive and negative energy states defining the initial and final states of the physical event. The reduction of the time-like entanglement during the state function reduction process corresponds to the measurement of the scattering matrix. In the case of negentropic time-like entanglement the reduction process is not random anymore and the resulting dynamics is analogous to that of cellular automata providing a natural description of the dynamics of self-organization in living matter.

Zero energy ontology leads to a precise identification of the subsystem at space-time level. General coordinate invariance in 4-D sense means that 3-surfaces related by 4-D diffeomorphisms are physically equivalent. It is conventient to perform a gauge fixing by a introducing a natural choice for the representatives of the equivalence classes formed by diffeo-related 3-surfaces.

1. Light-like 3-surfaces identified as surfaces at which the Minkowskian signature of the induced space-time metric changes to Euclidian one - wormhole contacts- are excellent candidates in this respect. The intersections of these surfaces with the light-like boundaries of CD defined 2-D partonic surfaces. Also the 3-D space-like ends of space-time sheets at the light-like boundaries of CDs are very natural candidates for preferred 3-surfaces.

2. The condition that the choices are mutually consistent implies effective 2-dimensionality. The intersections of these surfaces defining partonic 2-surface plus the distribution of 4-D tangent spaces at its points define the basic dynamical objects with 4-D general coordinate invariance reduced to 2-dimensional one. This effective 2-dimensionality was clear from the very beginning but is only apparent since also the data about 4-D tangent space distribution is necessary to characterize the geometry of WCW and quantum states. The descriptions in terms of 3-D light-like or space-like surfaces and even in terms of 4-D surfaces are equivalent but redundant descriptions. This has far reaching implications for the concrete mathematical realization of number theoretic universality [K73].

As far as consciousness is considered effective 2-dimensionality means holography and could relate to the fact that at least our visual experience is at least effectively 2-dimensional.

4.1.2 P-Adic Numbers And Consciousness

p-Adic number fields R_p (one number field for each prime $p = 2, 3, 5, ...$) are analogous to real numbers but differ from them in that p-adic numbers are not well-ordered. p-Adic numbers play

an absolutely essential role in the formulation of quantum TGD and of TGD inspired theory of consciousness. The inherent non-determinism of p-adic differential equations motivates the identification of the p-adic space-time sheets as cognitive representations of ordinary matter with p-adic non-determinism identified as non-determinism of imagination. Mind-matter duality is realized at the level of space-time geometry and mind stuff corresponds to p-adic regions of space-time. TGD Universe performs self mimicry in all length scales. Besides p-adic nondeterminism there is nondeterminism of Kähler action: these two nondeterminisms allow to represent some aspects of quantum jump sequences, that is contents of consciousness of selves, at space-time level cognitively and symbolically (language). This in turn makes possible self referentiality of consciousness: it is possible to become conscious about being conscious about...

Negentropy Maximization Principle and the notion of self

U-process is followed by a cascade of state function reductions. Negentropy Maximization Principle (NMP) states that in a given quantum state the most quantum entangled subsystem-complement pair can perform the quantum jump. More precisely: the reduction of the entanglement entropy in the quantum jump is as large as possible. This selects the pair in question and in case of ordinary entanglement entropy leads the selected pair to a product state. The interpretation of the reduction of the entanglement entropy as conscious information gain makes sense. The sequence of state function reductions decomposes at first step the entire system to two parts in such a way that the reduction entanglement entropy is maximal. This process repeats itself for subsystems. If the subsystem in question cannot be divided into a pair of entangled free system the process stops since energy conservation does not allow it to occur (binding energy).

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

p-Adic physics as correlate for cognition leads to the notion of negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness. Consistency with standard quantum measurement theory forces negentropic entanglement to correspond to density matrix proportional to unit matrix. Unitary entanglement typical for quantum computing systems gives rise to unitary entanglement.

The first state function reduction - wake-up of self- at given boundary of CD is a hierarchical cascade proceeding from long to short scales. The reduction process can stop also if the self in question allows only decompositions to pairs systems with negentropic entanglement. This does not require that that the system forms a bound state for any pair of subsystems so that the systems decomposing it can be free (no binding energy). This defines a new kind of bound state not describable as a jail defined by the bottom of a potential well. Subsystems are free but remain correlated by negentropic entanglement.

The ordinary state function reductions imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of an iteration like process leading to the asympotic self-organization patterns. One could regard dissipation as a Darwinian selector as in standard theories of self-organization. NMP thus predicts that self organization and hence presumably also fractalization can occur inside selves. NMP would favor the generation of negentropic entanglement. This notion is highly attractive since it could allow to understand how quantum self.organization generates larger coherent structures. Note that state function reduction for ne-

gentropic entanglement is highly deterministic since the number of degenerate states with same negative entanglement entropy is expected to be small. This could allow to understand how living matter is able to develop almost deterministic cellular automaton like behaviors. In ZEO this self-organization is for 4-D spatio-temporal patterns since 3-surfaces are pairs of space-like surfaces at the boundaries of CD and maxima of Kähler function are selected in the process. These temporal patterns correspond to behaviors and functions in living matter.

Positive entanglement negentropy is possible in the intersection of real and p-adic worls

Positive entanglement negentropy is possible in the intersection of real and p-adic worlds and is stable against NMP. Giving up the original ad hoc interpretation as a counterpart for bound state entanglement leads to a beautiful vision about the role of negentropic entanglement in cognition and functioning of living matter.

1. The first form of NMP was rather naive. There was no idea about the anatomy of quantum jump and NMP only stated that the allowed quantum jumps are such that the information gain of conscious experience measured by the reduction of entanglement entropy resulting in the reduction of entanglement between the subsystem of system and its complement is maximal. Later it became clear that quantum jump has a complex anatomy consisting of unitary process U followed by the TGD counterpart of state function reduction serving as a state preparation for the next quantum jump.

2. The attempts to formulate NMP in p-adic physics led to the realization that one can distinguish between three kinds of information measures.

   (a) In real physics the negative of the entanglement entropy defined by the standard Shannon formula defines a natural information measure, which is always non-positive.

   (b) In p-adic physics one can generalize this information measure to p-adic valued information measure by replacing the logarithms of p-adic valued probabilities with the p-based logarithms $log_p(|P|_p)$ which are integer valued and can be interpreted as p-adic numbers. This p-adic valued entanglement entropy can be mapped to a non-negative real number by the so called canonical identification $x = \sum_n x_n p^n \to \sum_n x_n p^{-n}$. In both cases a non-positive information measure results.

   (c) When the entanglement probabilities are rational numbers or at most finitely algebraically extended rational numbers one can still define logarithms of probabilities as p-based logarithms $log_p(|P|_p)$ and interpret the entropy as a rational or algebraic number. In this case the entropy can be however negative and positive definite information measure is possible. Irrespective of number field one can in this case define entanglement entropy as a maximum of number theoretic entropies S_p over the set of primes. The first proposal was that the algebraic entanglement corresponds to bound state entanglement turned out to be wrong.

3. At some stage the importance of the almost trivial fact that bound state entanglement must be kinematically stable against NMP became obvious. One can imagine that the state function reduction proceeds step by step by reducing the state to two parts in such a way that the reduction of entanglement entropy is maximal.

   (a) If a resulting subsystem corresponds to a bound state having no decomposition to free subsystems the process stops for this subsystem. The natural assumption is that subsystems lose their consciousness when U process leads to bound state entanglement whereas bound state itself can be conscious.

   (b) If the entanglement is negentropic (and thus rational or algebraic) a more natural interpretation consistent with the teaching of spiritual practices is that subsystems experience a fusion to a larger conscious entity. The negentropic entanglement between

free states is stabilized by NMP and negentropically entangled states need not reside at the bottom of potential well forbidding the reduction of entanglement. This makes possible new kinds of correlated states for which binding energy can be negative. Bound state entanglement would be like the jail of organized marriage and negentropic entanglement like a love marriage in which companions are free to leave but do not what it. The existence of this kind of negentropic entanglement is especially interesting in living matter, where metabolism (high energy phosphate bond in particular) and the stability of DNA and other highly charged polymers is poorly understood physically: negentropic entanglement could be responsible for stabilization making possible the transfer of metabolic energy [**?**].

4. For the negentropic entanglement the outcome of the state function reduction ceases to be random as it is for the standard definition of entanglement entropy. Note however that U process as a creative act yielding superposition of possibibilities from which state function reduction selects leaves means non-determinism. This has far reaching consequences. Ordinary state function reductions for an ensemble of systems lead to a generation of thermodynamical entropy and this explains the second law of thermodynamics. In the case of negentropic entanglement situation changes and the predicted breaking of second law of thermodynamics provides a new view to understand self-organization [K103]. and living matter could be identified as something residing in the intersection of real and p-adic worlds where p-adic intentions can be transformed to real actions.

5. One particular choice involved with state function reduction process could be the choice between generic entanglement and number theoretic entanglement possible only in the intersection of p-adic and real WCWs. If the choice is the generic entanglement, system ends up either to an unentangled state with maximal conscious freedom or to a bound state with a loss of consciousness. If the choice is algebraic entanglement, system ends up to negentropic entanglement and correlations with external world and experiences an expansion of consciousness. Maybe ethical choices are basically choices between these two options. Also positive emotions like love and experience of understanding could directly relate to various aspects of the negentropic entanglement.

4.1.3 TGD Inspired New Physics And Consciousness

ZEO, number theoretical universality, and hierarchy of Planck constants represent ideas, which have developed strongly during last half decade and have led to a considerable refinement of the overall view about consciousness and inspired also a vision about life as something residing in the intersection of real and p-adic worlds [K73].

TGD based space-time concept and the existence of macroscopic quantum phases

TGD implies a radical generalization of the space-time concept in all length and time scales. The concept of many-sheeted space-time leads to fresh proposals for how biosystems manage to be macroscopic quantum systems. Examples of these mechanisms are so called wormhole superconductivity, electronic high T_c super-conductivity, neutrino super-conductivity, ionic and a mechanism for generating coherent light and gravitons [K21, K22, K22, K85]. The notion of many-sheeted ionic equilibrium summarizes the basic vision about quantum control and coordination according to which the space-time sheets associated with the superconducting magnetic flux tube structures control ordinary biomatter at the atomic space-time sheets.

The so called massless exremals (MEs), which can be regarded as "topological light rays", are carriers of especially important exmple of macroscopic quantum states. The lightlike boundaries of MEs act as quantum holograms and carry representations of the superconformal and supersymplectic algebras. These states have gigantic almost-degeneracies, and are genuine quantum gravitational states (state functionals in the configuration space of 3-surfaces, "the world of classical worlds") and thus correspond to higher abstraction level than ordinary quantum states. MEs can control the supercurrents at superconducting magnetic flux tube structures by magnetic interactions, act as Josephson junctions, and induce magnetic quantum phase transitions. Therefore

the quantum holograms associated with MEs are excellent candidates for quantum correlates of higher level consciousness.

Quantum criticality

The systems possessing self correspond to macroscopic quantum phases. In standard physics context the existence of the required macroscopic quantum phases is not at all obvious whereas the new physics implied by TGD predicts their existence. The point is that the Universe according to TGD is a quantum critical system. Quantum criticality is mathematically very similar to thermodynamical criticality and implies long range quantum correlations in all length scales. This in turn implies the existence of macroscopic quantum phases with large value of effective Planck constant and able to have negentropic entanglement - say entanglement characterized by a unitary matrix. TGD Universe is also quantum spin glass with state degeneracy broken only by the classical gravitational energy of the space-time sheets having same induced Kähler field.

This degeneracy basically makes it possible to have quantum coherence over time periods longer than CP_2 time of order 10^{-39} seconds characterizing the duration of single quantum jump so that biosystems can act as quantum computers in macroscopic time scales.

The understanding of quantum criticality has developed dramatically after writing the above lines.

1. The physical interpretation for the hierarchy of Planck constants would be in terms of a hierarchy of quantum criticalities concretizing the vision about quantum criticality of TGD Universe. TGD Universe would be like a hill at the top of a hill at .... The larger the Planck constant the larger the size scale of the hill. Criticality involves crucially the notion of conformal gauge symmetry. The conformal symmetries correspond to sub-algebra of the full algebra isomorphic to it acting as gauge symmetries and with conformal weights coming as n-multiples of those for the full symmetry algebra. $h_{eff} = n \times h$ would label the levels of the hierarchy. This hierarchy would correspond directly to the hierarchy of measurement resolutions and to hierarchy of hyperfinite factors of type II_1 (HFFs). Also now one obtains infinite hierarchies of symmetry breakings and the identification with the hierarchies of inclusions of HFFs is compelling. Hence various hierarchies reflect the same underlying phenomenon.

2. The phase transitions reducing criticality would take place spontaneously unlike opposite phase transitions. This vision is especially powerful in biology, where homeostasis could be seen as mechanisms preventing the reduction of criticality but at expense of metabolic energy. The basic goal of living system would be staying at criticality. Eastern philosophies would formulate this fight for staying at criticality using the notions of ego and Karmic cycle. In the phase transition increasing $h_{eff} = n \times h$ part of gauge degrees of freedom assignable to a sub-algebra of the full super-symplectic algebra are transformed to physical ones and this implies better measurement resolution. The new HFF contains the previous one as sub-factor. Evolution understood as increase of h_{eff} forced by Negentropy Maximization Principle as also interpretation improvement of measurement/cognitive resolution.

Dark matter hierarchy

Basic objection against quantum theories of consciousness and biology relate to the smallness of Planck constant making difficult to imagine macroscopic quantum coherence in the scales of living matter. Zero energy ontology partially resolves the problem by assigning to elementary particles macroscopic length and time scales. For instance, the time scale assignable to the CD of electron is.1 seconds defining the fundamental bio-rhythm.

The anomalies related to the interaction of ELF em fields on living matter and Nottale's observation that planetary orbits correspond approximately to Bohr orbits with a gigantic value of Planck constant led to the hypothesis that Planck constant has a discrete spectrum and can have arbitrarily large values [K112, K37]. The identification of dark matter as phases having large value of Planck constant [K112, K44, K36] led to a vigorous evolution of ideas. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle

TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [K44].

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [K44]. The value of the Planck constant characterizes partially the given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. The most general spectrum comes in rational multiples of standard value of Planck constant which corresponds to the unit of rationals. For CDs the scaling of Planck constants means scaling of the size of CD. This could explain why the rational multiples of the fundamental frequency are so special for music experience.

All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory. These observations motivate the tentative identification of the macroscopic quantum phases in terms of dark matter and also of dark energy with gigantic "gravitational" Planck constant.

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by the following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

At least dark matter could be a key player in quantum biology.

1. Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the CD. For electron this time scale is.1 second, the fundamental bio-rhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $\hbar/\hbar_0$ multiples of this time scale.

2. The predicted breaking of second law of thermodynamics chacterizing living matter - if identified as something in the intersection of real and p-adic words - would be always below the time scale of CD considered but would take place in arbitrary long time scales at appropriate levels of the hierarchy. The scaling up of $\hbar$ also scales up the time scale for the breaking of the second law.

3. The hypothesis that magnetic body is the carrier of dark matter in large $\hbar$ phase has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of [J70] [K37]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K65, K37]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K37].

If one accepts the hierarchy of Planck constants [K44]. it might be un-necessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of

dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle could correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday.

There are thus two definitions of self. The first definition introduces self as a notion separate from quantum jump. Second definition reduces the notion of self to a fractal hierarchy of quantum jumps. The equivalence between two definitions of the notion of self will be proposed.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

4.2 What Are The Problems Of Quantum Mind Theories?

In the following I list briefly the basic problems of physics and quantum mind theories using a classification which is rather natural from the point of view of physics.

4.2.1 Some Philosophical Problems Of Quantum Physics

"Monism, dualism, or something else?" is the first basic question. Monism appears as two variants which are mirror images. Materialism has the problem that consciousness becomes something totally reducible to the state of material system so that free will must be an illusion if one believes in the deterministic laws of physics. This is in a sharp contrast to what we directly experience. In the idealistic framework one loses completely physics. The difficulty of dualism- pointed out very clearly by Chalmers [J59] - is that it is very difficult to achieve consistency with the basic laws of physics which do not allow free will. It seems that one must have something new allowing to achieve consistency of the determinism of field equations with (partially) free will.

"Reductionism or not?" is second key question. For me personally the realization that reductionism is a mere dogma was a painful process although it was from the beginning clear that TGD based view about space-time forces to challenge this belief. It was especially painful to take seriously the fact that even the reduction of chemical bond to wave mechanics alone is nothing but a belief since it it is not yet testable by performing numerical calculations. Gradually I became conscious about the many non-existing bridges of reductionism: the bridge from quarks and gluons to hadrons; the bridge from nucleons to nuclei; the bridge from atoms to molecules; the bridges from inorganic chemistry to organic chemistry to biochemistry: all these bridges are just figments of wishful thinking and implications of the reductionistic dogma rather than support for it. Also the widely accepted argument about living matter as something which is just complex fails to be distinguishable from a rhetoric trick.

"Determinism or not?" is the third question. Also here it took time to realize that the belief that free will is an illusion does not reflect the reality but our limited tools for describing it. The physicists of previous centuries did not have any conceptual and mathematical tools to describe free will without giving up the idea about laws of physics. Most importantly, they did not know anything about quantum non-determinism. Perhaps it is some kind of cognitive inertia that physicists have been ready to give up even the very notion of objective reality instead of accepting the fact that non-determinism is real and concluding that one should find an ontology consistent with both quantum non-determinism and Schrödinger equation.

- The notion of time is highly problematic.

- The relationship between experienced time and the geometric time of physicist is poorly understood. Subjective time is irreversible and has only recent moment and past, geometric time is reversible and spans entire eternity. The assignment of experienced time with a 3-D wave front shifting in the direction of geometric time direction is in conflict with Lorentz symmetry and general coordinate invariance, which do not allow to identify a unique time coordinate as the subjective time. The natural basic object in general relativity is 4-dimensional space-time region, not time=constant snapshot.

- In physics conceptual difficulties are encountered already in the phenomenological description of dissipation by adding to the reversible field equations phenomenological dissipation terms. Rather remarkably, the quantum mechanical formulas for the reaction rates in terms used to calculated dissipation coefficients involve integral over entire space-time so that quantum events have at least formally an infinite duration. Finite duration is certainly necessary by Uncertainty Principle. Somehow quantum jump seems to involve entire geometric eternity: as if it would take place between two geometric eternities.

- There is also the problem of initial state. If the dynamics is deterministic and conservation laws hold, only a single solution of field equations is realized in classical physics and theoretical physics becomes useless waste of time since it cannot be tested. If quantum non-determinism is allowed, conservation laws still restrict the physical states to those having fixed net values. "What was the initial state at the moment of Big Bang?" is the question which cannot be answered in the framework of physics alone and one ends up doing metaphysics. Indeed, the recent crisis of M-theory- meant to be the final jewel in the crown of materialistic and reductionistic science- has led to the landscape problem, and many colleagues have given up the hope that ultimate theory could predict anything so that anthropic principle would be the only manner to connect theory with experiment.

4.2.2 Basic Philosophical Problems Of Quantum Mind Theories

At least the following problems could be seen as basic philosophical problems of quantum mind theories.

- What are the quantum correlates for consciousness? Entanglement has been proposed as a correlate of consciousness. For instance, in the orchestrated reduction approach of Hameroff and Penrose the period of consciousness ends with a state function reduction and quantum gravitation is believed to play a fundamental role in the understanding of consciousness. The believer in free will could see state function reduction or its generalization as as a natural quantum correlate for a moment of consciousness. The basic objection is that the randomness of state function reduction does not allow genuine goal directed free will. One could also argue that state function reduction generates entropy at least at the level of ensemble whereas intentional action should do just the opposite. Here one must however remember that entropy generation at the level of aspect need not mean entropy generation at the level of the member of ensemble.

- How the determinism of field equations and Schrödinger equation can be consistent with the non-determinism of the state function reduction? This question must be answered unless one is ready to give up the notion of objective reality completely or to believe in multiverse interpretation. These ways to circumvent the basic problem do not however leave much room for quantum consciousness theorizing. The closely related question about the relationship between experienced time and time of physicist has been already mentioned.

- What is the quantum correlate for the notion of self? The quantum notion of self should be a generalization of the notion of observer which in quantum measurement theory still remains a structureless outsider.

- What conscious information is? Can one give it a mathematical measure? Can one measure physically the amount of conscious information? Unfortunately the recent day physics can

only provide measure for dis-information as Shannon entropy and the best that subsystem can achieve is no information at all if this picture is accepted.

- There is a bundle of questions about the quantum correlates of various aspects of conscious experience. For instance, what is the quantum correlate of mental image, and what are the quantum correlates of cognition, Boolean mind, sensory qualia, memory, and of emotions?

- An especially challenging question relates to the quantum correlate for the self referentiality of consciousness making possible reflective levels of consciousness. What it means physically to be conscious about what one is (or perhaps only "was") conscious? Jack Sarfatti was well aware about this problem and in his dualistic approach talked about feedback loop but still used a trick in which one divides various fields to matter-like and mind-like.

4.2.3 Basic Problems Of Quantum Biology And Quantum Neuroscience

The basic problems of quantum biology and neuroscience are closely related unless one is ready to believe that consciousness reduces to one particular function assignable to some particular part of brain ("consciousness module"). This kind of assignment can be imagined in engineerish neuroscience identifying brain as electric circuitry but does not have much sense in quantum mind approach.

The first list of first principle questions includes at least the following ones.

- What distinguishes between living and dead matter is certainly the fundamental question. In standard biology based on materialistic philosophy one tries to reduce the distinction to a list of properties which as such can be possessed by inanimate matter. Ability to replicate, to process information, to communicate, to form representations about the external world, the ability to self-organize to increasingly complex configurations, intentional behavior, ability to co-operate, ... could be properties of this kind. Up to self-organization the reduction seems plausible. It is easy to model self-organization (by say cell automatons) but it this dynamics is like the dynamics of traffic rules and neither classical nor quantum dynamics resembles it. Intentional behavior is impossible to understand in classical physics unless one claims that it is a mere illusion. This is the case also in quantum physics as we understand it since the randomness of the outcome of state function reduction seems to be in conflict with intentional behavior. Here one must however keep in mind that the individual subsystem performing a state function reduction could quite well experience it as an intentional action. In any case, standard view about state function reduction makes it difficult to co-operative behavior.

- What distinguishes between biochemistry and organic chemistry? For instance, how biomolecules can find themselves in the dense soup of biomolecules and how can one understand the effectiveness of bio-catalysts? One might think that these problems are well-understood since we have learned what happens in DNA replication, transcription, and translation and we know the complex reaction pathways. The dynamics involved is very much like the symbolic dynamics of society (one can predict the day of practicizing professional from knowing his profession but not from the knowledge of initial data of every possible elementary particle in his body). But what makes the soup of biomolecules a molecular society obeying a dynamics based on symbols? The description of biochemistry in terms of kinematics allows to construct complex reaction pathways based on the idea that each step of the reaction pathway requires a key which fits to a lock of a room containing a key to the lock to the next room [I43] but can one really deduce this kind of kinematics from standard quantum theory?

- Both biology and neuroscience characterizes subsystems of biological systems and brain in terms of functions they possess and one should also understand whether and how the quantum counterparts of functions emerge. The identification of various functions as time evolution of standard self-organization patterns is certainly a part of the answer. But what self-organization means? Conscious information is certainly the key notion but is the existing quantum theory able to characterize it?

- At the level of brain one of the key questions concerns EEG. Since EEG correlates strongly with the contents of consciousness it is difficult to believe that it is random side product of neural activity. What is then the real role of neuronal activity and EEG and its variants? Why EEG is needed? Signalling related to communication and control is what comes first in mind. But why this kind of signalling would be needed. Brain sends (receives) information but who receives (sends) it?

- How macroscopic quantum coherence is achieved allowing quantum super-positions in long time scales? How stable quantum entanglement is achieved? These are difficult problems if one wants to understand quantum mind without generalizing quantum theory itself. Planck constant is simply too small so that dissipation rates are too high and coherence times and lengths are too short. Should physicists adopt a humbler attitude and consider seriously the possibility that the existing physics is not enough and try to learn from biology instead of saying that living systems are just complex?

4.2.4 Could Anomalies Help?

Anomalies are the best way to end up with a discovery of something new. Of course, living matter as such is a gigantic anomaly but this does not help much. One should pick up the anomalies which are in sharp conflict with the existing physics and give a clear hint about what is wrong with our cherished assumptions.

- In quantum mind approach EEG should be a quantal phenomenon since it correlates with consciousness. From the basic formula $E = hf$ of quantum mechanics the energies of EEG photons are however ridiculously small as compared to the thermal energy at physiological temperatures. The strange quantal looking effects of ELF photons on vertebrate (why just vertebrate?!) brain at frequencies which correspond to cyclotron frequencies of biologically important ions such as Ca^{++} are however an experimental fact (see for instance [J57]). The effects of magnetic field patterns on brain studied by Persinger and collaborators represent also an example of this kind of strange effects [J132]. The strange findings about the behavior of cell membrane [I39] suggest that ionic currents do not dissipate much. The recently discovered burning of water when irradiated by radio wave photons [D11, D1] suggests that energetically these photons behave like photons of visible light. The recent findings about photosynthesis [I18] suggest quantum coherence in cellular length scale.

  Is standard quantum theory able to explain these findings? Should one challenge the belief that Planck constant is just a conversion factor between units which can be put equal one with a suitable choice of units? Could Planck constant have a spectrum of discrete values? This would explain the strange findings since by $E = hf$ relation low frequencies could correspond to high energies and dissipation rates -in the first guess inversely proportional to $\hbar$- could be very small. Large values of Planck constant would also increase the spatial and time scales of quantum coherence and might solve the basic technical problem of quantum consciousness theories.

- Also bio-photons [I34] correlate with the state of living system but are poorly understood in the existing theoretical framework.

- Libet's findings about strange time delays associated with the passive aspects of consciousness serve also as a hint. Our sensory data has age which is a fraction of second and corresponds to a photon wavelength $\lambda = cT$ to a length scale, which is of order of Earth size. As if sensory data would be communicated somewhere. Where?

- Cyclotron frequencies of biologically important ions in a magnetic field.2 Gauss (smaller than the nominal value of.5 Gauss of the Earth's magnetic field) are involved with the effects of ELF radiation on vertebrate brain. Also Schumann resonances are reported to have effects on brain. Are some kind of magnetic field structures involved? Earth's magnetic field and perhaps also the magnetic field patterns associated with biological system itself with $B = 2B_E/5$ for one important level in the hierarchy? As noticed in [J148], the cyclotron energy scale of electron in pT range is in EEG range and pT range indeed characterizes the magnetic

field associated with brain activity. Do also these magnetic structures carry Cooper pairs of electrons?

- ADP-ATP machinery is the core of energy metabolism and its description involves the problematic notion of high energy phosphate bond [I10]. Does this notion really reduce to standard quantum theory?

- The chiral selection of biomolecules in living matter [I4, I73] means a large parity breaking. This is a complete mystery in standard model which predicts extremely small parity breaking effects. Therefore chiral selection is extremely valuable anomaly helping to guess what kind of new physics might be involved with living matter. Somehow it seems that the parity breaking effects which are large in electro-weak scale appear in immensely zoomed up scales (scaling factors of order 10^{10} would be involved)

4.3 Some Aspects Of Quantum TGD

In the following I summarize very briefly those basic notions of TGD which are especially relevant for TGD inspired consciousness theory and quantum biology. The representation will be practically formula free. The article series published in Prespace-time Journal [L14, L15, L18, L19, L16, L13, L17, L20] describes the mathematical theory behind TGD. The seven books about TGD [K135, K127, K24, K79, K83, K102, K115] provide a detailed summary about the recent state of TGD.

4.3.1 New Space-Time Concept

The physical motivation for TGD was what I have christened the energy problem of General Relativity. The notion of energy is ill-defined because the basic symmetries of empty space-time are lost in the presence of gravity. The way out is based on assumption that space-times are imbeddable as 4-surfaces to certain 8-dimensional space by replacing the points of 4-D empty Minkowski space with 4-D very small internal space. This space -call it S- is unique from the requirement that the theory has the symmetries of standard model: $S = CP_2$, where CP_2 is complex projective space with 4 real dimensions [L20], is the unique choice.

The replacement of the abstract manifold geometry of general relativity with the geometry of surfaces brings the shape of surface as seen from the perspective of 8-D space-time and this means additional degrees of freedom giving excellent hopes of realizing the dream of Einstein about geometrization of fundamental interactions.

The work with the generic solutions of the field equations assignable to almost any general coordinate invariant variational principle led soon to the realization that the space-time in this framework is much more richer than in general relativity.

1. Space-time decomposes into space-time sheets with finite size: this lead to the identification of physical objects that we perceive around us as space-time sheets. For instance, the outer boundary of the table is where that particular space-time sheet ends. Besides sheets also string like objects and elementary particle like objects appear so that TGD can be regarded also as a generalization of string models obtained by replacing strings with 3-D surfaces.

2. Elementary particles are identified as topological inhomogenuities glued to these space-time sheets. In this conceptual framework material structures and shapes are not due to some mysterious substance in slightly curved space-time but reduce to space-time topology just as energy- momentum currents reduce to space-time curvature in general relativity.

3. Also the view about classical fields changes. One can assign to each material system a field identity since electromagnetic and other fields decompose to topological field quanta. Examples are magnetic and electric flux tubes and flux sheets and topological light rays representing light propagating along tube like structure without dispersion and dissipation making em ideal tool for communications [K85]. One can speak about field body or magnetic body of the system.

Field body indeed becomes the key notion distinguishing TGD inspired model of quantum biology from competitors. The magnetic body inherits from the biological body an onion-like fractal structure. Each part of the magnetic body can be seen as an intentional agent using the corresponding part of the biological body as a motor instrument and sensory receptor. The size scale of the magnetic body is in general much larger than that of biological body. Cyclotron frequency identified as frequency of photons able to exist as oscillations at magnetic body gives an estimate for the size of the magnetic body corresponding to a particular magnetic field strength. For 10 Hz frequency the size scale is of order Earth size. In this framework a fractal generalization of EEG and its variants provides a communication and control tool for magnetic body. The findings of Libet about time delays associated with the passive aspects and meaning that sensory data is a fraction of second old [J87] could be understood as delays due to the finite velocity of light: it takes finite time for the signal to propagate from biological body to the magnetic body.

This obviously means a profound modification of the views about what we are. The identification with the biological body could be understood as an illusion: a child looking a movie assimilates completely with the hero. There is a rich variety of illusions related to this identification of observer with the region of space from which the dominating contribution to consciousness comes from.

4.3.2 Zero Energy Ontology

In standard ontology of quantum physics physical states are assumed to have positive energy. In zero energy ontology physical states decompose to pairs of positive and negative energy states such that all net values of the conserved quantum numbers vanish. The interpretation of these states in ordinary ontology would be as transitions between initial and final states, physical events. By quantum classical correspondences zero energy states must have space-time and embedding space correlates.

1. Positive and negative energy parts reside at future and past light-like boundaries of causal diamond (CD) defined as intersection of future and past directed light-cones and visualizable as double cone. The analog of CD in cosmology is big bang followed by big crunch. CDs for a fractal hierarchy containing CDs within CDs. Disjoint CDs are possible and CDs can also intersect.

2. p-Adic length scale hypothesis [**?**]otivates the hypothesis that the temporal distances between the tips of the intersecting light-cones come as octaves $T = 2^n T_0$ of a fundamental time scale T_0 defined by CP_2 size R as $T_0 = R/c$. One prediction is that in the case of electron this time scale is.1 seconds defining the fundamental biorhythm. Also in the case u and d quarks the time scales correspond to biologically important time scales given by 10 ms for u quark and by and 2.5 ms for d quark [K12]. This means a direct coupling between microscopic and macroscopic scales.

Zero energy ontology conforms with the crossing symmetry of quantum field theories meaning that the final states of the quantum scattering event are effectively negative energy states. As long as one can restrict the consideration to either positive or negative energy part of the state ZEO is consistent with positive energy ontology. This is the case when the observer characterized by a particular CD studies the physics in the time scale of much larger CD containing observer's CD as a sub-CD. When the time scale sub-CD of the studied system is much shorter that the time scale of sub-CD characterizing the observer, the interpretation of states associated with sub-CD is in terms of quantum fluctuations.

ZEO solves the problem of initial state since in principle any zero energy state is obtained from any other state by a sequence of quantum jumps without breaking of conservation laws. The fact that energy is not conserved in general relativity based cosmologies can be also understood since each CD is characterized by its own conserved quantities. As a matter fact, one must be speak about average values of conserved quantities since one can have a quantum superposition of zero energy states with the quantum numbers of the positive energy part varying over some range.

For thermodynamical states this is indeed the case and this leads to the idea that quantum theory in ZEO can be regarded as a "complex square root" of thermodynamics obtained as a product of positive diagonal square root of density matrix and unitary S-matrix. M-matrix defines

time-like entanglement coefficients between positive and negative energy parts of the zero energy state and replaces S-matrix as the fundamental observable. In standard quantum measurement theory this time-like entanglement would be reduced in quantum measurement and regenerated in the next quantum jump if one accepts Negentropy Maximization Principle (NMP) [K73] as the fundamental variational principle. Various M-matrices define the rows of the unitary U matrix characterizing the unitary process part of quantum jump. From the point of view of consciousness theory the importance of ZEO is that conservation laws in principle pose no restrictions for the new realities created in quantum jumps: free will is maximal.

4.3.3 The Hierarchy Of Planck Constants

The motivations for the hierarchy of Planck constants come from both astrophysics and biology. The biological motivations have been already discussed. In astrophysics the observation of Nottale [E1] that planetary orbits in solar system seem to correspond to Bohr orbits with a gigantic gravitational Planck constant motivated the proposal that Planck constant might not be constant after all [K112, K87].

This led to the introduction of the quantization of Planck constant as an independent postulate. It has however turned that quantized Planck constant in effective sense could emerge from the basic structure of TGD alone. Canonical momentum densities and time derivatives of the embedding space coordinates are the field theory analogs of momenta and velocities in classical mechanics. The extreme non-linearity and vacuum degeneracy of Kähler action imply that the correspondence between canonical momentum densities and time derivatives of the embedding space coordinates is 1-to-many: for vacuum extremals themselves 1-to-infinite.

A convenient technical manner to treat the situation is to replace embedding space with its n-fold singular covering. Canonical momentum densities to which conserved quantities are proportional would be same at the sheets corresponding to different values of the time derivatives. At each sheet of the covering Planck constant is effectively $\hbar = n\hbar_0$. This splitting to multi-sheeted structure can be seen as a phase transition reducing the densities of various charges by factor $1/n$ and making it possible to have perturbative phase at each sheet (gauge coupling strengths are proportional to $1/\hbar$ and scaled down by $1/n$). The connection with fractional quantum Hall effect [D2] is almost obvious. At the more detailed level one finds that the spectrum of Planck constants would be given by $\hbar = n_a n_b \hbar_0$.

This has many profound implications, which are wellcome from Quantum Mind perspective.

1. Quantum coherence and quantum superposition become possible in arbitrary long length scales. One can speak about zoomed up variants of elementary particles and zoomed up sizes make it possible to satisfy the overlap condition for quantum length parameters used as a criterion for the presence of macroscopic quantum phases. In the case of quantum gravitation the length scale involved are astrophysical. This would conform with Penrose's intuition that quantum gravity is fundamental for the understanding of consciousness and also with the idea that consciousness cannot be localized to brain.

2. Photons with given frequency can in principle have arbitrarily high energies by $E = hf$ formula, and this would explain the strange anomalies associated with the interaction of ELF em fields with living matter [J57]. Quite generally the cyclotron frequencies which correspond to energies much below the thermal energy for ordinary value of Planck constant could correspond to energies above thermal threshold.

3. The value of Planck constant is a natural characterizer of the evolutionary level and biological evolution would mean a gradual increase of the largest Planck constant in the hierarchy characterizing given quantum system. Evolutionary leaps would have interpretation as phase transitions increasing the maximal value of Planck constant for evolving species. The space-time correlate would be the increase of both the number and the size of the sheets of the covering associated with the system so that its complexity would increase.

4. The phase transitions changing Planck constant change also the length of the magnetic flux tubes. The natural conjecture is that biomolecules form a kind of Indra's net connected

by the flux tubes and $\hbar$ changing phase transitions are at the core of the quantum biodynamics. The contraction of the magnetic flux tube connecting distant biomolecules would force them near to each other making possible for the bio-catalysis to proceed. This mechanism could be central for DNA replication and other basic biological processes. Magnetic Indra's net could be also responsible for the coherence of gel phase and the phase transitions affecting flux tube lengths could induce the contractions and expansions of the intracellular gel phase. The reconnection of flux tubes would allow the restructuring of the signal pathways between biomolecules and other subsystems and would be also involved with ADP-ATP transformation inducing a transfer of negentropic entanglement [K45, K46] (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). The braiding of the magnetic flux tubes could make possible topological quantum computation like processes and analog of computer memory realized in terms of braiding patterns [K3].

5. p-Adic length scale hypothesis and hierarchy of Planck constants suggest entire hierarchy of zoomed up copies of standard model physics with range of weak interactions and color forces scaling like $\hbar$. This is not conflict with the known physics for the simple reason that we know very little about dark matter (partly because we might be making misleading assumptions about its nature).

   Dark matter would make possible the large parity breaking effects manifested as chiral selection of bio-molecules [I4]. What is required is that classical Z^0 and W fields responsible for parity breaking effects are present in cellular length scale. If the value of Planck constant is so large that weak scale is some biological length scale, weak fields are effectively massless below this scale and large parity breaking effects become possible.

   For the solutions of field equations which are almost vacuum extremals Z^0 field is non-vanishing and proportional to electromagnetic field. The hypothesis that cell membrane corresponds to a space-time sheet near a vacuum extremal (this corresponds to criticality very natural if the cell membrane is to serve as an ideal sensory receptor) leads to a rather successful model for cell membrane as sensory receptor with lipids representing the pixels of sensory qualia chart. The surprising prediction is that bio-photons [I34] and bundles of EEG photons can be identified as different decay products of dark photons with energies of visible photons. Also the peak frequencies of sensitivity for photoreceptors are predicted correctly [K97].

4.3.4 P-Adic Physics And Number Theoretic Universality

p-Adic physics [K120, K79] has become gradually a key piece of TGD inspired biophysics. Basic quantitative predictions relate to p-adic length scale hypothesis and to the notion of number theoretic entropy. Basic ontological ideas are that life resides in the intersection of real and p-adic worlds and that p-adic space-time sheets serve as correlates for cognition.

p-Adic number fields

p-Adic number fields Q_p [A15] -one for each prime p- are analogous to reals in the sense that one can speak about p-adic continuum and that also p-adic numbers are obtained as completions of the field of rational numbers. One can say that rational numbers belong to the intersection of real and p-adic numbers. p-Adic number field Q_p allows also an infinite number of its algebraic extensions. Also transcendental extensions are possible. For reals the only extension is complex numbers.

p-Adic topology defining the notions of nearness and continuity differs dramatically from the real topology. An integer which is infinite as a real number can be completely well defined and finite as a p-adic number. In particular, powers p^n of prime p have p-adic norm (magnitude) equal to p^{-n} in Q_p so that at the limit of very large n real magnitude becomes infinite and p-adic magnitude vanishes.

p-Adic topology is rough since p-adic distance $d(x,y) = d(x-y)$ depends on the lowest pinary digit of $x-y$ only and is analogous to the distance between real points when approximated by taking into account only the lowest digit in the decimal expansion of $x-y$. A possible interpretation is in terms of a finite measurement resolution and resolution of sensory perception. p-Adic topology looks somewhat strange. For instance, p-adic spherical surface is not infinitely thin but has a finite

thickness and p-adic surfaces possess no boundary in the topological sense. Ultra-metricity is the technical term characterizing the basic properties of p-adic topology and is coded by the inequality $d(x-y) \leq Min\{d(x), d(y)\}$. p-Adic topology brings in mind the decomposition of perceptive field to objects.

Physical and biological motivations for p-adic number fields

The physical motivations for p-adic physics came from the observation that p-adic thermodynamics -not for energy but infinitesimal scaling generator of so called super-conformal algebra [A4] acting as symmetries of quantum TGD [K127] - predicts elementary particle mass scales and also masses correctly under very general assumptions [K79]. In particular, the ratio of proton mass to Planck mass, the basic mystery number of physics, is predicted correctly. The basic assumption is that the preferred primes characterizing the p-adic number fields involved are near powers of two: $p \simeq 2^k$, k positive integer. Those nearest to power of two correspond to Mersenne primes $M_n = 2^n - 1$. One can also consider complex primes known as Gaussian primes, in particular Gaussian Mersennes $M_{G,n} = (1+i)^n - 1$.

It turns out that Mersennes and Gaussian Mersennes are in a preferred position physically in TGD based world order. What is especially interesting is that the p-adic length scale range 10 nm-5 μm contains as many as four scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$ assignable to Gaussian Mersennes $M_k = (1+i)^k - 1$, $k = 151, 157, 163, 167$ [K97]. This number theoretical miracle supports the view that p-adic physics is especially important for the understanding of living matter.

p-Adic length scale hypothesis suggests the identification of metabolic energy currencies as energy quanta liberated as particle drops from space-time sheet to a larger one. These energy quanta correspond to increments of zero point kinetic energy. Metabolic energy currencies would be completely universal and exist already during the prebiotic era so that metabolic machinery would build up around this pre-existing structure. A simple (and also rough) model based on p-adic length scale hypothesis allows to estimate the increments of zero point kinetic energy. The quantum corresponding to about.5 eV has place in this hierarchy for which basic energies (those for which larger space-time sheet is very large) come as octaves of basic energy quantum [K12, K59]. These energy quanta do not have interpretation in terms of molecular transitions and there exist anomalous lines of radiation from interstellar space both in IR, visible, and UV region [K12].

Life as something in the intersection of real and p-adic worlds

The philosophical for p-adic numbers fields come from the question about the possible physical correlates of cognition [K81]. Cognition forms representations of the external world which have finite cognitive resolution and the decomposition of the perceptive field to objects is an essential element of these representations. Therefore p-adic space-time sheets could be seen as candidates of thought bubbles, the mind stuff of Descartes.

Rational numbers belong to the intersection of real and p-adic continua. An obvious generalization of this statement applies to real manifolds and their p-adic variants. When extensions of p-adic numbers are allowed, also some algebraic numbers can belong to the intersection of p-adic and real worlds. The notion of intersection of real and p-adic worlds has actually two meanings.

1. The intersection could consist of the rational and possibly some algebraic points in the intersection of real and p-adic partonic 2-surfaces at the ends of CD. This set is in general discrete. The interpretation could be as discrete cognitive representations.

2. The intersection could also have a more abstract meaning. For instance, the surfaces defined by rational functions with rational coefficients have a well-defined meaning in both real and p-adic context and could be interpreted as belonging to this intersection. There is strong temptation to assume that intentions are transformed to actions only in this intersection. One could say that life resides in the intersection of real and p-adic worlds in this abstract sense.

Additional support for the idea comes from the observation that Shannon entropy $S = -\sum p_n log(p_n)$ allows a p-adic generalization if the probabilities are rational numbers by replacing

$log(p_n)$ with $-log(|p_n|_p)$, where $|x|_p$ is p-adic norm. Also algebraic numbers in some extension of p-adic numbers can be allowed. The unexpected property of the number theoretic Shannon entropy is that it can be negative and its unique minimum value as a function of the p-adic prime p it is always negative. Entropy transforms to information!

In the case of number theoretic entanglement entropy there is a natural interpretation for this. Number theoretic entanglement entropy would measure the information carried by the entanglement whereas ordinary entanglement entropy would characterize the uncertainty about the state of either entangled system. For instance, for p maximally entangled states both ordinary entanglement entropy and number theoretic entanglement negentropy are maximal with respect to R_p norm. Entanglement carries maximal information. The information would be about the relationship between the systems, a rule. Schrödinger cat would be dead enough to know that it is better to not open the bottle completely.

Negentropy Maximization Principle [K73] coding the basic rules of quantum measurement theory implies that negentropic entanglement can be stable against the effects of quantum jumps unlike entropic entanglement. Therefore living matter could be distinguished from inanimate matter also by negentropic entanglement possible in the intersection of real and p-adic worlds. In consciousness theory negentropic entanglement could be seen as a correlate for the experience of understanding or any other positively colored experience, say love.

Negentropically entangled states are stable but binding energy and effective loss of relative translational degrees of freedom is not responsible for the stability. Therefore bound states are not in question. The distinction between negentropic and bound state entanglement could be compared to the difference between unhappy and happy marriage. The first one is a social jail but in the latter case both parties are free to leave but do not want to. The special characterics of negentropic entanglement raise the question whether the problematic notion of high energy phosphate bond citebbioHEP central for metabolism could be understood in terms of negentropic entanglement. This would also allow an information theoretic interpretation of metabolism since the transfer of metabolic energy would mean a transfer of negentropy [K45, K46].

4.4 Consciousness Theory As Extension Of Quantum Measurement Theory

TGD inspired theory of consciousness [K68] could be seen as a generalization of quantum measurement theory. The notions of quantum jump and self self are the key notions. Negentropy Maximization Principle (NMP) [K73] is the basic dynamical principle. NMP is mirror image for the second law of thermodynamics and states that the amount of conscious information gain in quantum jump is maximal. NMP reproduces standard quantum measurement theory for entropic entanglement and is in this case consistent with the second law since the non-determinism of state function reductions implies the increase of ensemble entropy.

4.4.1 Quantum Jumps As Moment Of Consciousness

The starting point of TGD inspired theory of consciousness was the identification of quantum jump as a moment of consciousness [K68].

1. Quantum jump has a complex anatomy which however simplifies in ZEO. Quantum jump involves unitary time evolution leading from a state resulting in state function reduction to a quantum superposition of states: one could speak of multiverse. This step is described by the counterpart of the unitary process of Penrose and is coded by a unitary matrix U in the state space formed by zero energy states. U is therefore not identifiable directly as S-matrix of quantum field theories but contains as its rows all possible M-matrices which are what particle physicist tries to measure in laboratory. State function reduction and state preparation can be assigned to the opposite light-like boundaries of CD.

   A good metaphor is Djinn in the bottle. In U-process bottle is opened and Djinn comes out and creates a quantum superposition of all possible worlds. The wish of the observer is fulfilled and leads to a state function reduction. Actually there is an entire cascade of state function

reductions starting from the level of the entire universe which splits the entangleement subsystems already obtained in a step-wise manner to pairs un-entangled sub-systems. The splitting for a given sub-system occurs only if it is consisent with NMP.

For the ordinary definition of entanglement entropy the process would lead to a completely unentangled situation. If the number theoretic entanglement entropy making sense for rational (and even algebraic) entanglement probabilities is allowed, the process stops unless the reduction of entanglement reduces the entanglement entropy. Therefore the number theoretic entanglement possible in the intersection of real and p-adic worlds can be stable and living systems are able to preserve their coherence.

2. Since the reduction cascade proceeds from top to bottom, one can speak about fractal formed by quantum jumps within quantum jumps. One cannot assign to the steps of this sequence any duration of geometric time. One can however associate to it an experienced duration and it is very tempting to assume that the experienced duration increases as one climbs up in the self hierarchy.

3. Quantum jump replaces the quantum superposition of classical histories (space-time surfaces, classical worlds) with a new one whereas ordinary state function reduction would do this for time=constant snapshot of Schrödinger evolution. Quantum jump does not spoil the determinism of classical dynamics or of Dirac equation since it occurs entirely outside space-time and Hilbert space. In quantum jump both the geometric future and past (defined only within measurement resolution) are replaced with new ones. The mysterious finding of Libet [J44] that intentional action is preceded by neural activity can be interpreted in this framework without giving up the notion of free will. This raises a fascinating question about time scales in which the geometric past can be affected in quantum jump. Also memories stored in the geometric past can be affected in quantum jumps and the fact that memories are highly unstable suggest that the time scale is measured in years.

   It must be added that the notion of classical determinism in its standard form fails due to the special properties of Kähler action (vacuum degeneracy mathematically analogous to a gauge degeneracy but physically analogous to 4-D spin glass degeneracy). This failure provides a space-time correlate for the non-determinism of the quantum jump sequence.

4.4.2 The Notion Of Self

The notion of self can be seen as a generalization of the notion of observer. The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of zero energy ontology (ZEO) only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant. The parts of zero energy states at second boundary of CD change even the position of opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self. Hence act of free will means change of the arrow of psychological time at some level of hierarchy of CDs.

This allows to understand the relationship between subject and geometric time and how the arrow of and flow of psychological time emerges. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience

to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

There exists an infinite hierarchy of number theoretical entropies [K73] making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that Negentropy Maximization principle (NMP) favors generation of negentropic entanglement, which need not be bound state entanglement in standard sense.

In the case of negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) a more natural interpretation is that expansion of consciousness rather than loss of it is experienced as self entangles with second system negentropically. Only entropic entanglement would lead to a loss of consciousness. Second condition would be that self is stable against splitting to unentangled subsystems. This criterion is satisfied if self corresponds to a system for which the entanglement between its subsystems is negentropic.

This leads to the vision that negentropic entanglement defines kind of Akashic records, kind of library storing conscious or potentially conscious information. According to the recent view, Akashic records could define self as opposed to self model defined in terms of memory representations relying on bits. Consistency with standard quantum measurement theory [K73] requires that density matrix for negentropic entanglement is proportional to unit matrix associated to unitary entanglement matrix associated with quantum computation. "Akashic records" would define self and would be consciously experienced.

Self experiences its sub-selves as mental images and even we would represent mental images of some higher collective self. Everything would be conscious but consciousness could be only lost. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.

By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J148] could be understood as a sharing of mental images between brain hemispheres which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.

At the level of 8-dimensional embedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. As already noticed, .1 second time scale defining the duration of moment for sensory experience corresponds to that of electron's CD which suggests that Cooper pairs of electrons are essential for the sensory qualia.

4.4.3 How Experienced Time And The Geometric Time Of Physicist Relate To Each Other?

The relationship between experienced time and time of physicist is one of the basic puzzles of modern physics. In the proposed framework they are certainly two different things and the challenge is to understand why the correlation between them is so strong that it has led to their identification. One can imagine several alternative views explaining this correlation [K133, **?**, K10] and it is better to keep mind open.

Basic questions

The flow of subjective time corresponds to quantum jump sequences for sub-selves of self having interpretation as mental images. If mind is completely empty of mental images subjectively experienced time ceases to exists. This leaves however several questions to be answered.

1. Why the contents of conscious of self comes from a finite space-time region looks like an easy question. If the contents of consciousness for sub-selves representing mental images is localized to the sub-CDs with indeed have defined temporal position inside CD assigned with the self the contents of consciousness is indeed from a finite space-time volume. This implies a new view about memory. There is no need to store again and again memories to the "brain now" since the communications with the geometric past by negative energy signals and also time-like negentropic quantum entanglement allow the sharing of the mental images of the geometric past.

2. There are also more difficult questions. Subjective time has arrow and has only the recent and possibly also past. The subjective past could in principle reduce to subjective now if conscious experience is about 4-D space-time region so that memories would be always geometric memories. How these properties of subjective time are transferred to apparent properties of geometric time? How the arrow of geometric time is induced? How it is possible that the locus for the contents of conscious experience shifts or at least seems to be shifted quantum jump by quantum jump to the direction of geometric future? Why the sensory mental images are located in a narrow time interval of about .1 seconds in the usual states of consciousness (not that sensory memories are possible: scent memories and phantom pain in leg could be seen as examples of vivid sensory memory)?

The recent view about arrow of time

The basic intuitive idea about the explanation for the arrow of psychological time has been the same from the beginning - diffusion inside light-cone - but its detailed realization has required understanding of what quantum TGD really is. The replacement of ordinary positive energy ontology with zero energy ontology (ZEO) has played a crucial role in this development. The TGD based vision about how the arrow of geometric time is by no means fully developed and final. It however seems that the most essential aspects have been understood now.

1. What seems clear now is the decisive role of ZEO and hierarchy of CDs, and the fact that the quantum arrow of geometric time is coded into the structure of zero energy states to a high extent. The still questionable but attractively simple hypothesis is that U matrix two basis with opposite quantum arrows of geometric time: is this assumption really consistent with what we know about the arrow of time? If this is the case, the question is how the relatively well-defined quantum arrow of geometric time implies the experienced arrow of geometric time. Should one assume the arrow of geometric time separately as a basic property of the state function reduction cascade or more economically- does it follow from the arrow of time for zero energy states or only correlate with it?

2. The state function reductions can occur both boundaries of CD. If the reduction occurs at given boundary is immediately followed by a reduction at the opposite boundary, the arrow of time alternates: this does not conform with intuitive expectations: for instance, this would imply that there are two selves assignable to the opposite boundaries!

   Zero energy states are however de-localized in the moduli space CDs (size of CD plus discrete subgroup of Lorentz group defining boosts of CD leaving second tip invariant). One has quantum superposition of CDs with difference scales but with fixed upper or lower boundary belonging to the same light-cone boundary after state function reduction. In standard quantum measurement theory the repetition of state function reduction does not change the state but now it would give rise to the experienced flow of time. Zeno effect indeed requires that state function reductions can occur repeatedly at the same boundary. In these reductions the wave function in moduli degrees of freedom of CD changes. This implies "dispersion" in the moduli space of CDs experienced as flow of time with definite arrow. This view lead to a precise definition of self as sequence of quantum jumps to the reducing to the same boundary of CD.

3. This approach codes also the arrow of time at the space-time level: the average space-time sheet in quantum superposition increases in size as the average position of the "upper boundaries" of CDs drift towards future state function reduction by state function reduction.

4. In principle the arrow of time can temporarily change but it would seem that this can occur in very special circumstances and probably takes place in living matter routinely. Phase conjugate laser beam is a non-biological example about reversal of the arrow of time. The act of volition would correspond to the first state function reduction to the opposite boundary so that the reversal of time arrow at some level of the hierarchy of selves would take place in the act of volition.

4.4.4 Quantum Correlates For Various Aspects Of Conscious Experience

The identification of quantum correlates of cognition and intentionality, of sensory qualia, Boolean mind, and of emotions [K50] represents one challenge for Quantum Mind theories. As already explained, p-adic physics, the vision about life as something residing in the intersection of real and p-adic worlds, and the notion of number theoretic entropy provide a plausible starting point when one tries to say something about the geometric and quantum correlates of cognition and intentionality. Zero energy ontology makes possible the transitions transforming p-adic zero energy states to their real counterparts and having interpretation in terms of intentional action.

1. Quantum numbers characterize quantum states. Therefore the increments ΔQ of quantum numbers for a subsystem should characterize quantum jumps and it is attractive to assign classify fundamental qualia in terms of quantum number increments. "The increments of quantum numbers for a sub-system representing self" looks innocent but what it really means is surprisingly difficult to make precise. The following attempt relies on ZEO.

   (a) For the positive energy part of state located at "lower" boundary of CD self - subsystem S - and environment E are un-entangled. At the "upper" boundary there is entanglement between S and E, and it should be able to assign qualia as quantum number increments to this entanglement.

   (b) Consider increments of color quantum numbers identified in terms of visual colors as an example. In the positive energy state color quantum numbers for an unentangled subsystem S vanish by color confinement. In negative energy state they can be non-vanishing for S but vanish for $S \otimes E$. The experienced qualia for S are determined as quantum averages of color quantum numbers in the entangled state and expressible in terms of the sub-system density matrix. One can indeed assign to the zero energy state increments ΔQ_{ZEO} of color quantum numbers as difference of color quantum numbers for S at "upper" and "lower" boundaries of C. These increments characterize zero energy state rather than quantum jump.

   (c) In state function reduction the entanglement at upper boundary is reduced if the entanglement is entropic whereas negentropic entanglement can be stable. Quale is experienced sensorily as long as quantum jumps preserve negentropic entanglement. When entanglement is eventually reduced, the experience can be only a memory about the experienced quale. The increments ΔQ of color quantum numbers in quantum jump can be identified as $\Delta Q = \Delta Q_{ZEO}$. Hence this notion is indeed well-defined.

   (d) This interpretation allows to assign to the quantum jump also space-time evolution changing the quantum numbers in the same manner as they change in quantum jump. This is what quantum-classical correspondence indeed requires.

   One application is the identification of basic colors in terms of color quantum number increments of quantum states [K50]. This identification makes sense if one accepts the fractal hierarchy of QCD like dynamics allowed by p-adic length scale hierarchy and by the hierarchy of Planck constants. The original concrete model was provided by the capacitor model of sensory qualia in which a large number of particles which same quantum numbers flows to a subsystem during quantum jump inducing the analog of di-electric breakdown (note the analogy with nerve pulse). Bose-Einstein condensation provides one possible realization. In this case one can say that the quantum numbers of the particle in question represent the basic quale which is amplified.

The above picture forces to modify this view by replacing a color capacitor with a fixed size with that of a variable size corresponding to the size of system S and $S \otimes E$: the second plate of capacitor either in S or environment. The flow of charges associated with the transition generating quale still makes sense and generates strong color polarization in the scale $S \otimes E$. In the model the increase of the size of the color capacitor means a formation of flux tubes between the sensory receptor and environment such that net color is non-vanishing only for these flux tubes. In state function reduction reducing entanglement the flux tubes are split and S become color neutral but can represent a memory about the quale as negentropic color neutral entanglement in the scale of S: some sub-system of S can now experience the color quale. This suggests a holographic memory in which quale eventually is represented in very small scale in terms of negentropic entanglement.

The argument involves assumption about color confinement. In the case of qualia assignable to electromagnetic charges, spin, etc... similar assumption makes sense. Even in case of momentum and angular momentum this assumption makes sense and means that subsystem in the state of experiencing momentum or angular momentum increment as quale is in a real accelerated motion in the scale of CD. As a matter fact, the vanishing of quantum numbers of S in absence of entanglement might not be necessary for the interpretation.

2. One could also speak about Boolean qualia and fermions provide possible correlates for them. The 2^N many-fermion states of fermionic Fock space for N fermionic qubits define a basis of Boolean algebra. The entangled pairs of fermionic states associated with the positive and negative energy parts of zero energy states define quantal Boolean functions as sums over entangled pairs of many fermion states. Negentropic entanglement could define a representation of a rule with entangled pairs representing various instances of the rule. Time-like entanglement would define a representation for a "law of physics" and M-matrices would be fundamental representations of this kind. The increments of the fermionic quantum numbers could define Boolean qualia and one can imagine Boolean capacitor mechanism allowing to amplify a given Boolean statement.

One should be also able to say something about the quantum correlates of emotions. Here the notion of negentropic entanglement might be the key concept.

1. Emotions have a quale like character. For instance, psychological pleasure and pain resemble their physiological counterparts- and quite generally there is a tendency to assign to emotions the attributes of sensory experience. It would be attractive to assign this positive/negative dichotomy to the increase/reduction of entanglement negentropy. Emotion would represent Boolean bit as the sign of negentropy increment. The destruction of generation of negentropic entanglement would therefore be the core element of emotional quale. The character of entanglement involved would determine whether the emotion corresponds to pleasure or pain, joy or sorrow, pride or shame.

   In the case of physiological pain or pleasure it is easy to imagine that the cause of pain destroys/creates negentropic entanglement. Pain and pleasure at this level relates directly to what happens to metabolism. This is easy to understand if the basic function of energy metabolism is to transfer negentropic entanglement. For higher level emotions the negentropy reduction or increase could be produced artificially to give an emotional content for something regarded as important.

2. Very often emotions are characterized by good-bad/right-wrong dichotomy characterizable by single binary digit. Perhaps emotions provide a representation of a high level summary about large amounts information, a kind of Boolean function of very many qubits. The function of neural transmitters can be often interpreted in terms of reward or punishment. Information and emotions seem to be closely related: peptides are often regarded as both information molecules and molecules of emotion [J55]. This can be understood if the function of information molecule is to induce emotional response representing the information.

3. Comparison to a standard -be it moral rule, expected or desired behavior, or something else- is rather often an essential aspect of emotion. Comparison can in principle be represented as a quantal Boolean function involving the standard (say moral rule) represented in terms of

negentropic entanglement. If the Boolean instance compared with the rule corresponds to an instance allowed by the rule, positive emotion results. Otherwise the emotion is negatively colored. One might also think that there is expectation for the result of comparison. If the outcome differs from expected- which corresponds to a flip of bit, positive or negative emotion results but could do so as a secondary representation. The above argument suggests that the outcome of comparison does not represent the emotion as such but there is a neural circuitry encoding the outcome to reward or punishment.

4.4.5 Self Referentiality Of Conscious Experience

Self referentiality of consciousness is one of its most mysterious looking aspects. In a loose formulation one could say that system is able to be conscious what it *is* conscious of. This formulation however leads to an infinite hierarchy of reflective levels and therefore to a paradox. One can however milden the formulation by saying that self-referential system is able to be conscious about what it *was* conscious of (with respect to subjective time of course!)

In this formulation quantum classical correspondence gives hopes about the understanding of self-referentiality. Quantum classical correspondence means in TGD framework that not only quantum states but also quantum jump sequences have space-time correlates. The failure of classical determinism for Kähler action in standard sense of the word is responsible for this and relates directly to the basic properties distinguishing TGD Universe from that of standard model. This allows to imagine that quantum jump leading from a superposition of space-time surfaces to a new one also gives rise to a representation of the conscious experiences which preceded the last quantum jump at the level of space-time geometry. Reductio ad absurdum would transform to evolution of consciousness able to add to the existing hierarchy a new reflective level in each quantum jump.

I have proposed several correlates for the self-referentiality of consciousness. Many-sheeted space-time would provide the physical representation (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book).

Many-sheeted space-time and self-referentiality

The fractal hiearchy of magnetic flux tubes giving rise to braids, which in turn make possible topological quantum computation would be a rather realization of this representation, A possible concrete physical realization of self-referentiality is suggested by DNA as quantum computer model [K3]. One assumes that DNA nucleotides and lipids are connected by magnetic flux tubes. Since the lipid layer of the cell membrane is 2-dimensional liquid crystal, the lipids are in continual hydrodynamical motion and this means in time direction entanglement of the orbits. The events in nearby environment and also nerve pulses affect this flow. This braiding in time direction defines a topological quantum computation. This motion entangles also the flux tubes connecting the lipids to DNA nucleotides so that when the topological quantum computation halts it becomes stored into memory as space-like entanglement. In TGD framework also the time-like braiding provides a space-time representation of the quantum computation which also gives to a conscious experience at some level of the hierarchy.

Infinite primes and self-referentiality

The hierarchy of infinite primes (and of integers and rationals) [K118] was the first mathematical notion stimulated by TGD inspired theory of consciousness. The construction recipe is equivalent with a repeated second quantization of a super-symmetric arithmetic quantum field theory with bosons and fermions labeled by primes such that the many-particle states of previous level become the elementary particles of new level. At a given level there are free many particles states plus counterparts of many particle states. There is strong structural analogy with polynomial primes. For polynomials with rational coefficients free many-particle states would correspond to products of first order polynomials and bound states to irreducible polynomials with non-rational roots.

The hierarchy of space-time sheets with many particle states of space-time sheet becoming elementary particles at the next level of hierarchy. For instance, the description of proton as an

elementary fermion would be in a well defined sense exact in TGD Universe. Also the hierarchy of n: th order logics are possible correlates for this hierarchy.

This construction leads also to a number theoretic generalization of space-time point since a given real number has infinitely rich number theoretical structure not visible at the level of the real norm of the number a due to the existence of real units expressible in terms of ratios of infinite integers. This number theoretical anatomy suggest a kind of number theoretical Brahman=Atman identity stating that the set consisting of number theoretic variants of single point of the embedding space (equivalent in real sense) is able to represent the points of WCW or maybe even quantum states assignable to causal diamond. One could also speak about algebraic holography.

The correspondence between the quantum states defined by WCW spinor fields and wave functions in the infinite-dimensional discrete space of hyper-octonionic units can be made more concrete [K118]. These wave functions must transforming irreducibly under discrete subgroup SU(3) of octonion automorpisms transforming ordinary hyper-octonionic prime to a new hyper-octonionic prime. SU(3) has interpretation as color group. One can assign standard model quantum numbers to these wave functions and prime property in principle fixes the spectrum of possible quantum states- in particular the spectrum of masses. Therefore the extremely esoteric looking notion of infinite prime might turn out to be very practical calculational tool.

Quantum Mathematics and self referentiality of consciousness

In Quantum Mathematics numbers are replaced with Hilbert spaces and the dimension of Hilbert space - in appropriately. generalized sense - characterizes the number.

1. This suggests a generalization of calculus for Hilbert spaces. Mathematical objects which are defined for numbers in various number fields become well defined when these numbers are replaced with Hilbert spaces. One can speak of the Hilbert space analogs of algebraic numbers, transcendentals, p-adic numbers and their extensions. Anything having as a building brick rationals, algebraic numbers, real or p-adic numbers or finite fields generalizes. Even the notions like matrix group, algebras, and ring generalize. Also the notion of manifold generalizes as well as the notion of calculus.

2. The Hilbert space in associated with the element of number field characterizes its number theoretic anatomy and therefore could be a correlate of cognition. The crucial step in the generalization of this process to the level of the Hibert space representing points. Points of Hilbert spaces can be replaced with Hilbert spaces and process can be repeated ad infinitum. This suggests that the self-referentiality at the deepest level corresponds to this fractal view about space-time based on assignment of quantum dynamics to numbers. Also a connection with the hierarchy of n: th order logics. A close relationship to infinite primes would not be surprising since in both cases one an infinite hierarchy of processes analogous to second quantization is involved. A natural question is whether many-sheeted space-time provides a dynamical representation in terms of space-time sheets for the number theoretic anatomy so that kind of Brahman=Atman identity or algebraic holography would hold true. This correspondence could be see as a cognitive representation of external world and one could also see the external world as symbolic representation of the world of cognition.

3. A connection with generalized Feynman diagrams and hierarchy of Planck constants is suggestive and the idea was originally inspired by the observation that the two vertices of generalized Feynman diagrams identifiable as generalizations of the basic stringy 3-vertex for closed strings and basic 3-vertex for Feynman diagrams correspond naturally to direct sum and tensor product in turn having natural correspondence with + and $\times$ of the usual arithmetics. This correspondence motivates the introduction of co-operations of direct sum and tensor product meaning that quantum dynamics is brought into the game through these vertices. This suggests that Quantum Mathematics is actually Quantum dynamics in which generalized Feynman diagrams define sequences of arithmetic or even more general algebraic operations.

   If so, the basic structures of Quantum Mechanics (QM) might reduce to fundamental mathematical and metamathematical structures, and that one even consider the possibility that

Quantum Mechanics reduces to Quantum Mathematics with mathematician included or expressing it in a concise manner: QM=QM!

The fractal character of the Quantum Mathematics is what makes it a good candidate for understanding the self-referentiality of consciousness. The replacement of the Hilbert space with the direct sum of Hilbert spaces defined by its points would be the basic step and could be repeated endlessly corresponding to a hierarchy of statements about statements or hierarchy of n^{th} order logics. The construction of infinite primes leads to a similar structure.

What about the step leading to a deeper level in hierarchy and involving the replacement of each point of Hilbert space with Hilbert space characterizing it number theoretically? What could it correspond at the level of states?

1. Suppose that state function reduction selects one point for each Hilbert space $x_n \times p^n$. The key step is to replace this direct sum of points of these Hilbert spaces with direct sum of Hilbert spaces defined by the points of these Hilbert spaces. After this one would select point from this very big Hilbert space. Could this point be in some sense the image of the Hilbert space state at previous level? Should one imbed Hilbert space $x_n \times p^n$ isometrically to the Hilbert space defined by the preferred state $x_n \times p^n$ so that one would have a realization of holography: part would represent the whole at the new level. It seems that there is a canonical manner to achieve this. The interpretation as the analog of second quantization suggest the identification of the embedding map as the identification of the many particle states of previous level as single particle states of the new level.

2. Could topological condensation be the counterpart of this process in many-sheeted space-time of TGD? The states of previous level would be assigned to the space-time sheets topologically condensed to a larger space-time sheet representing the new level and the many-particle states of previous level would be the elementary particles of the new level.

3. If this vision is correct, second quantization performed by theoreticians would not be a mere theoretical operation but a fundamental physical process necessary for cognition! The above proposed unitary embedding would imbed the states of the previous level as single particle states to the new level. It would seem that the process of second quantization, which is indeed very much like self-reference, is completely independent from state function reduction and unitary process. This picture would conform with the fact that in TGD Universe the theory about the Universe is the Universe and mathematician is in the quantum jumps between different solutions of this theory.

4.5 Various Types Of Conscious Experiences

In the following the general structure and classication of conscious experiences is discussed. Most predictions are brain independent. Assuming that zero modes of the configuration space, characterizing the geometry of macroscopic classical space-time, determine the geometric information contents of conscious experience and identifying macroscopic quantum phases as quantum correlates of various sensory modalities, one can make rather far reaching predictions about basic aspects of, say, sensory experience of any experiencer, be it human brain or some strange life form in distant galaxy.

4.5.1 Basic Structure Of Conscious Experience

Before continuing, it is perhaps useful to recall the basic anatomy of the quantum jump: $\Psi_i \to U\Psi_i \to \Psi_{f_0} \to ....\Psi_f$, where the final quantum history Ψ_f is a superposition of space-time surfaces, which are macroscopically equivalent and only bound state entanglement is present. Every space-time surface of the superposition consists of parallel space-time sheets (connected by wormhole contacts). Some of these space-time sheets have infinite time extension and some have not. The latter ones are "mindlike space-time sheets". One must make a clear distinction between the quantum superposition of the space-time surfaces and the decomposition of the space-time surface to space-time sheets.

Real and imagined experiences

The assumption that p-adic physics is physics of imagination means division of qualia to real qualia and imagined qualia. There are good arguments based on mathematical consistency that in p-adic WCW degrees of freedom complete localization occurs in each quantum jump (see Appendix). This means that there are no quantum fluctuations in p-adic degrees of freedom and since non-geometric sensory qualia like color correspond to quantum number increments in quantum fluctuating degrees of freedom, there are no p-adic non-geometric qualia. This however leaves p-adic geometric qualia determined by the increments of p-adic WCW coordinates. This view is certainly consistent with intuitive notion that cognitive qualia are only about the geometric aspects, like shape and size, of the objects of the external world.

One could debate about whether cognition can be identified as imagination but this is the working hypothesis made. The tranformations of thoughts into actions or sensory experiences and of sensory inputs into thoughts correspond to p-adic–real phase transitions for mindlike space-time sheets so that one can speak about matter-mind interaction in a well-defined sense. Cognition is predicted to be present already at elementary particle length scales and this assumption is crucial for understanding the success of the p-adic length scale hypothesis works and p-adic mass calculations.

One can identify p-adic space-time sheets as correlates of memes [J162] and relate them to the morphic fields of Sheldrake. The p-adic vision about cognition is discussed in [K81].

Whole-body consciousness and ordinary consciousness

TGD predicts two basic modes of consciousness.

1. Reducible self is the state in which sub-selves are "falling asleep" and "waking up" all the time, corresponds naturally to the ordinary state of consciousness. Sub-selves represent mental images which pop out and dissappear all the time.

2. In case of irreducible self quantum jumps do not lead to a generation of sub-selves. Thus the sub-systems of irreducible self have only bound state entanglement and self measurement cascade stops at irreducible self. This state is presumably accompanied by the experience of "oneness" and could therefore be called a state of "whole-body consciousness". The absence of the sub-selves means the absence of mental images so that the identification as a state of pure self awareness without any contents is natural. Less ideal situation is that sub-selves are generated but are very short lived and represent short flashes against background awareness. "Whole-body-consciousness" presumably means abnormally low metabolism since dissipation inside sub-selves is not present.

Active and passive aspects of conscious experience

Conscious experience involves two fundamental contributions.

1. The "non-classical" contribution from the quantum measurement reducing quantum entanglement associated with the fermionic degrees of freedom and with the quantum fluctuating configuration space degrees of freedom (as opposed to zero modes).

2. The "classical" contribution determined by the localization in zero modes and by the selection between different degenerate preferred extremals.

The natural guess is that the experienced free will corresponds to the non-determinism of the quantum jump somehow. The standard objection is that the non-determinism of the quantum measurement gives rise to randomness rather than volition. Quantum numbers relate to microscopic aspects of the quantum jump and the average quantum numbers measured in quantum jumps probably sum up to zero in the presence of energy feed and external perturbations. Indeed, if temporal binding for the experiences of self involves averaging, this component of experience need not give rise to an experience of volition since it is expected to average out for large number of quantum jumps (10^{38} per second by the argument for the arrow of psychological time). Therefore the time averaging involved with the temporal binding smooths out this non-determinism.

Here the special features of TGD however come in rescue.

1. The first candidate for the quantum correlate of volition is the localization in zero modes. This localization corresponds to the spontaneous symmetry breaking of quantum field theories which selects one classical configuration among many degenerate ones. Spontaneous symmetry breaking has been suggested to be a basic aspect of the quantum jump also by Joel Henkel [J110]. Asymptotic localization in zero modes seems to be however determined statistically by the self-organization process taking the system to the bottom of some valley of the spin glass energy landscape. Hence volition need not be in question.

2. The second candidate for volition is classical non-determinism of Kähler action (which gives rise to the geometric model of thought as "association sequence"). The selection between the different degenerate alternative classical time evolutions, that is different degenerate absolute minima $X^4(Y^3)$ going through a given 3-surface Y^3, is an excellent candidate for the volitional act. The reason is that absolute minima differ macroscopically so that the choice between degenerate minima dramatically affects the entire geometric future. Note also that the selection between branches of a multifurcation of macroscopic space-time is in question, the choice can be done only when mindlike space-time sheet is located in a narrow time interval around multifurcation and is hence irreversible.

   The identification of the classical non-determinism as a geometric correlate of the volitional non-determinism is in nice accordance with the "ontogeny recapitulates phylogeny" principle stating that the geometric time evolution at the level of the space-time surface reflects the time evolution by quantum jumps at the level of the configuration space. One can however argue that this kind of volition is still passive in that it is only a selection between given alternatives rather than a transformation of an intention to action. The second objection is that there are actually infinite number of options between which to select in the state function reduction: why do we not experience these alternatives consciously?

3. The third candidate for volition is a quantum jump in which p-adic-to-real transformation for a p-adic space-time sheet representing cognitively intention occurs so that it becomes an action. For long time I believed that this identification of the volitional act is the most realistic one. It does not however explain why intention develops as a plan and will to do something and leads to horrible mathematical challenges which might be impossible to meet.

4. The recent view is implied by zero energy ontology (ZEO). In ZEO self corresponds to a sequence of state function reductions at fixed boundary of causal diamond (CD) changing only the situation at the opposite boundary (in standard quantum measurement theory nothing would happen to the state). This sequence can also give also rise to the development of intention. The volitional action begins with the first state function reduction to the opposite boundary of CD and means that the sub-self (mental image, we are also mental images) dies and reincarnates at the opposite boundary of CD. This picture leads to a simple answer to the basic questions and is certainly the most feasible one found hitherto. The strong prediction is that the arrow of time is not fixed and the behavior of living systems can be interpreted by accepting that the arrow of time can change.

An interesting possibility is that the zero modes characterizing the macroscopic features of the macroscopically equivalent space-time surfaces present in the *final* quantum state of quantum jump determine the contents of at least sensory experiences. This would be in accord with the idea that pure sensory experiences represent quantities which indeed "are in the world", the world being identified as the macroscopic space-time associated with the final quantum history of the quantum jump. One could however argue that it is only *the increments of zero modes* in quantum jump, which are perceived directly consciously: this claim is consistent with the fact that insects are able to see only the motion and that also human visual consciousness is crucially dependent on saccadic motion. Localization in the zero modes involves the fixing of the parameters characterizing the shape and size of the 3-surface X^3 as well as the Kähler field of $X^4(X^3)$. Kähler field can reduce to a purely electromagnetic or Z^0 type classical gauge field and is in general also accompanied by a classical color field. The spatio-temporal patterns of the induced Kähler field should correlate strongly with the contents of the conscious experience.

4.5.2 Cognition And P-Adic Physics

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a way that a unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the embedding space. Presumably the uniqueness requirement implies aunique pinary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

4.5.3 Reflective- And Proto-Levels Of Consciousness

The decomposition into proto consciousness and reflective consciousness (consciousness about being conscious) is one of the fundamental features of conscious experience. Logical thinking is also a fundamental component of conscious mind and probably also the mind unconscious-to-us, in fact so fundamental one that is has inspired the computationalistic approach to consciousness. One can consider two alternative identifications for the reflective level of consciousness.

Boolean mind as reflective mind?

The state basis of the Fock space generated by N fermionic creation operators is isomorphic with the Boolean algebra consisting of 2^N possible statements about N basic statements. This follows from the simple observation that by Pauli exclusion principle the fermion number associated with a given fermion state can have only two values: 0 (false) or 1 (true). This observation leads to the idea that many fermion states give representation for what might be called reflective consciousness in the sense that the information contents for experiences about conscious experiences could correspond to the quantum jumps in the fermionic sector.

A more convincing interpretation is that Boolean mind is onlh a special case of reflective mind. In p-adic case only quaternion conformal degrees of freedom are possible for WCW spinors (see appendix) and since pure cognition involves no emotions and no values it must correspond to logic (true/false). In real case the spin associated with the WCW metric correlates with the sensory experience and naturally corresponds to the logic of aesthetics (beautiful/ugly) whereas real quaternion conformal degrees of freedom having no correlation with the sensory experience correspond naturally to the logic of ethics (right/wrong), or more generally the true/false logic of belief system having strong right/wrong emotional coloring. Thus the Goodness-Truth-Beauty trinity would thus have a reduction to the Boolean algebra defined by the Fock basis for the WCW spinor s.

TGD based model of abstraction process involves a hierarchy of statements about statements about.... starting from 2 basic statements such that the statement represented by empty set in the set theoretic realization of Boolean algebra is thrown away at each step. The model predict besides the genetic code also a memetic code consisting of 127-bit code words such that 126-bit statements form a maximal number of mutually consistent statements. In case of genetic code 7-bit code words represent all possible statements and 64-bit codewords represent statements consistent with a fixed atomic statement (single bit fixed).

In real context, 6-bit code words for the genetic code and 126 bit code words for the memetic code code form a maximal number of mutually consistent "this is right thing to do" beliefs. 7-bit resp. 127-bit code words can be interpreted as coding these statements and their negations: all bits must be realized in p-adic case since formal logic requires also the negations of the basic statements.

Lying is a cognitive skill. Genetic code would represent in case of the molecular society the moral and social rules whereas memetic code would represent these rules in case of the ordinary society. DNA would provide a symbolic representation for the 64 fundamental truths, kind of a legal code.

Symbolic and cognitive representations as means of becoming conscious about being conscious about?

An alternative identification of the reflective mind is in terms of language and cognitive representations made possible by the nondeterminism of Kähler action and inherent nondeterminism of p-adic differential equations. These nondeterminisms allow to represent contents of consciousness of self (quantum jump sequence) cognitively and symbolically and to become conscious these representations: this is nothing but becoming conscious about being conscious about...

The (inconvincing) Boolean identification of reflective mind predicts a single directly experienced reflective level. In the second case given quantum jump allows the emergence of only single new reflective level. Indeed, it is easy to become conscious about seeing red but one cannot have direct experience of being conscious about being conscious about seeing red. It is also easy to build theorems about theorems (or imagine what happens under given circumstances) but deriving theorems about theorems about theorems looks impossible without paper and pencil.

Zero energy ontology allows to realize the vision about the reflective hierarchy of consciousness in a concrete manner. The basic building blocks would be negentropically entangled systems representing rules with state pairs defining the entangled state interpreted as instances of the rule. One can construct rules about rules as states formed from this kind of states. The many-sheeted space-time would provide geometric correlates for these rules about rules. The hierarchy of infinite primes would also relate to this abstraction hierarchy.

4.5.4 General model for sensory experiences

The concept of self provides considerable insight to the model of sensory experiencing.

1. If temporal binding involves averaging over the experiences occurred after the wake-up, experiences are reliable.

2. Also the averaging over the experiences of separate sensory subsub-selves implied by the summation hypothesis could be involved.

3. Sensory experiences can involve more than the direct experiencing: also a comparison with the earlier sensory data could quite well be involved and is made possible by subjective and geometric memories. Sensory experiences certainly involve computational aspects.

In the following the general model of sensory experiencing is discussed only briefly [K105].

Macroscopic quantum phases are needed

Self must be able to remain unentangled in subsequent quantum jumps. The presence of the macroscopic quantum condensate means usually energy gap between ground state and excited states. This can make the generation of real entanglement very slow process and self can exist.

The fact that macroscopic quantum phases have coupling to the classical gauge fields, suggests that the order parameters of the macroscopic quantum phases are compeletely determined by the localization in the zero modes. Thus the contents of the sensory experience should correlate with these order parameters. This motivated the original attempt to identify macroscopic quantum phases as quantum correlates of the sensory qualia. A more refined approach identifies quantum phase transitions of the macroscopic quantum phases as correlates of sensory qualia so that the increments of quantum numbers in the phase transition label various qualia. This identification is completely general and almost brain independent (cell length scale turns however be crucially important p-adic length scale).

Many-sheeted space-time concept makes possible large number of macroscopic quantum phases not possible in standard physics context. In particular, the so called massless extremals (MEs) representing "topological light rays" provide a model for how linear structures such as DNA and microtubules could act as quantum antennae emitting and absorbing coherent photon

distribution fixed completely by localization in zero modes. Coherent photons could realize the concept of global workspace [J48] and could make possible "mass media" at neural level. Also the concept of "neural window" abstracting the notion of hologramic brain suggests itself [K26, K50]. MEs form a fractal hierarchy and are carriers of super-symplectic representations for which states are genuine functionals in the space of 3-surfaces ("world of worlds") and thus correspond to higher abstraction level than ordinary quantum states. Super-symplectic states have also gigantic almost degenaries. MEs act also as quantum holograms.

For these reasons MEs are ideal candidates for a hierarchy of life forms [K50]. In particular, the assignment of *"our"* sensory qualia with super-symplectic quantum transitions looks reasonable whereas magnetic quantum phase transitions might well correspond to more primitive chemical qualia not directly conscious to us.

The functions of nerve pulses

The identification of the sensory qualia in terms of the quantum phase transitions associated with macroscopic quantum phases is in conflict with the general belief that neuronal activity determines completely the contents of the sensory experiences. In TGD framework one can understand the role of the nerve pulse activity differently. Brain is quantum spin glass and the evolution of sub-selves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape. The contents of the sensory experiences are determined by the zero modes which in turn determine the ground state patterns of the order parameters of various macroscopic quantum phases.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. One role of the nerve pulses is to provide this metabolic energy feed. This suggests that the axons are seats of the self-organization patterns coding at least part of the neuronal experience. Brain seems to systematically maximize the length of the axons feeding sensory data (for instance, right ear feed its sensory input to the left hemisphere). Brain anatomy seems also to favour long pyramidal axons. This phenomenon, which seems to be in conflict with the principles of good metabolic economy, is consistent with the maximization of the expressive power of the sensory pathways. Microtubule conformations are excellent candidates for realizers of declarative memory and this would also explain why the lengths of sensory axons tend to be maximized. Myelin sheets guarantee that external perturbations do not affect the self-organization patterns. It is also possible that myelin sheets form together with the axon Josephson junctions for various super conductors predicted by TGD and are thus essential for the generation of neuronal sensory experiences.

Nerve pulses affect also the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is that the incoming nerve pulses push and pull the postsynaptic cell in different directions and in this manner cause frustrations typical for spin glass like systems. The assumption that neural transmitters give rise to some kind of chemical senses at neuronal level as well as neuronal emotions is in accordance with this. Also frequency coding is consistent with the identification of the nerve pulse activity as a control function.

Of course, spatio-temporal patterns of nerve pulses might also code information about sensory experience. There is indeed evidence that various odours are coded into spatio-temporal nerve pulse patterns [J116]. For instance, for the neurons of the associative regions of cortex receiving inputs from several sensory modalities this kind of discrimination is obviously highly desirable. One can even consider the possibility that nerve pulse patterns, in some parts of brain at least (in output axons of association regions), provide a precise naming for axonal experiences.

The model for sensory qualia and sensory representations [K50, K62] assumes that nerve pulse patterns generate EEG MEs (massless extremals) entangling brain with the sensory magnetic canvas. The question where the mental images responsible for the sensory qualia are located, still lacks a convincing answer. Primary qualia could even correspond to mental images associated with the sensory receptors and sensory pathways could serve as cortex-receptor entanglers. Brain would give names for sensory inputs and percepts rather than creating the primary qualia. This would require feedback from brain to the sensory organs.

Frequency coding is not the only manner to code information to nerve pulse patterns and delicate temporal coding mechanisms exist. For instance, frequencies can be coded to peaks of the spike interval distribution by stochastic resonance [D6]. Also the coding of spike interval

distribution to EEG frequencies is possible (a kick to a harmonic oscillator at the correct half period leads to a resonant amplification [K100]).

How qualia are associated with neural pathways?

Since TGD predicts entire hierarchy of selves, it is important to specify whose sensory experience one is talking about. In TGD framework nerve pulse patterns as such need not give rise to our sensory exerience and it is quite possible that also primary sensory organs have sensory experiences.

Frustratinly, the question about the seat of quale mental images remains unanswered.

1. The assumption that primary qualia are somehow associated with or determined by the sensory receptors would resolve a difficult question about how sensory pathways, which do not seem to have any obvious differences at the level of brain, give rise to qualia. The entanglement of the sensory receptors with brain in turn entangled with the magnetic body would give rise to the sensory representations. Our sensory experience would not be localizable to what happens in the brain region: indeed, MEs in EEG frequency region have size of order Earth size.

   Various objections (hallucinations, experiences generated by the stimulation of the sensory pathways, phantom leg phenomenon, dreams) against this view can be circumvented if there is a feedback between brain and sensory organs (as there indeed is), and if sensory experiences can also correspond to geometric memories (say in the case of phantom leg experience).

   For instance, pain in phantom leg would be sensory memory of pain in the leg, which still existed. The memory feats of idiot savants and people with left brain damage would be most naturally also due to sensory (visual or auditory) memories. Also ordinary people can have sensory memories when neurons in temporal lobes are stimulated electrically.

   If sensory receptors are the experiencers of the primary sensory qualia, then conscious experience can precede the neural activity in the cortex, as observed by Libet in his classical experiements concerning the timing of the sensory experiencing [J87].

2. A more general view is that the neuronal receptors (also "field receptors" responsible for neuronal vision and hearing can be present) along the sensory pathway are specialized to experience only special sensory qualia characterizing the sensory pathway.

How the primary and possible also secondary sensory receptors or sensory pathways could then give rise to particular qualia? Quite generally qualia correspond to average increments of quantum numbers for the quantum jump sequence defining sub-self. In the case of color qualia one has a partial answer. For MEs super-symplectic quantum transitions are characterized by WCW Hamiltonians carrying spin and color ($SU(3)$) quantum numbers. For WCW photons state functional in WCW degrees of freedom is nontrivial and characterized by WCW Hamiltonian with quantum numbers characterizing a particular quale. This suggests that somehow neural pathway or sensory receptor should be able to generate " WCW photons" (MEs) BE condensing on larger MEs and inducing visual color qualia at least. This would mean that WCW photons would in a well-defined sense carry qualia: the photons generated by sensory receptors and brain could be colored after all!

The educated guess is that the EEG transition frequencies coded the spike interval distributions associated with the sensory pathway characterize the sensory pathway partially. EEG frequencies in turn determine partially the quantum phase transitions which can be stimulated by that particular sensory pathway. The miminal option is that these transitions relate only with what parts of magnetic body the sensory pathway is entangled with. This would make possible very high functional flexibility in accordance with the observed plasticity of brain.

Only changes are perceived

One of the basic laws about sensory experiencing is that only changes and novelties are perceived. For instance, totally monochromatic illumination is experienced as darkness. The zero modes characterizing the macroscopic space-time associated with the final quantum history of the quantum jump should determine the contents of the sensory experience. Part of the zero modes corresponds

to the induced Kähler of CP_2 which is nonlinear Maxwell field closely related to the classical electromagnetic and Z^0 fields. There are also zero modes representing the size and shape of 3-surface: these might be related to the discriminative sense of touch. A possible generalization of the law is that sensory stimulus generates Kähler electric field proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go in this kind of situation?

The solution of the problem might be very simple: mindlike space-time sheet is generated and the flux goes to the mindlike space-time sheet through wormhole contacts. Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mindlike space-time sheets and give rise to selves, mental images already at the level of the sensory organ or the sensory pathway leading to thalamus.

The extreme generality of the mechanism suggests that it could be at work also at the level of brain. Understanding of the computational aspects of sensory experience (say stereovision) is not possible unless one assumes that mindlike space-time sheets in sensory pathway combine with the primary sensory organs to form coherent quantum systems. "Ontogeny recapitulates phylogeny" principle requires that these space-time sheets are connected by flux tubes most naturally associated with axons leading from sensory organ to brain.

Are the ultimate sensory representations realized outside brain?

One of the dramatic almost predictions of TGD inspired theory of consciousness is that our physical body is accompanied by a hierarchy of field bodies, in particular magnetic body. A given field body provides abstract representations about quantum aspects of the physical body, kind of a manual. This prediction plus some general arguments lead to the view that sensory representations are most naturally realized outside the physical body at the personal magnetic body (first person aspect of consciousness) and at the magnetic body of Earth (third person aspect of consciousness).

This vision leads to the interpretation of EEG as being involved with MEs projecting sensory data to the magnetic body. EEG ME would generate quantum entanglement between two mental images: a feature inside brain and a "simple feeling of existence" mental image at the magnetic body and representing a point of the external world. Thus the main function of brain would be the construction of features and sensory representations would be completely separated from their construction. Note that also in the case of computers the representation of the data is separated from the generation of the data.

4.5.5 Emotions

TGD suggests several visions about emotions and it is not yet completely clear whether these views are really mutually consistent.

Emotions and comparisons

The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. Subjective and geometric memories make it possible to compare the expectations with what really occurred during the time interval since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. Many higher emotions such as sorrow, depression, frustration, desire, happiness, feeling of relief, pain, fear, anger, envy, hatred, etc... clearly involve comparison of expectations and reality. This could perhaps mean that these emotions are created by the comparison of the predicted or desired geometric time history and subjective time history (what really happened). This would mean that at least higher emotions differ from the sensory qualia, which seem to be determined solely by the localization into zero modes representing the non-quantum fluctuating aspects of space-time geometry.

One might however argue that very primitive emotions such as rage without any object and involving only the activity of the limbic brain could be quale like and that hormones are the

quantum correlates of these emotions. These emotions involve however a change of behaviour (e-motion!) so that one could argue that also now there is a simple comparison involved. Perhaps changes in the hormone concentrations could be regarded as consequences of the change of the emotional state. Or vice versa, if hormones are messangers telling to very simple selves of limbic brain whether the real course of events was the desired one or not, then hormones indeed effectively control the emotional state and can be regarded as quantum correlates of emotions.

It is difficult to assign any comparison to an emotion like deep love since it involves a complete acceptance of the object of love and is free of desires. Perhaps the claim of mystics that deep experience of love means that subject and object of love cease to exist as separate objects, makes sense. Lovers quantum entangle and die as separate selves (for some fraction of time only, of course!) and the higher self consisting of lovers experiences whole-body consciousness. Perhaps more mundane love means that my sub-selves representing me and the loved one entangle to form a sub-self experiencing whole-body consciousness. Perhaps also feelings like empathy belong to this class of emotions.

Emotions and entropy

The concrete model of qualia to be developed in [K50] provides an alternative general vision about emotions which allows to understand the difference between comparison type emotions and other emotions as well as the role of emotions in control.

1. The statistical physics approach to qualia leads to the hypothesis that emotions correspond to rates for the generation of various type of entropies for the sub-selves of self. The sign of the rate tells whether emotion is positive or negative. Negative emotions would thus be conscious control variables warning self when some sub-system is generating entropy. The holistic nature of the emotions can be understood easily in this picture and also the fact that they are not directly related to sensory input. One could perhaps also understand higher level emotions like sorrow as reflecting the growing disorder of the virtual world of brain resulting from the primary cause of sorrow.

2. It is known that peptides correlate strongly with emotions and moods [J55] and they are even called molecules of emotions. Peptides are also regarded as information molecules. This connection between information and emotions fits nicely with the fact that peptides and other important biomolecules certainly induce strong entropy gradients with respect to subjective time.

3. Sensory qualia can be divided to geometric and non-geometric ones. One can classify also emotions in this manner. Emotions corresponding to the localization in zero modes would perhaps correspond to "higher level emotions" about external world (say, aesthetic qualia) whereas the non-geometric emotions associated with the state preparation would correspond to "self-centered" emotions about the state of body (pain, physical pleasure, ...).

4. Also pure emotions which seem to involve no obvious comparison (love, joy, excitement, ..) are possible. For instance, the emotions produced by music might represent this kind of emotions. The view about emotions as entropy gradients allows to understand also emotions of this kind. In state of deep love, self enters into very low-entropy state and mental images (not necessarily even present in "enlightened states") become very pure.

5. An interesting question is whether the entropy growth of our sensory sub-selves is only sensory representation for the entropy growth occurring at the level of atomic space-time sheets or corresponds directly to it. The enormous difference of the temperatures associated with the atomic space-time sheets (ordinary matter) and superconducting magnetic flux tube structures would suggest that the growth rates for these entropies are of totally different order of magnitude and our emotions serve have the role of conscious control variables telling whether things are going well at the atomic space-time sheets.

Consider now the comparison type emotions and the relation of emotions to control in more detail.

1. Many emotions are comparison type emotions. These emotions tend to be negative (say envy). The first option is that comparison type emotions result from the comparison of geometric and subjective memories occurring automatically in any quantum jump and thus to some degree with any quale. Unfortunately, it is very difficult to imagine how to concretely test this kind of hypothesis and it is also difficult to see how the connection with entropy gradient could emerge.

2. One must also seriously consider the possibility that emotions result from the comparison of remembered/anticipated experience and real experience rather than the fundamental comparison involved with anticipation and memory: kind of quasi-computerized version of geometric memory would be in question. The result of comparison would be coded to the sign of the growth rate of some entropy variable. The comparison could perhaps be realized in such a way that subsequent quantum jumps for comparing sub-system could represent either the anticipated or real quale. If this were the case, the difference between anticipated and real would automatically induce growth of entropy and negative emotion would result. This would be the basic mechanism of dissappointment. In this picture comparison type emotions could be seen as a system of rewards and punishments used to control the self (the controller could be higher level self (conscience) or higher levels selves which also want to survive (the emotions generated by hunger, first, and physical pain). Punish/reward mechanisms could basically involve negentropy/entropy feed to some sub-self.

3. One could also regard emotion as induced by generalized sensory qualia giving information about CNS itself rather than external world or the boundary between external world and body. The regulation involved with the homeostasis involves comparison in an essential manner so that one could perhaps regard emotions as analogous to control variables representing consciously the result of comparison of expected and desired forcing the organism to behave in a way to reduce this difference and end up to a rest and digest state. This aspect is consistent with the statistical interpretation since the entropy gradients associated with the organism are stronger than those associated with the surrounding world. Also amplification mechanisms exaggerating the entropy gradients might have developed. For instance, our reactions to some odours or tastes could involve this kind of amplification.

4. A hypothesis consistent with these views is that emotional component is involved with all sensory experiences and that we are used to call generalized sensory experiences emotions when they are about body. The emotionality of qualia indeed increases in the sequence of perceptive fields external world – CNS-world boundary – body. The degree of emotionality of experience should be characterized by the deviation of real from expected or desired and this suggests that the emotional component is much stronger for sensory experiences about CNS itself, since the system in question is much less predictable than the external world consisting of dead objects. Interpretation of emotion as measure for entropy gradient explains also this hierarchy.

5. Depression could be seen as a lost ability to experience emotions, be they positive or negative. Depression indeed involves emotional flatness. This state results when mental images become maximally entropic (emotional counterpart of heat death). That depression can follow deep sorrow is natural since negative emotions tend to increase the entropy of the mental images. It is known that depression involves over-activity of the amygdala and under-activity of some forebrain regions and an abnormally small population of glial cells known to be closely involved with metabolism and "cleansing activities" at brain level. This supports the view that glial cells might be warriors in the war against second law at the level of atomic space-time sheets and the loss of this war is sensorily mapped to the level of mental images and leads to depression. One function of serotonin, dopamin and various other neuropharmaca tending to produce pleasant experiences could be a reduction of entropy either at atomic space-time sheets or, less probably, directly at the level of our sensory sub-selves.

4.5.6 Directed Attention

The possibility to interpret self as a statistical ensemble suggests that the entropy of the mental image measures its fuzziness. Thus both attentiveness, alertness and level of arousal should relate

very closely to the entropy of the mental images. Attention to a mental image could mean fight against second law to keep the mental image in a low entropy state and this requires metabolism (the icons on the computer screen provide a good example of this). Also alertness means mental images with low entropy content. 7 ± 2 rule of cognitive science suggests that the maximum number of our cognitive sub-selves which can be awake simultaneously, is rather limited. The rule might be based on the metabolic limitations: sub-selves can have low entropy content only in the presence of an external negentropy feed and metabolism must provide the needed negentropy feed. Note however that the needed metabolic energy might be extremely low.

Directed attention is one of the basic processes of consciousness occurring continually. Directed attention seems to involve free choice but focusing of attention could also occur spontaneously. One can imagine several models for the focusing of attention.

1. One possibility is that subsub-self inside sub-self representing mental image (say "monitor screen" as average over subsub-selves representing the visual objects) somehow pops up one level higher in the self hierarchy so that it becomes mental image. Geometrically this could correspond to the re-gluing of the corresponding space-time sheet to the space-time sheet of self instead of that of sub-self. In this case attended object would not pre-exist.

2. A further aspect of the focused of attention is as a wake-up of sub-self and keeping it in wake-up state and hence in short term memory. This could occur at the expense of the other sub-selves, which would be in wake-up state for only short times. A possible mechanism of selection is a phase transition changing the topology of chosen region (say from p-adic to real or from p_1-adic to p_2-adic) so that a new sub-self pops up from the background.

3. Self directs automatically its attention only to sub-systems immediately below it in the hierarchy. It seems however possible to direct attention to lower levels of the self hierarchy. For instance, I can direct my attention to the entire sentence, which I am writing here or to some word of this sentence or to individual letters of this word. The phenomenon of bio-feedback demonstrates that it is possible to learn to direct the attention to even single neuron. This suggests that selves are able to modify the hierarchy of selves by raising some sub...sub-self to the role of sub-self temporarily and thus experience the former sub...sub-self as a direct mental image. Formation of the flux tubes between mindlike space-time sheets at various levels of the self hierarchy provides a general geometric mechanism making possible temporary changes of the structure of the self hierarchy. Also the learning taking place during sleep [J102] migh involve interaction between different levels of the self-hierarchy.

Anyone can do a simple but thought provoking experiment suggesting the presence of the macroscopic quantum entanglement at the level of brain and a change of the level of sub-self in the self hierarchy. Look at a mirror, direct your attention at your left eye, and redirect the gaze to the right eye. What you find that it is impossible to perceive the change in the direction of the eye gaze.

1. Consider first what probably happens when we perceive a moving object. A negentropic binding of the mental images of the visual field to single mental image implies that both the parts and the whole can be experienced so that the motion is perceived. If the direction of the gaze is stationary, the object moves relative to the background, and if the direction of the gaze follows the object the background moves with respect to the direction of gaze. In both cases the motion can be perceived.

2. If the eye follows its own rotating mirror image, neither of these options is realized if the environment to which the attention is directed is restricted to be the eye itself. The direction of the gaze should remain the same in order to perceive the change of the direction of the gaze but this is impossible.

3. The perceptive field however contains also other objects and one could argue that if the attention is directed also to these simultanenously, it should be possible to perceive the changing direction of gaze as they move relative to the changing direction of gaze. Does the very act of directing attention to the mirror image of eye separate it from the negentropic entanglement with the other mental images so that the conscious comparison with them is

not possible anymore? Or is the visual mental image representing eye at a different level of hierarchy as mental images from the very beginning and cannot negentropically entangle with the other visual mental images? Eye cannot perceive itself! Not even in mirror.

One should also understand what it means to direct the attention to an object of perceptive field. Certainly this process is directed and selective. Could the direction of attention to an object of perceptive field separate the corresponding mental image from the negentropic fusion of mental images as a separate mental image? Could it be that the motion of object can be perceived only if the attention is fixed only temporarily to the object? There are almost incredible sounding experiments demonstrating that the attention directed intensely to a fixed object makes it impossible to perceive what happens in environment.

4.5.7 Altered States Of Consciousness

The proposed concept of self provides allows rather rich a palette of altered states of consciousness and one cannot avoid the temptation to a concrete modelling of various altered states of consciousness. It seems that negentropic entanglement provides a general explanation for the reported characteristic of these experiences.

Whole-body consciousness and ordinary consciousness

Krishnamurti has described in his books states of consciousness having natural identification as states of "whole-body consciousness". For instance, according to Krishamurti, one can achieve this state only if one is able to stop thinking entirely. If thoughts correspond to cascades of selves decomposing into sub-selves during state function reduction proess, then this is just what is required. The characteristic of this state of consciousness as reported by meditators are the experience of one-ness and the absence of all separations. The absence of separation would conform with negentropic entanglement. One-oneness could correspond to irreducible selfness without subselves or to the negentropic fusion of mental images to single mental image. Also "timelessness" characterizes these experiences: the explanation is that internal clock is provided by some sub-self waking up periodically and since there are no sub-selves there can be no time. Note also that negentropic time like entanglement fuses the subselves assignable to the future and past boundaries of CD to single self.

I have personally experienced states of whole-body consciousness and also states in which whole-body consciousness is limited to some part of body. These states begin with a sudden fall of silence: all the usual "noise" from the body disappears suddenly although ordinary physical sounds are still heard. This could be interpreted as disappearance of sub-selves from body or as generation of negentropic entanglement stable under quantum jumps. There is experience like thrill in spine going through the entire body. Interesting experience of this kind occurred when my cat was sleeping over my breast: I woke up and realized that my breast was in the state of whole-body consciousness. Could this mean that sleeping cat was also in this state and that my breast had entangled with the quantum state of cat? Could this in turn mean that during sleep we indeed are in a state of whole-body consciousness or even that our entire body is entangled with some large self? Could the absence of neuronal quantum jumps explain why we do not remember anything about these states? Are remembered states of whole-body-consciousness always such that at least some part of brain is awake?

Possession of ego defined as a collection subselves, which repeatedly unentangle themselves from the external world means dissipation, aging and eventual physical death (note however that self lives as a conscious memory realized as a sub-self of higher level self providing kind of summary about the lifetime of self). There would be two ways to getting rid of ego. Get rid of subselves or try to achieve a state in which they negentropically entangle to single mental image.

The absence of neuronal and cell level dissipation during states of whole-body consciousness provides a possible test for the phenomenonon. Test persons could be trained meditators and test should involve the measurement of neural or cellular dissipation occurred during the state of whole-body consciousness. Reduced rate of metabolism could be a measurable signature of whole-body consciousness. Dissipation should be absent or should be very small during this state at least if it is present for sufficiently large fraction of time. The absence of dissipation means

that all changes suffered by the cells during whole-body consciousness are reversible and curable. This could explain various miraculous healings. Whole-body consciousness, if possible to arrange artificially, could provide medical means of saving the lifes of victims of accidents (say of victim of heart attack or bleed in brain).

Negentropic entanglement allows the component systems to be free in the sense that there is no binding energy. Even more, negentropic systems could carry metabolic energy but would not liberate it or liberate it in much longer time scale than usually (also large $\hbar$ could be involved). As a matter fact, the high energy phosphate bond assumed in the model of metabolism could correspond to negentropic entanglement carrying metabolic energy [K45, K46].

Synchronous neural firing is a possible candidate for whole-body consciousness at the level of brain.

1. The anomalously low value of neuronal oxidative metabolism during synchronous neuronal firing in cortex could be interpreted in terms of negentropic inter-neuronal entanglement during which ATP-ADP Karma's cycle is absent and dissipation is reduced.

2. One could of course argue that metabolic energy is liberated but from other source than ATP. For instance, the formation of bound state entanglement between the group of firing neurons could liberate the binding energy as metabolic energy. The formation of hydrogen bonds could be the counterpart for the process at molecular level. This mechanism would however imply dissipation and there is no strong reason to assign whole-body consciousness to this kind of state (of course, synchoronous neural firing need not corre.

Whole-body consciousness could explain some spectacular phenomena (not of course taken seriously by skeptics).

1. The claimed ability of yogis to survive for months without eating anything and even without oxygen could have explanation in terms of whole-body consciousness. Oxygen consumption compensates the loss of chemical energy caused by the quantum jumps in biochemical length scales. These quantum jumps occur only if neuronal and lower level chemical selves exist. Under usual circumstances the continuous supply of oxygen makes the aging of cells slow and the lack of oxygen leads to rapid dissipation and neuronal death. The situation is analogous to Benard flow: if heat feed is stopped, the beautiful flow pattern rapidly dissipates away. If all cells are entangled during whole-body consciousness, no dissipation occurs and the lack of the oxygen supply does not have any irreversible effects and possible effects might be cured automatically. An alternative explanation for the mystery of yogis who need not eat is that the generation of bound state entanglement involves the liberation of the binding energy as a usable energy possibly compensating for the ordinary metabolic energy.

2. In certain cultures people in trance are able to dance with their bare feet on burning charcoals without any disastrous effects. The disastrous effects of the interaction of heat from burning charcoals with cells in soles of foot must be irreversible changes. If these persons are in a state of whole-body consciousness, then the changes of the invididual cells would reversible.

That-which-is experiences

Irreducible self does not possess any sub-selves. The absence of sub-selves in turn means the absence of mental images. This kind of situation could correspond to that-which-is experience. The reports of Buddhist meditators about pure awareness with discrete twinkles of consciousness identifiable as short-lived sub-selves are in accord with this view.

In principle meditation could make possible to silence the hierarchy sub-selves and make it possible to directly experience quantum jumps occurring at elementary particle level! In zero energy ontology the temporal size scales assignable to elementary particles are time scales of human consciousness (electron corresponds to.1 second time scale and u and d quarks to millisecond time scale) plus the hierarchy of Planck constants as a realization of dark matter hierarchy crucial for living matter and predicting scaled up variants of these time scales, this idea need not be so crazy at it looks at first sight. In this speculative spirit one could even consider the possibility that the abstract theories of elementary particle physics result basically as a summation of the experiences

of matter-mind sub-systems entangled with elementary particles! One can even consider the possibility that genetic code is realized in terms of the sub-CDs assignable to the electronic CDs and could form first level realization of the phonemes of language.

One can also considera weaker notion of one-ness in which self has only single mental image. In this case sub-selves would fuse to single subself either by bound state entanglement or negentropic entanglement. The formation of these states is accompanied by the formation of flux tubes -say magnetic flux tubes- between space-time sheets representing binding sub-systems. State function reduction does not occur in these degrees of freedom anymore, macroscopic quantum coherence is preserved from quantum jump to quantum jump, and the system behaves as macroscopic multiverse with new macroscopic degrees of freedom making possible macroscopic quantum computation. This might be the mechanism for how water, DNA, protein, tubulin, ... molecules and even neurons bind to quantum computing macroscopic multiverses [K3].

Zen type experiences and negentropic entanglement

Negentropic entanglement is possible in the intersection of real and p-adic worlds. Negentropic states are not eigenstates of measured observables giving information about the quantum numbers of the system or its complement but about the entire system. Conscious experience is an abstraction about the correlation between states of entangled systems- a rule with instances of the rule being represented as state pairs. Negentropic entanglement can be also time-like and between systems corresponding to space-time sheets in different number fields in the intersection of real and p-adic worlds. The simplest example about negentropic entanglement are fuzzy qubits. Zero energy ontology allows to imagine entire hierarchies of negentropic entanglements between negentropic states and an attractive interpretation is in terms of a reflective hierarchy producing statements about statements.

The reported experience about disappearence of illusions would conform with the interpretation about experience of understanding assignable to the state. The disappearence of the decomposition to observer and observed would correspond to the experience of oneness. Zen Buddhists experiences are often characterized as states of consciousness in which no selection is made between mutually exclusive alternatives. Hofstadter has described this aspect of Zen in hilarious manner in his book "Gödel, Escher, Bach". Also this aspect conforms with the basic properties of negentropic entanglement.

The absence of external-world-me separation and absence of desires is also reported to be a characteristic feature of that-which-is and Zen type experiences. Ego separates itself from external world in quantum jump by state function reduction leading to an uncorrelate product state. Ego disappers when the self fuses with external world negentropically. Perhaps also desires could be equated with the tendency to preserve ego.

Extended states of consciousness

Extended states of consciousness seem to be the exact opposite of that-which-experiences. Psi experiments concern subtle connections between subjects removed in space, and occasionally also in time. These experiments are reviewed in [J72] and the following representation follows this review closely. The pioneering work related with card and dice-guessing was done by J. B. Rhine in 1930s.

The formation of negentropic entangelement gives a natural general explanation of these experiences. Negentropic sharing and fusion of mental images would be part of the mechanism for extended states of consciousness.

The notions of geometric memory and electromagnetic self allow also to understand basic features of these experiences. For instance, the notion of geometric memory allows to understand memories about previous lives and prenatal experiences in which the the contents of consciousness is time shifted. The model for sensory representations leads to the conclusion that the topological field quanta of ELF fields, having frequencies in EEG range and by Uncertainty Principle having size of Earth, are crucial element of our sensory experience. The formation of flux tubes between topological field quanta associated with different selves could explain a large variety of paranormal experiences.

1. The experiments of Russel Targ and Harold Puthoff

The experiments of Russel Targ and Harold Puthoff [J170] were carried in the 1970's some of the best known experiments on subtle connections among distant subjects in regard to the transference of thoughts and images. Both sender and receiver were closed in a sealed, opaque, electrically shielded chamber so that no sensory communication was possible. Sender was subjected to light flashes at regular intervals. This caused a characteristic pattern in the EEG of the sender. In some cases also the receiver exhibited these rhytms.

In remote vision experiments sender served as a beacon. Receiver tried to describe verbally or by scetches what the beacon saw. Independent judges matched on the average 66 per cent of time with what was actually seen by the beacon. There are also remote viewing experiments from other laboratories. The distances between sender and receiver vary from miles to thousands of miles and it seems that distance does not matter.

Distance independence supports the interpretation of both experiments in terms of fusion and sharing of mental images.

2. The experiments of Stanley Krippner

In the experiments of Stanley Krippner [J173] image transmission was studied while receiver was asleep. Experimenter, sender and volunteer met each other in the beginning of the experiment. Sender spent the night concentrating on an art print, which he/she had received in the beginning of the experiment in a closed envelope. The brain waves and eye movements of the volunteer were recorded. The experimenter woke the volunteer at the end of the REM period by intercom and the volunteer described the dream.

A correlation between the contents of the dream and of the art print was observed. The score was higher on nights, when there were few or no electric storms in the area and sunspot activity was lowest.

The simplest interpretation is again in terms of fusion of mental images of the subject persons. These mental images are perhaps represented at the personal magnetic sensory canvas. Electric storms and sunspot activity affect directly Earth's magnetic field and should affect the communication mechanism since the experiments of Blackman and other suggest that em selves could correspond to magnetic transition frequencies associated with magnetic field of.2 Gauss which is near to the nominal value .5 Gauss of the Earth's magnetic field. In fact, there exists independent evidence for a general correlation of geomagnetic activity with psi experiences [J133].

3. The experiments of J. Grinberg-Zylverbaum

In the experiments of J. Grinberg-Zylverbaum [J81] the transfer of EEG potentials was studied. Two subject persons were involved. They were closed in Faraday cages. The sender was meditating. Another subject person was subject to a stimulus in random intervals; not even the experimenter knew, when they were applied. Non-stimulated subject person was in a relaxed state. Stimulus was sudden, short light or sound or short electric shock to index and ring fingers of the right hand causing a characteristic pattern in the EEG of the stimulated person.

The EEG's of the subject persons were synchroninized. The possible presence of transferred potentials in the EEG of nonstimulated subject was studied. Transferred potentials were detected in 25 percent of all cases *provided* persons had met before the experiment. A dramatic example was young couple, deeply in love, whose EEGs remained synchronized throughout the experiment.

The fusion of ELF selves means synchronization of ELF em fields and since ELF selves correspond directly to EEG frequencies, synchronization of EEGs is an immediate consequence and can transfer the synchronous firing in brain circuit of the sender to corresponding brain circuit of the receiver. The personal contact before the experiment certainly enchanges the probablity for the fusion of ELF selves. Also quantum entanglement between sub-selves of subject persons might be involved.

It is known that the EEGs of right and left brain are synchronized in deep meditation. There are also experiments of synchronization of EEGs for different subjects in group meditation [J140]. The explanation is same as in above case. Also quantum entanglement might be involved. For instance, quantum entanglement is crucial for the fusion of left and right perceptive fields to single perceptive field.

4. Telesomatic effects

Also the tansfer of actual bodily effects from subject person to another has been studied:

references to these experiments can be found in [J72]. Physiological changes are found to be triggered in the targeted person by the mental process of another. Distance makes little of no difference. Thus the interpretation in terms of quantum entanglement suggests itself.

There are also reports of the transference of pain between persons having very close mutual relationship. Identical twins, mothers and their sons or daughers, couples in love, etc, . Also the relationship between psychiatrist and patient provides example of this kind and is known as projective identification. The general rule seems to the that the relationship between inviduals is always involved with psi effects. This is in accordance with the hypothesis about sharing of mental images having ELF em fields and field bodies as physical correlates. For instance, the field bodies of persons in an intimate relationhip might develop gradually direct contacts (say magnetic flux tubes connecting physical bodies).

5. Grof's experience with altered states of consciousness

Findings of modern psychotherapists, especially the work of Stanislav Grof [J72, J163] suggest that besides the ordinary "biographic-recollective" domain of psyche also perinatal and transpersonal domains of psyche exist. Transpersonal domain can mediate connection between our mind and practically any part or aspect of the phenomenal world. Grof studied for several decades altered states of consciousness induced by psychedelic drugs or holotropic breathing.

In the experience of *"dual unity"* , loosening and melting of the boundaries of the body ego happens but in the merging with another person, own identity is not lost. In the *identification* with another person loss of own identity occurs. Body image, physical sensations, emotional reactions and attitudes, thought processes, memories, facial expressions, typical gestures and mannerisms, postures, movement and even the inflection of the voice become those of the second person. The other can be someone in the presence or absent. Identification involving time shift is also possible. Part of an experience can come from subject's childhood, his or her ancestry or even of a previous lifetime.

Also group identification and group consciousness is possible. Person can identify with an entire group of people having some racial, cultural, national, ideolological, religional, political or professional characteristics. People may experience the totality of suffering of all the soldiers or tenderness of all lovers and dedication of all mothers in regard to their babies.

Identification with animals is possible. This involves body image, specific physiological sensations, instinctual drives, unique perceptions of the environment, emotional reactions, etc.. Person can identify with plants and botanical processes. Also identification with inorganic world can occur. People can identify with rivers, storms, tornadoes, mountains, ... Or stones, quartz crystals, minerals.... Even the identification with structures of atomic and sub-atomic world is claimed to be possible. At the second end of spectrum are racial and collective experiences and identification with entire human species and the experiences in which one identifies with the whole Earth or even entire cosmos. Also out of body experiences, clairvoyance, clairaudience and telepathy are common. Displacement in time is possible. Patient can have embryonical and fetal experiences and even ancestral experiences as well as past incarnation experiences.

Identification experiences can be generally understood as sharing and fusion of mental images. The fusion of mental images can occur between very many inviduals, say members of a species and would give rise to kind of stereo consciousness analogous to the stereo vision resulting in the fusion of left and right visual fields. We could also share this stereo consciousness: for instance, shamanist could share the mental images of animal species.

Perinatal experiences and memories extending beyond the lifetime of individual could be explained in terms of geometric memory and the notion of 4-dimensional body: actually these experiences do not in any significant manner differ from ordinary memories. The content of the conscious experience is multilocal both in subjective and geometric time in the sense that the experience contains contributions from several moments of geometric time simultaneously.

Our personal self hierarchy could actually contain higher levels than the levels represented by ELF emf fields associated with EEG. This hypothesis makes sense if the contribution of the higher levels of our self hierarchy to our conscious experience under normal circumstances is only some kind of general awareness ("silent observer"). These higher levels could actually explain the experienced continuity of self. For instance, during sleep there there would be some kind of basic awareness present: the lack of memories about sleep state would lead to, in this framework, erraneous conclusion that sleep state is unconscious.

4.6 Boolean Mind And Cognition

4.6.1 Fermions And Boolean Cognition

Fermionic Fock state basis defines naturally a quantum version of Boolean algebra. In zero energy ontology predicting that physical states have vanishing net quantum numbers, positive and negative energy components of zero energy states with opposite fermion numbers define realizations of Boolean functions via time-like quantum entanglement. One can also consider an interpretation of zero energy states in terms of rules of form $A \to B$ with the instances of A and B represented as elements Fock state basis fixed by the diagonalization of the density matrix defined by $M-$-matrix. Hence Boolean consciousness would be basic aspect of zero energy states. Physical states would be more like memes than matter. Note also that the fundamental super-symmetric duality between bosonic degrees of freedom (size and shape of the 3-surface) and fermionic degrees of freedom would correspond to the sensory-cognitive duality.

This would explain why Boolean and temporal causalities are so closely related. Note that zero energy ontology is certainly consistent with the usual positive energy ontology if unitary process U associated with the quantum jump is more or less trivial in the degrees of freedom usually assigned with the material world. There are arguments suggesting that U is tensor product of of factoring S-matrices associated with 2-D integrable QFT theories [K28]: these are indeed almost trivial in momentum degrees of freedom. This would also imply that our geometric past is rather stable so that quantum jump of geometric past does not suddenly change your profession from that of musician to that of physicist.

4.6.2 Fuzzy Logic, Quantum Groups, And Jones Inclusions

Matrix logic [A6] emerges naturally when one calculates expectation values of logical functions defined by the zero energy states with positive energy fermionic Fock states interpreted as inputs and corresponding negative energy states interpreted as outputs. Also the non-commutative version of the quantum logic, with spinor components representing amplitudes for truth values replaced with non-commutative operators, emerges naturally. The finite resolution of quantum measurement generalizes to a finite resolution of Boolean cognition and allows description in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of infinite-dimensional Clifford algebras of the world of classical worlds (WCW) identifiable in terms of fermionic oscillator algebras. $\mathcal{N}$ defines the resolution in the sense that quantum measurement and conscious experience does not distinguish between states differing from each other by the action of $\mathcal{N}$.

The finite-dimensional quantum Clifford algebra $\mathcal{M}/\mathcal{N}$ creates the physical states modulo the resolution. This algebra is non-commutative which means that corresponding quantum spinors have non-commutative components. The non-commutativity codes for the that the spinor components are correlated: the quantized fractal dimension for quantum counterparts of 2-spinors satisfying $d = 2cos(\pi/n) \leq 2$ expresses this correlation as a reduction of effective dimension.

The moduli of spinor components however commute and have interpretation as eigenvalues of truth and false operators or probabilities that the statement is true/false. They have quantized spectrum having also interpretation as probabilities for truth values and this spectrum differs from the spectrum $\{1, 0\}$ for the ordinary logic so that fuzzy logic results from the finite resolution of Boolean cognition [K138].

4.6.3 P-Adic Physics As Physics Of Cognition

p-Adic physics as physics of cognition and intentionality provides a further element of TGD inspired theory of consciousness. At the fundamental level light-like 3-surfaces are basic dynamical objects in TGD Universe and have interpretation as orbits of partonic 2-surfaces. The generalization of the notion of number concept by fusing real numbers and various p-adic numbers to a more general structure makes possible to assign to real parton a p-adic prime p and corresponding p-adic partonic 3-surface obeying same algebraic equations. The almost topological QFT property of quantum TGD is an essential prerequisite for this. The intersection of real and p-adic 3-surfaces would consists of a discrete set of points with coordinates which are algebraic numbers. p-Adic partons would relate to both intentionality and cognition.

Real fermion and its p-adic counterpart forming a pair would represent matter and its cognitive representation being analogous to a fermion-hole pair resulting when fermion is kicked out from Dirac sea. The larger the number of points in the intersection of real and p-adic surfaces, the better the resolution of the cognitive representation would be. This would explain why cognitive representations in the real world are always discrete (discreteness of numerical calculations represent the basic example about this fundamental limitation).

All transcendental p-adic integers are infinite as real numbers and one can say that most points of p-adic space-time sheets are at spatial and temporal infinity in the real sense so that intentionality and cognition would be literally cosmic phenomena. If the intersection of real and p-adic space-time sheet contains large number of points, the continuity and smoothness of p-adic physics should directly reflect itself as long range correlations of real physics realized as p-adic fractality. It would be possible to measure the correlates of cognition and intention and in the framework of zero energy ontology [K28] the success of p-adic mass calculations can be seen as a direct evidence for the role of intentionality and cognition even at elementary particle level: all matter would be basically created by intentional action as zero energy states.

4.6.4 Infinite Primes And Cognition

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and TGD inspired theory of consciousness. What this role precisely is has remained an enigma although I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a representation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed. Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic variants as space-time correlates for the fermionic super generators. Intentions/actions are represented by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action. It must be emphasized that this interpretation is not identical with the one discussed above since it introduces different identification of the space-time correlates of infinite primes.

Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given level define the building blocks of the infinite primes of the next level. One can map infinite primes to polynomials and these polynomials in turn could define space-time surfaces or at least light-like partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B, n_B, and s_F are defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors. The integers m_B and n_B characterize the occupation numbers of bosons in modes labelled by p_i and q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the possibility that the quaternionic components represent some quantum numbers at least in the sense that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether WCW degrees of freedom and WCW spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly hyper-octonionionic primes would define as such the quantum numbers of fermionic super generators does not make sense. It is however possible to have a map from the quantum numbers labelling

super-generators to the finite primes. One must also remember that the infinite primes considered are only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

Algebraic Brahman=Atman identity

The proposed view about cognition emerges from the notion of infinite primes [K118], which was actually the first genuinely new mathematical idea inspired by TGD inspired consciousness theorizing. Infinite primes, integers, and rationals have a precise number theoretic anatomy. For instance, the simplest infinite primes correspond to the numbers $P_\pm = X \pm 1$, where $X = \prod_k p_k$ is the product of all finite primes. Indeed, $P_\pm \ mod \ p = 1$ holds true for all finite primes. The construction of infinite primes at the first level of the hierarchy is structurally analogous to the quantization of super-symmetric arithmetic quantum field theory with finite primes playing the role of momenta associated with fermions and bosons. Also the counterparts of bound states emerge. This process can be iterated: at the second level the product of infinite primes constructed at the first level replaces X and so on.

The structural similarity with repeatedly second quantized quantum field theory strongly suggests that physics might in some sense reduce to a number theory for infinite rationals M/N and that second quantization could be followed by further quantizations. As a matter fact, the hierarchy of space-time sheets could realize this endless second quantization geometrically and have also a direct connection with the hierarchy of logics labeled by their order. This could have rather breathtaking implications.

1. One is forced to ask whether this hierarchy corresponds to a hierarchy of realities for which level below corresponds in a literal sense infinitesimals and the level next above to infinity.

2. Second implication is that there is an infinite number of infinite rationals behaving like real units ($M/N \equiv 1$ in real sense) so that space-time points could have infinitely rich number theoretical anatomy not detectable at the level of real physics. Infinite integers would correspond to positive energy many particle states and their inverses (infinitesimals with number theoretic structure) to negative energy many particle states and $M/N \equiv 1$ would be a counterpart for zero energy ontology to which oneness and emptiness are assigned in mysticism.

3. Single space-time point, which is usually regarded as the most primitive and completely irreducible structure of mathematics, would take the role of Platonia of mathematical ideas being able to represent in its number theoretical structure even the quantum state of entire Universe. Algebraic Brahman=Atman identity and algebraic holography would be realized in a rather literal sense.

This number theoretical anatomy should relate to mathematical consciousness in some manner. For instance, one can ask whether it makes sense to speak about quantum jumps changing the number theoretical anatomy of space-time points and whether these quantum jumps give rise to mathematical ideas. In fact, the identifications of Platonia as spinor fields in WCW on one hand and as the set number theoretical anatomies of point of embedding space force the conclusion that WCW spinor fields (recall also the identification as correlates for logical mind) can be realized in terms of the space for number theoretic anatomies of embedding space points. Therefore quantum jumps would be correspond to changes in anatomy of the space-time points. Embedding space would be experiencing genuine number theoretical evolution. The whole physics would reduce to the anatomy of numbers. All mathematical notions which are more than mere human inventions would be imbeddable to the Platonia realized as the number theoretical anatomies of single embedding space point.

In [K29, K118] a concrete realization of this vision is discussed by assuming hyper-octonionic infinite primes as a starting point. The simplest realization of infinite octonionic/quaternionic primes as products of infinite primes and octonions avoids the problems related to non-associativity and commutativity. Quantum states are required to be associative in the sense that they correspond to quantum super-positions of all possible associations for the products of finite primes (say $|A(BC)\rangle + |(AB)C\rangle$). The ground states of super conformal representations would correspond to

infinite primes mappable to space-time surfaces (quantum classical correspondence). The excited states of super-conformal representations would be represented as quantum entangled states in the tensor product of state spaces $\mathcal{H}_{h_k}$ formed from Schrödinger amplitudes in discrete subsets of the space of 8 real units associated with embedding space 8 coordinates at point h_k: the interpretation is in terms of a 8-fold tensor power of basic super-conformal representation. Although the representations are not completely local at the level of embedding space, they involve only a discrete set of points identifiable as arguments of n-point function. The basic symmetries of the standard model reduce to number theory if hyper-octonionic infinite rationals are allowed. Color confinement reduces to rationality of infinite integers representing many particle states.

4.7 Quantum Correlates Of Qualia

The basic theoretical ingredients described above lead to the following general vision about qualia described in detail in [K50]. In the following the latest view about theory is summarized. The notion of quale is understood in an extremely general sense: "primary attribute of conscious experience" might serve as a synonym for "quale" in the sense as it is used in the following.

4.7.1 Development Of Ideas

To achieve something which would deserve to be called a general theory of qualia required almost a decade. During the first years, and in lack of any general theory of qualia, I could only make educated guesses, which were doomed to be wrong.

1. A connection between qualia and EEG MEs emerged, when I learned about the effects of classical electromagnetic fields on brain at frequencies which are cyclotron frequencies or amplitude modulated by cyclotron frequencies [J64].

2. The discovery that p-adic physics is physics of cognition (or at least imagination, one should be very cautious in order to avoid over generalizations!) clarified the views about the relationship between cognition and sensory experience [K81].

3. The notion of the many-sheeted ionic flow equilibrium was a further important breakthrough [K21, K22]. It allowed to realize that MEs, superconducting magnetic flux tubes, and ordinary biomatter at atomic space-time sheets form a three-levelled master-slave hierarchy.

4. The realization that MEs carrying super-symplectic representations at their light-like boundaries are excellent candidates for the carriers of at least some of our qualia, gave a totally new perspective to the problem of qualia [K85]. It seems however that MEs are not all that is needed: our qualia involve both super-symplectic and magnetic quantum phase transitions.

5. The work with the problems related to the precise formulation of Negentropy Maximization Principle led to the realization that each quantum jump defines a quantum measurement followed by a state preparation leading to an unentangled product state. This means the reduction of the quantum measurement theory to basic quantum TGD. The next realization was that the quantum jump sequence defining self defines a statistical ensemble of prepared states. One can identify the fundamental statistical ensembles of statistical physics as selves and implied a deep and precise connection between thermodynamics and the theory of qualia allowing a general classification of qualia and an identification of their thermodynamical correlates.

6. The last breakthrough in development, which is still continuing, was the realization that very general arguments lead to the view that ultimate (conscious-to-us) sensory representations are realized outside the body on the magnetic canvas provided by the magnetic flux tube structures associated with brain and having most plausibly size for which Earth size as a natural unit. One can see cortex as a collection of standard features some of which are associated to the objects of the perceptive field represented as magnetic sub-selves. Frequency place coding (MEs generate magnetic quantum phase transitions) plays a key role in this association.

Music metaphor at axonal level

Music metaphor has been one philosophical quide line behind the identification of the quantum correlates of the sensory qualia.

1. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes and this generates EEG MEs at EEG frequencies serving as entanglers to the sensory magnetic canvas and the variation of these frequencies could code for the distance to the object of the perceptive field.

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

   A stronger interpretation of the metaphor is that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a sensory modality associated with the sensory pathway. Nerve pulse patterns determine the experience as chords from from the notes of various instruments in the same sense as the musician produces the music. This leads to a generalization of the idea about brain as an associative net.

   More concretely, postsynaptic receptors act as neuronal sensory receptors and transmitters emitted and MEs generated by the presynaptic neuron induce neuronal sensory experiences in the postsynaptic neuron. The specialization of the neuronal receptors would be same for the entire sensory pathway and determine the qualia associated with it.

2. Resonance is an essential aspect of music instrument as is resonant frequency modulation which can involve several levels. The frequencies characterizing the hierarchical modulation provides a partial characterization of the sensory representations. Quantum mechanically resonance corresponds to a harmonic perturbation with frequency which is difference of energies for the states of some sub-system. In this kind of situation quantum jumps can be amplified to quantum phase transitions and sub-self representing mental image wakes up.

Unfortunately, music metaphor is only a metaphor and has led to a plethora of various models for qualia.

ME's and qualia

The identification of MEs as building blocks of sensory and cognitive structures leads to a rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other, magnetic flux tube structures, and the matter at atomic space-time sheets. The realization that MEs serve as quantum holograms and the properties of the super-symplectic stats gave the final justification for this identification. The model allows to understand EEG as a direct physical correlate of mind-like space-times sheets (MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also what might be called RF (radio frequency) and MW (microwave) MEs representing our mental images are crucial for the model.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our radiation body. Also the notion of magnetic body is needed. It took a long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; or with self having literally infinite size. The last two options seems to be more plausible than the first two: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body. The simplest option is that the relevant magnetic flux tube structures have same sizes as ELF MEs. During sleep our attention might be directed to transpersonal levels of consciousness.

MEs, magnetic superconductors, and many-sheeted ionic flow equilibrium

The lack of clearcut empirical evidence for the predicted supra phases has been a stumbling block for the quantitative development of the theory for a long time. The situation changed dramatically when I learned about the effects of ELF em fields on living matter[1]. This article provided the ingredients making possible a general quantitative model of quantum control and coordination in which self hierarchy has as its dynamical correlate hierarchy of weakly coupled super conductors and massless extremals (MEs) interacting with the ordinary matter at atomic space-time sheets. MEs indeed provide a model of Josephson junction and an explanation for the amplitude windows observed in the experiments of Blackman and others [J139].

Later the experimental findings challenging the notions of ionic channels and pumps [I39] led to the identification of homeostasis as many-sheeted ionic flow equilibrium in which the ionic concentrations at atomic space-time sheets are controlled by much smaller ionic concentrations at superconducting magnetic flux tubes. MEs control superconducting magnetic flux tubes via magnetic induction, by inducing magnetic phase transitions and by acting as Josephson junctions between magnetic flux tubes.

Magnetic transitions at superconducting magnetic flux tubes serve as seeds for phase transitions in quantum critical quantum spin glass type phase of macroscopic super conductor leading to generation of a region of new kind of phase whose quantum numbers differ from old one by the quantum numbers associated with magnetic transition frequency. Thus quantum transitions are amplified to macroscopic quantum transitions and Bose-Einstein condensation (analogous to induced emission) is the basic mechanism behind the process.

The first natural guess was that magnetic quantum phase transitions correspond to our qualia. That transition frequencies are involved is indeed in nice accordance with quantum jumps between histories as moment of consciousness identification. However, the fact that magnetic states correspond to a lower level of abstraction than super-symplectic states associated with MEs, suggests that magnetic qualia do not correspond to our qualia directly. Rather primitive chemical qualia experienced by cell level selves might be in question.

The role of super-symplectic algebra

An important step in the development of the theory of qualia was the realization of the importance of super-symplectic symmetries. The answer to this question might have been guessed by taking quantum measurement theory as a starting point.

1. Basic geometric objects is the configuration space of all possible 3-surfaces in $M^4_+ \times CP_2$. In absence of non-determinism of Kähler action everything would reduce to the boundary of the future light-cone ($\delta M^4_+ \times CP_2$) carrying representations of super-symplectic and superconformal algebra localized with respect to the light-like radial coordinate of the light-cone boundary. These symmetries are obviously cosmological. Also quaternion conformal symmetries are possible and these can be identified as the TGD counterparts of string model conformal symmetries responsible for elementary particle quantum numbers.

2. The non-determinism of Kähler action forces to introduce super-symplectic representations at the light-like boundaries X^3 of MEs acting as quantum holograms. Thus superconformal and super-symplectic symmetries become macroscopic symmetries and must be crucial for consciousness.

3. There are two kinds of WCW degrees of freedom: quantum fluctuating non-zero modes and zero modes which can be regarded as classical, non-quantum fluctuating degrees of freedom in complete consistency with the reduction of standard quantum measurement theory to the localization in zero modes occurring in each quantum jump. Zero mode algebra contains the generators of super-symplectic algebra with even conformal weight. In particular, zero modes contain the points of an infinite-dimensional flag-manifold extended to contain the radial Virasoro algebra of the light-like boundary of ME localized with respect to CP_2. Radial coordinate corresponds to the light-like coordinate of the light-like boundary of ME. This flag-manifold parametrizes all possible choices of the quantization axes for the canonical Lie-algebra.

[1] I am grateful for Gene Johnson for sending me the popular article of Yarrow [J64] about bio-electromagnetism.

4.7.2 Qualia And Thermodynamics

The connection between thermodynamics and qualia was the real breakthrough in the development of ideas. In some sense this finding is not a news: the close connection between pressure sense and temperature sense and thermodynamics is basic facts of psychophysics. In TGD framework the contents of consciousness is determined as some kind of average over the sequence of very large number of quantum jump and this suggests strongly that non-geometric qualia allow statistical description generalizing ordinary thermodynamical ensemble to the ensemble formed by the prepared states in the sequence of quantum jumps after the last "wake-up" of self. This picture allows to see the aging of self with respect to subjective time as an approach to thermal equilibrium.

1. There are geometric qualia corresponding to zero modes expressing the result of quantum measurement in each quantum jump. All geometric information about space-time surface should reduce to geometric qualia. For instance, geometric data given by visual, auditory, and tactile senses should reduce to conscious information about zero modes or about increments of zero modes in quantum jump.

2. The sequence of the prepared states can be modelled as a statistical ensemble of Fock states, which suggests that thermodynamics is basically part of theory of consciousness. The ensemble of prepared states gives rise to a large number of statistical qualia. The relationship $dE = TdS - PdV + \mu dN + B \cdot dM...$ generalizes to TGD context: note however that in case of ME selves energy is replaced with the Super Virasoro generator L_0 associated with the light-cone boundary of ME. Each intensive-extensive variable pair in the differential should correspond to a non-geometric quale, which results only when there is gradient (flow) of the extensive variable in the direction of the subjective time. Super-symplectic thermodynamics should obviously map ordinary thermodynamics to the level of conscious experience.

3. Since subjective experience corresponds to quantum jumps, it is natural to assume that only the increments of zero modes and quantum numbers are experienced consciously. Statistical interpretation also suggests that an averaging over increments occurs. The possibility of subselves makes possible to have mental images of finite time duration and this makes possible structured subjective memories (for instance, it becomes possible to remember the digits of phone number). A further working hypothesis is universality: qualia associated with quantum phase transitions depend only on the quantum number increments. In particular, the increments of Poincare and color and electroweak quantum numbers define what might be called universal kinesthetic qualia.

The thermodynanical expression for dE suggests a general classification of qualia consistent with the "holy trinity" of existences implied by TGD.

1. Emotions as order-disorder qualia

$T - S$ pair correspond subjective existence and generalizes to disorder-order type, information theoretic qualia qualia about the state of self: hot-cold and pain-pleasure type sensations and also more abstract experiences associated with various sub-selves of self. These qualia are strongly emotional single-pixel holistic qualia measuring whether some kind of an entropy variable is increasing or decreasing. The total entropy for the statistical ensemble defined by self determines how sharp the mental image is. Low entropy content means alertness and attentiveness. High entropy content means fuzzy mental image. Getting tired means inability to keep mental images in low entropy state.

2. Kinestetic qualia defined by generalized forces

p-V pair corresponds to the geometric existence and is replaced with generalized force-generalized coordinate pairs in quantum fluctuating degrees of freedom. The increments of maximum number of mutually commuting Poincare, color and electroweak quantum numbers define this kind of qualia. The increments of four-momentum code for the sensation of force whereas the increments of orbital angular momentum code for the sensation of torque. Spin flip could code for something else. Tactile senses such as pressure sense and their generalizations involve kinesthetic qualia. The increment of energy or equivalently, increment of frequency, can be identified as correlate for hearing in generalized sense responsible for the dynamical nature of auditory experience

(hearing is time-like version of force sense). It is not clear whether spin flip has interpretation as torque or possibly as figure background separation. In TGD based model of auditory experience hearing relates to Z^0 magnetic spin flip phase transitions for cognitive neutrino pairs.

The rate for the increase of the two diagonal color quantum numbers should code intensity type variables associated with color sensation. The rate for the increase of electric charge of subself should code for electric sense possessed by, say, fishes. Also $B-M$, $\phi\rho$ and $E-P$ pairs correspond to generalized forces since electromagnetic fields are reduced to space-time geometry in TGD framework.

3. Generalized chemical qualia vm

$\mu - N$ pair corresponds to "objective existence" defined by quantum histories and N is generalized to a number of particle like excitations in the Fock state resulting in the state preparation. In this case there must be a flow of particle number in the direction of the subjective time, that is Bose-Einstein condensation type process for, say Cooper pairs. Quite generally, super-symplectic and quaternion conformal super algebras should define these qualia and the number of these qualia is very large.

i) One can assign particle numbers to phases with various magnetic quantum numbers and these could define generalized chemical qualia which could perhaps be regarded as qualia and subqualia of chemical qualia defined by a particular ion and chemical qualia could actually reduce to magnetic qualia. Since the changes of magnetic field induce these quantum phase transition, it would seem that magnetic and Z^0 magnetic quantum phase transitions at superconducting magnetic flux tubes could correspond to this kind of qualia. In principle, endogenous NMR and its generalizations induced by the interaction of magnetic and Z^0 magnetic fields of MEs with magnetic and Z^0 magnetic flux tube structures are possible. Chemical qualia would very naturally correspond to the Bose-Einstein condensation of ions to the superconducting magnetic flux tubes: these ions could be even the ions of tastant or odorant. Also secondary representations at the level of cortex in terms of superconducting light ions are possible and would give rise to classification of tastes and odours. Magnetic qualia are characterized by definite transition frequencies and this makes possible place-/time coding by magnetic transition frequencies if magnetic or Z^0 magnetic field varies along magnetic flux tube/is a function of time. The activation of a point of living map would generate some quale at that point.

ii) For super-symplectic qualia the number of Bose-Einstein condensed " WCW photons" having nontrivial dependence on WCW degrees of freedom replaces number of molecules. The condensation rates for the numbers of the WCW photons with non-vanishing color quantum numbers could be interpreted as correlates of color qualia whereas the condensation rates for color singlet WCW photons could relate to the intensity of color sensation. If the rates for the transfer of color quantum numbers define intensity type variables associated with color experience then BE condensation to color singlet states does not give rise to experienced quale so that only non-diagonal color generators correspond to visual colors. Also the BE condensation of the ordinary coherent light should give rise to some kind of quale: perhaps vibratory sense which can be developed to effective vision, could correspond to non-colored vision. WCW Hamiltonians are also labelled by 2-dimensional orbital spin quantum number and longitudinal momentum. Polarization sense and sensation about motion of the object of visual field would naturally relate to spin and longitudinal momentum.

iii) Tactile senses involve topological phase transitions involving the creation of flux tubes between object and skin whose number would thus be the relevant variable. The purely sensory aspect of physical pain could correspond to a topological phase transition involving the splitting of join-along boundaries bonds between space-time sheets (MEs could even define these bonds) so that N would be now the number of flux tubes. The simplest picture requires that the MEs associated with sensory organs are connected to the MEs responsible for our experience. Of course, splitting and generation of flux tubes could occur also at the level of sensory representations.

4. Boolean qualia

Boolean qualia

Boolean qualia would be naturally associated with fermion number or fermionic spin degrees of freedom. There are super-symplectic and super-Kac Moody type Boolean qualia. The spin flip-

ping transitions associated with the fermionic generators of super-symplectic algebra might give rise to Boolean consciousness with intrinsic meaning ("This is true") but there are many other possibilities.

A general model for abstraction process based on the Combinatorial Hierarchy [K52] not only explains the basic numbers of the genetic code but also suggests an entire hierarchy of codes in accordance with fractality of TGD Universe.

The next code after genetic code in the hierarchy of codes defined by Combinatorial Hierarchy is very attractive candidate for a "memetic code". The hypothesis predicts correctly the .1 second time scale for the duration of "our" self (immediate short term memory, duration of psychological moment). Code-words correspond to the sequences of 126 bits with a duration of 1/1260 seconds: this is slightly below the time scale of nerve pulse so that membrane oscillations are perhaps a more natural realization for the code. The facts that the time scale of causal diamond CD associated with d quark corresponds to 1280 Hz frequency and the time scale of electron's CD corresponds to 10 Hz frequency suggest that quark pairs allow a realization of the memetic code with single quark sub-CD representing and electron CD the code word.

4.7.3 Geometric Qualia And Zero Modes

The zero modes of WCW are special in the sense that in each quantum jump localization occurs in this space. Zero modes characterize the size and shape of 3-surface and are excellent candidate to represent information about the state of organism (3-surface itself) geometrically. Zero modes can be parametrized as an infinite-dimensional flag-manifold associated with the algebra of the infinitesimal canonical transformations of $E^2 \times CP_2$, where S^2 is sphere at the light-cone boundary extended by Virasoro algebra acting in radial direction of light-cone boundary. Physically this space corresponds to all possible choices of the quantization axes for generators of super-symplectic Algebra and, in accordance with the basic assumptions of quantum measurement theory, each quantum jump involves this kind of choice. Infinite-dimensional flag manifold contains as sub-flag-manifold $S^2 \times F_3$ parameterizing choices of quantization axes of spin and color ($F_3 = SU(3)/U(1) \times U(1)$). Lorentz invariance suggests the extension of S^2 to 2+2 dimensional flag-manifold $F = SO(3,1)/SO(2) \times R$ parameterizing various choices of the quantization axes for Lorentz quantum numbers [K50].

There are continuous, geometric and kinestetic (both geometric in four-dimensional sense) qualia like position and velocity; orientation and angular velocity, and also geometric time and experienced rate of time flow. All these pairs correspond to mutually in-compatible observables quantum mechanically. The hypothesis motivated by the work of Barbara Shipman [Shipman$_{1,2,3}$] is that some coordinates of F_3 parametrize positions. The generalization of this hypothesis is that the infinite-dimensional flag-manifold associated with the zero mode part super-symplectic algebra somehow gives rise to a conscious representation of continuous, classical qualia basically assignable to the choise of quantization axes. The hypothesis indeed makes sense: the entire isometry group of WCW , in particular the sub-group defined by zero modes, leaves induced Kähler form invariant but affects magnetic and Z^0 magnetic fields and hence magnetic transition frequencies. Also color rotations act in F_3 nontrivially and, although they leave Kähler form invariant, they affect magnetic and Z^0 magnetic fields and thus the corresponding magnetic transition frequencies. This means that a curve of the infinite-dimensional flag-manifold can be mapped to a varying cyclotron frequency.

4.8 Solutions To Some Paradoxes

The TGD inspired theory of consciousness provides a solution to the many paradoxes related to the basic quantum physics and the philosophy of conscious mind. The solution of these paradoxes is basically due to the replacement of the dualistic and monistic world views by the tripartistic world view of TGD.

4.8.1 Paradoxes Related To Quantum Physics

The basic paradox is the conflict between the non-determinism of the state function reduction and the determinism of the Schrödinger equation. At a more general level this paradox is the conflict between the subjectively experienced actuality of the free will and the determinism of the objective world. The resolution of this paradox is simple in TGD context. One must give up the idea of single objective reality and replace it with a deterministic quantum history, which changes in each quantum jump, which is a genuine act of free will occurring outside the realm of the geometric space-time. Thus the objective reality, in the sense of a physical theory, is indeed deterministic, apart from the non-determinism related to the special properties of the Kähler action. In fact, a determinism of the Kähler action is achieved by replacing the ordinary concept of the 3-space with the concept of an association sequence and this naturally leads to a model for thinking systems. Volition seems to correspond to the selection between various degenerate absolute minima of the Kähler action and has thus a direct classical counterpart.

In the context of the deterministic physics, theoretician encounters two rather unpleasant paradoxes. The determinism implies that the unique objective reality corresponds to a single solution of the field equations. The first question is "What determines the initial conditions, say at the moment of the big bang?" and the attempt to answer this question leads necessarily outside the physical theory: one possibility is to postulate anthrophic principle. In TGD objective reality changes at each quantum jump and the localization in zero modes and NMP imply a genuine evolution: therefore the recent objective reality is an outcome of conscious selections. The second problem encountered by a theoretician is that in principle it is not possible to test a deterministic theory since only single solution of the field equations is realized and a genuine testing would require the comparison of the time developments for various initial data. In practice this problem can be circumvented by assuming the existence of identical sub-systems having very weak interactions with the external world but in principle the problem remains unsolved.

The famous Einstein-Bohr debate was related with the question whether God plays dice or not. Amusingly, in TGD context both were correct in their own ways! Quantum histories are indeed deterministic but God can replace the old quantum history with a new one: perhaps one should not however call this act dice playing but simply an act of free will. Einstein was also an advocate of local realism: this led to Einstein-Podolski-Rosen paradox created by the possibility of quantum entanglement between distant system. In TGD framework local realism holds true at the level of the infinite-dimensional WCW but not at the level of space-time since point like particles are replaced with 3-surfaces.

The Schrödinger cat paradox has also an elegant solution in TGD context. The point is that conscious experience is associated with a quantum jump leading to a final state in which cat is either dead or alive. There is no conscious experience about the situation in which the cat is both dead and alive giving answer to the question "Dead or alive?". More generally, this feature of consciousness also could explain why the world of our conscious experience looks classical: it simply cannot look but classical since the very moment of consciousness makes it classical. In fact, the world *is* predicted to be genuinely classical to the extent that mutual quantum entanglement between different p-adic sub-Universes seems impossible for purely mathematical reasons. The localization into zero modes occurring in quantum jumps strengthens this conclusion considerably since it implies that the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces: the world of conscious experience is genuinely classical.

The phenomenon of dissipation is paradoxal from the point of view of standard physics. It is generally accepted that the fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of the fundamental physics and the irreversible and mathematically rather ugly "real" world, seem to exist simultaneously. The quantum jumps between quantum histories concept solves the paradox and one can understand the dissipative world as an effective description forming an "almost" -envelope for the sequence of reversible worlds (time developments).

The standard physics is based on positive energy ontology and leads to the paradox caused by conservation laws. Quantum jumps preserve the values of conserved quantum numbers so that the question about initial values of the quantum numbers arises and leads to the necessity to postulate some meta level principle selecting the quantum states of entire universe having the

preferred values of total quantum numbers. Of course, the problems are also caused by the fact that one must be able to compare the infinite values of total conserved quantum numbers- at least in the case of energy. Zero energy ontology provides an elegant solution of the problem and implies that any zero energy state is in principle creatable from vacuum.

4.8.2 Paradoxes Related To The Theories Of Consciousness

Chalmers describes in his book "Conscious Mind" [J59] several paradoxes related to the materialistic and dualistic theories of mind. A common denominator for these problems is the assumption that consciousness is a property of a physical state: hence these paradoxes disappear in TGD context. These paradoxes are encountered also in the quantum theories of consciousness identifying consciousness as a property of a macroscopic quantum state, say Bose Einstein condensate.

In the materialistic theories of mind, postulating a unique objective reality, consciousness is an epiphenomenon and free will is necessarily a peculiar illusion and one can always ask why the consciousness is needed at all: nothing changes in the physical reality if consciousness is dropped away. It is also very difficult to understand how the contents of consciousness are determined by the state of the material world.

In the dualistic theories postulating a unique objective reality (say the theory of Chalmers [J59]), the problems are related to the coupling between matter and mind. The basic problem of the dualistic theories is what Chalmers calls hard problem: how the physical processes in the brain give rise to conscious experience? If the laws of the physics determine the behaviour of the system completely then one ends up immediately either with a complete separation of the mind and matter so that our conscious experience tells nothing about the material world or with materialism and epiphenomenalism. One can also consider a non-trivial coupling between matter and "mind like" fields but assuming a deterministic physics one ends up with a situation in in which the mind fields are effectively just additional physical fields and consciousness is again redundant.

An exotic example of this kind of a paradox is the following one described in [J59]. In the dualistic theories in which the physical laws determine the objective reality, all psychological (third person) aspects of the mind are in principle purely physical. The book written by Chalmers about consciousness is obviously an example of a completely physical phenomenon. Therefore the contents of the book need not have anything to do with Chalmers's ideas about consciousness! More generally, the reports about the states of consciousness need not have anything to do with the states of consciousness in the dualistic theories of this kind. The only manner to save the day (and the uniqueness of the objective reality) is to accept materialism and epiphenomenalism.

In TGD framework, which could be called tripartistic, hard problem and other problems of the dualistic theories disappear since there is no need to assign consciousness to quantum history. Moment of consciousness as quantum jump between quantum histories hypothesis allows even to define measures for the information contents of the conscious experience despite the fact that one cannot write explicit formulas for the contents of conscious experience.

4.8.3 Logical Paradoxes And Concept Of Time

Many logical paradoxes could be resolved if one assumes that there are two times: geometric and subjective and that the space-time surface providing linguistic representations changes quantum jump by quantum jump. In particular, during the conscious argument leading to the logical paradox!

The objections of Uri Fidelman [J172] against the Platonic vision about reality involve the paradoxes of the cyclic cosmology (one might think that Turing machine in cyclic cosmology might be able to "know" whether it has halted immediately after starting and thus be much more powerful than ordinary Turing machine). Basic paradox is that in cyclic cosmology allowing time travel one can imagine a son who murders his mother.

It is interesting to consider this paradox as resulting from identification of the identification of subjective time with geometric time, which I see only as an approximation. In TGD the counterpart of time travel would be sequence of quantum jumps changing the entire classical history quantum jump by quantum jump and inducing the shift of the space-time region, where the contents of consciousness of time traveller are concentrated, to the geometric past. No paradoxes result since space-time is not a fixed arena of dynamics but changes in each quantum jump.

As a second example one can take the second objection of Uri Fidelman [J172] against Penrose's program known as Berry's paradox. *Non-formalizable theory cannot provide a model of the physical world which includes the brain's cognitive function, since such a model must be lingual, written or spoken. However, such a model implies the following paradox of Berry: Let n be the smallest number which cannot be defined by an English sentence having less than, say, a hundred letters. This number exists, since the number of all possible combinations of a hundred letters is finite. Nevertheless, it has just now been defined by a sentence comprising less than a hundred letters.*

Berry's paradox could be understood when the piece of text is seen as inducing a sequence of quantum jumps in which the space-time region at which the argument is represented symbolically changes. For the initial space-time region representing my cognitive state there is indeed smallest number n which cannot be defined by using less than one hundred words (using the English in that space-time!). After reading the statement quantum history is replaced by a new, more complex one in which this this number can be defined by using less than one hundred words since a new reflective level of cognitive consciousness has emerged and is represented at space-time level.

This example encourages to think the possibility of replacing the idea of a fixed axiomatic system with a living and dynamically evolving system becoming conscious of new axioms from which new theorems can grow. Mathematician would not be anymore an outsider but and active participator affecting the mathematical system he is studying. For instance, when paradoxal statement represented symbolically becomes conscious in quantum jump sequence, also the context in which it was originally stated changes. This dynamical view about mathematical system could allow to solve antinomies.

Chapter 5

Negentropy Maximization Principle

5.1 Introduction

Quantum TGD involves "holy trinity" of time developments. There is the geometric time development dictated by the preferred extremal of Kähler action crucial for the realization of General Coordinate Invariance and analogous to Bohr orbit. There is what I originally called unitary "time development" U: $\Psi_i \to U\Psi_i \to \Psi_f$, associated with each quantum jump. This would be the counterpart of the Schrödinger time evolution $U(-t, t \to \infty)$. Quantum jump sequence itself defines what might be called subjective time development.

Concerning U, there is certainly no actual Schrödinger equation involved: situation is in practice same also in quantum field theories. It is now clear that in Zero Energy Ontology (ZEO) U can be actually identified as a sequence of basic steps such that single step involves a unitary evolution inducing delocalization in the moduli space of causal diamonds CDs) followed by a localization in this moduli space selecting from a superposition of CDs single CD. This sequence replaces a sequence of repeated state function reductions leaving state invariant in ordinary QM. Now it leaves in variant second boundary of CD (to be called passive boundary) and also the parts of zero energy states at this boundary. There is now a very attractive vision about the construction of transition amplitudes for a given CD [K126], and it remains to be see whether it allows an extension so that also transitions involving change of the CD moduli characterizing the non-fixed boundary of CD.

A dynamical principle governing subjective time evolution should exist and explain state function reduction with the characteristic one-one correlation between macroscopic measurement variables and quantum degrees of freedom and state preparation process. Negentropy Maximization Principle is the candidate for this principle. In its recent form it brings in only a single little but overall important modification: state function reductions occurs also now to an eigen-space of projector but the projector can now have dimension which is larger than one. Self has free will to choose beides the maximal possible dimension for this sub-space also lower dimension so that one can speak of weak form of NMP so that negentropy gain can be also below the maximal possible: we do not live in the best possible world. Second important ingredient is the notion of negentropic entanglement relying on p-adic norm.

The evolution of ideas related to NMP has been slow and tortuous process characterized by misinterpretations, over-generalizations, and unnecessarily strong assumptions, and has been basically evolution of ideas related to the anatomy of quantum jump and of quantum TGD itself.

Quantum measurement theory is generalized to theory of consciousness in TGD framework by replacing the notion of observer as outsider of the physical world with the notion of self. Hence it is not surprising that several new key notions are involved.

1. ZEO is in central role and brings in a completely new element: the arrow of time changes in the counterpart of standard quantum jump involving the change of the passive boundary of CD to active and vice versa. In living matter the changes of the of time are inn central role: for instance, motor action as volitional action involves it at some level of self hierarchy.

2. The fusion of real physics and various p-adic physics identified as physics of cognition to single adelic physics is second key element. The notion of intersection of real and p-adic worlds (intersection of sensory and cognitive worlds) is central and corresponds in recent view about TGD to string world sheets and partonic 2-surfaces whose parameters are in an algebraic extension of rationals. By strong form of of holography it is possible to continue the string world sheets and partonic 2-surfaces to various real and p-adic surfaces so that what can be said about quantum physics is coded by them. The physics in algebraic extension can be continued to real and various p-adic sectors by algebraic continuation meaning continuation of various parameters appearing in the amplitudes to reals and various p-adics.

   An entire hierarchy of physics labeled by the extensions of rationals inducing also those of p-adic numbers is predicted and evolution corresponds to the increase of the complexity of these extensions. Fermions defining correlates of Boolean cognition can be said so reside at these 2-dimensional surfaces emerging from strong form of holography implied by strong form of general coordinate invariance (GCI).

   An important outcome of adelic physics is the notion of number theoretic entanglement entropy: in the defining formula for Shannon entropy logarithm of probability is replaced with that of p-adic norm of probability and one assumes that the p-adic prime is that which produces minimum entropy. What is new that the minimum entropy is negative and one can speak of negentropic entanglement (NE). Consistency with standard measurement theory allows only NE for which density matrix is n-dimensional projector.

3. Strong form of NMP states that state function reduction corresponds to maximal negentropy gain. NE is stable under strong NMP and it even favors its generation. Strong form of NMP would mean that we live in the best possible world, which does not seem to be the case. The weak form of NMP allows self to choose whether it performs state function reduction yielding the maximum possible negentropy gain. If n-dimensional projector corresponds to the maximal negentropy gain, also reductions to sub-spaces with $n-k$-dimensional projectors down to 1-dimensional projector are possible. Weak form has powerful implications: for instance, one can understand how primes near powers of prime are selected in evolution identified at basic level as increase of the complexity of algebraic extension of rationals defining the intersection of realities and p-adicities.

4. NMP gives rise to evolution. NE defines information resources, which I have called Akashic records - kind of Universal library. The simplest possibility is that under the repeated sequence of state function reductions at fixed boundary of CD NE at that boundary becomes conscious and gives rise to experiences with positive emotional coloring: experience of love, compassion, understanding, etc... One cannot exclude the possibility that NE generates a conscious experience only via the analog of interaction free measurement but this option looks un-necessary in the recent formulation.

5. Dark matter hierarchy labelled by the values of Planck constant $h_{eff} = n \times h$ is also in central role and interpreted as a hierarchy of criticalities in which sub-algebra of super-symplectic algebra having structure of conformal algebra allows sub-algebra acting as gauge conformal algebra and having conformal weights coming as n-ples of those for the entire algebra. The phase transition increasing h_{eff} reduces criticality and takes place spontaneously. This implies a spontaneous generation of macroscopic quantum phases interpreted in terms of dark matter. The hierarchies of conformal symmetry breakings with $n(i)$ dividing $n(i+1)$ define sequences of inclusions of HFFs and the conformal sub-algebra acting as gauge algebra could be interpreted in terms of measurement resolution.

   n-dimensional NE is assigned with $h_{eff} = n \times h$ and is interpreted in terms of the n-fold degeneracy of the conformal gauge equivalence classes of space-time surfaces connecting two fixed 3-surfaces at the opposite boundaries of CD: this reflects the non-determinism accompanying quantum criticality. NE would be between two dark matter system with same h_{eff} and could be assigned to the pairs formed by the n sheets. This identification is important but not well enough understood yet. The assumption that p-adic primes p divide n gives deep connections between the notion of preferred p-adic prime, negentropic entanglement, hierarchy of Planck constants, and hyper-finite factors of type II_1.

6. Quantum classical correspondence (QCC) is an important constraint in ordinary measurement theory. In TGD QCC is coded by the strong form of holography assigning to the quantum states assigned to the string world sheets and partonic 2-surfaces represented in terms of super-symplectic Yangian algebra space-time surfaces as preferred extremals of Kähler action, which by quantum criticality have vanishing super-symplectic Noether charges in the sub-algebra characterized by integer n. Zero modes, which by definition do not contribute to the metric of "world of classical worlds" (WCW) code for non-fluctuacting classical degrees of freedom correlating with the quantal ones. One can speak about entanglement between quantum and classical degrees of freedom since the quantum numbers of fermions make themselves visible in the boundary conditions for string world sheets and their also in the structure of space-time surfaces.

NMP has wide range of important implications.

1. In particular, one must give up the standard view about second law and replace it with NMP taking into account the hierarchy of CDs assigned with ZEO and dark matter hierarchy labelled by the values of Planck constants, as well as the effects due to NE. The breaking of second law in standard sense is expected to take place and be crucial for the understanding of evolution.

2. Self hierarchy having the hierarchy of CDs as embedding space correlate leads naturally to a description of the contents of consciousness analogous to thermodynamics except that the entropy is replaced with negentropy.

3. In the case of living matter NMP allows to understand the origin of metabolism. NMP demands that self generates somehow negentropy: otherwise a state function reduction to the opposite boundary of CD takes place and means death and re-incarnation of self. Metabolism as gathering of nutrients, which by definition carry NE is the way to avoid this fate. This leads to a vision about the role of NE in the generation of sensory qualia and a connection with metabolism. Metabolites would carry NE and each metabolite would correspond to a particular qualia (not only energy but also other quantum numbers would correspond to metabolites). That primary qualia would be associated with nutrient flow is not actually surprising!

4. NE leads to a vision about cognition. Negentropically entangled state consisting of a superposition of pairs can be interpreted as a conscious abstraction or rule: negentropically entangled Schrödinger cat knows that it is better to keep the bottle closed.

5. NMP implies continual generation of NE. One might refer to this ever expanding universal library as "Akaschic records". NE could be experienced directly during the repeated state function reductions to the passive boundary of CD - that is during the life cycle of sub-self defining the mental image. Another, less feasible option is that interaction free measurement is required to assign to NE conscious experience. As mentioned, qualia characterizing the metabolite carrying the NE could characterize this conscious experience.

6. A connection with fuzzy qubits and quantum groups with NE is highly suggestive. The implications are highly non-trivial also for quantum computation allowed by weak form of NMP since NE is by definition stable and lasts the lifetime of self in question.

In the sequel the formulation of NMP and various ideas involved with NMP are discussed first. The formulation of NMP for hyper-finite factors is discussed in separate section. The last section considers some consequences of NMP discussed in more detail in various books.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

5.2 Basic Notions And Ideas Behind NMP

In the following the basic ideas and notions behind NMP as well as evolution of NMP are summarized. The first form of NMP was rather naïve. There was no idea about the anatomy of quantum

jump and NMP only stated that the allowed quantum jumps are such that the information gain of conscious experience measured by the reduction of entanglement entropy resulting in the reduction of entanglement between the subsystem of system and its complement is maximal. Later it became clear that quantum jump has a complex anatomy. The term quantum jump is still however used about the process in question.

5.2.1 Zero Energy Ontology

Zero energy ontology (ZEO) changes considerably the interpretation of the unitary process. In zero energy ontology (ZEO) quantum states are replaced with zero energy states defined as a superpositions of pairs of positive and negative energy states identified as counterparts of initial and final states of a physical event such as particle scattering. The matrix defining entanglement between positive and negative - christened as M-matrix - is the counterpart of the ordinary S-matrix but need not be unitary. It can be identified as a "complex square root" of density matrix expressible as a product of positive square root of diagonal density matrix and unitary S-matrix. Quantum TGD can be seen as defining a "square root" of thermodynamics, which thus becomes an essential part of quantum theory.

U-matrix is defined between zero energy states and cannot therefore be equated with the S-matrix used to describe particle scattering events. Unitary conditions however imply that U-matrix can be seen as a collection of M-matrices labelled by zero energy states so that the knowledge of U-matrix implies the knowledge of M-matrices. The unitarity conditions will be discussed later. A natural guess is that U is directly related to consciousness and the description of intentional actions. For positive energy ontology state function reduction to the opposite boundary of CD would serve as a state preparation for the next quantum jump: state preparation and reduction are therefore related by time reflection.

In ZEO state function preparation and reduction can be assigned to the positive and negative energy states defining the initial and final states of the physical event. The reduction of the time-like entanglement during the state function reduction process corresponds to the measurement of the scattering matrix. In the case of negentropic time-like entanglement the reduction process is not random anymore and the resulting dynamics is analogous to that of cellular automata providing a natural description of the dynamics of self-organization in living matter. This self-organization is also 4-dimensional in ZEO: this is of utmost importance in attempts to understand living matter.

According to standard quantum measurement theory state function reductions can take place repeatedly without any change in the state. In ZEO state function reduction to a given boundary of CD can occur repeatedly without changing the corresponding part of zero energy state but affecting the part at the opposite boundary. Superposition of CDs with different sizes is possible and one can assign to the second (active) boundary a wave function in the space of moduli, which include the proper time distance between the tips of CD and discrete boosts by a subgroup of Lorentz group leaving the tip of the fixed (passive) boundary invariant. This distance must increase in average sense and this gives rise to the arrow of experienced time. Self can be identified as a sequence of quantum jumps reducing to same boundary of CD.

The simplest assumption is that there are sequences of repeated state function reductions leaving everything at the passive boundary of CD invariant. In the moduli space for active boundary (parametwrized by Lorentz boost leaving passive boundary invariant and integer shift for the proper time distance between the tips of CD given repeated reduction, which consist of a unitary evolution in the moduli space of CDs inducing delocalization followed by localization to a fixed CD.

ZEO leads to a precise identification of the subsystem at space-time level. General coordinate invariance (GCI) in 4-D sense means that 3-surfaces related by 4-D diffeomorphisms are physically equivalent. It is convenient to perform a gauge fixing by a introducing a natural choice for the representatives of the equivalence classes formed by diffeo-related 3-surfaces.

1. Light-like 3-surfaces identified as surfaces at which the Minkowskian signature of the induced space-time metric changes to Euclidian one - wormhole contacts- are excellent candidates in this respect. The intersections of these surfaces with the light-like boundaries of CD define 2-D partonic surfaces. Also the 3-D space-like ends of space-time sheets at the light-like boundaries of CDs are very natural candidates for preferred 3-surfaces.

2. The condition that the choices are mutually consistent implies effective 2-dimensionality, whose original formulation was as follows. The intersections of these surfaces defining partonic 2-surface plus the distribution of 4-D tangent spaces at its points define the basic dynamical objects with 4-D general coordinate invariance reduced to 2-dimensional one. This effective 2-dimensionality was clear from the very beginning but is only apparent since also the data about 4-D tangent space distribution is necessary to characterize the geometry of WCW and quantum states. The quantum descriptions in terms of 3-D light-like or space-like surfaces and even in terms of 4-D surfaces are equivalent but redundant descriptions. 4-D space-time is necessary for classical part of description necessary in order to perform and interpret quantum measurements. Holography defines the correspondence between quantal (2-D surfaces) and 4-D classical degrees of freedom in space-time interior.

3. The recent formulation of effective 2-dimensionality is slightly different. Partonic 2-surfaces and string world sheets at which the modes of the induced spinor field are localized by well-definedness of em charge define the basic entities of strong form of holography [K139]. Space-time surfaces can be determined as preferred extremals from these data assuming quantum criticality meaning that clasical super-symplectic Noether charges associated with the sub-algebra of super-symplectic algebra with conformal weights coming as n-ples of those for the full algebra vanish for them.

As far as consciousness is considered effective 2-dimensionality means holography and could relate to the fact that at least our visual experience is at least effectively 2-dimensional.

5.2.2 Fusion Of Real And P-Adic Physics

The fusion of real and p-adic physics to a larger structure has been a long standing challenge for TGD. The motivations come both from elementary particle physics and TGD inspired theory of consciousness. The basic idea is that various number fields are fused to a larger structure by gluing them along rationals and common algebraic numbers. The challenge is to imagine what quantum jump and NMP could mean in this framework. The first question is how the unitary process acts.

1. U-process acts in spinorial degrees of freedom of WCW (fermionic Fock space for a given 3-surface) and in WCW degrees of freedom (the space of partonic 2-surfaces roughly).

2. WCW should decompose to sectors corresponding to space-time surfaces in varioys number fields. This suggests strongly an adelic view [K137] in which reals and various p-adic number fields form a structure analogous to a Cartesian product. These number fields froming adele (`http://tinyurl.com/64pgerm`) would have rationals in common. One can define adele also for any algebraic extension of rationals and now the algebraic extension is shared by the factors. This suggests that the various number fields are glued together like pages of a book along common back defined by the algebraic extension. Thus one has something which is not quite the Cartesian product. The implication would be a hierarchy of algebraic extensions forming an evolutionary hierarchy.

3. If one would have Cartesian proeuct, the tensor product for the fermionic Fock spaces for corresponding sub-WCWs would at the first look very natural but would lead to a situation in which each sector would contain fermionic states separately. This does not look natural. Rather, the real space-time sheets should correspond to a sensory representation of the quantum state and p-adic space-time sheets to cognitive representations of one and the same thing [K137]. Hence fermions must be localized at the back of the book.

   Fermions are indeed localized at string world sheets and partonic 2-surfaces already from the well-definedness of em charges and also the equivalence of octonionic spinor structure with the ordinary one necessary for twistorialization demands this. Also the strong form of holography is consistent with the vision that the quantum dynamics is coded by the data at these 2-D surfaces. Classical physics would be 4-D and necessary for the physical testing and interpretation of the theory. Fermions would correspond to Boolean cognition in intersection of realities and p-adicities and would be number theoretically universal as already their anti-commutation relations suggest: also the quantal version of the anti-commutation relations is number theoretically universal in the algebraic extension of rationals.

4. What can one say about the U-matrix and its satellites M and S [K78]? The earlier vision was that the transitions between different number fields are possible. The construction of transition amplitudes for them - interpreted as amplitudes for the realization of intention represented as p-adic space-time sheet as action predicted as real space-time sheet - would be possible in the intersection but their continuation to different number fields does not seem to make sense: one should always chose on number field.

   In the intersection everything is number theoretically universal. Hence the only reasonable conclusion is that these matrices exist separately in each sector and coincide in the intersection: this is very powerful constraint and means reduction to algebraic geometry. They would give different representations of one and same thing. p-Adic mass calculations would serve as an excellent example about the usefulness of the cognitive representations - p-adic arithmetics is extremely simple as compared to the real one and the number theoretical existence fixes the physics to a high degree. This would give extremely powerful constraints also the real U-matrix.

5.2.3 Dark Matter Hierarchy

The identification of dark matter as phases having large value of Planck constant [K112, K44, K36] led to a vigorous evolution of ideas. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [K44].

The original vision was that the hierarchy of Planck constants demands a generalization of quantum TGD. This would have required a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. It however became clear that the hierarchy of Planck constants labels a hierarchy of quantum criticalities characterized by sub-algebras of super-symplectic algebras possessing a natural conformal structure. The sub-algebra for which the conformal weights come as n-ples of those for the entire algebra is isomorphic to the full algebra and acts as a conformal gauge algebra at given level of criticality.

In particular, the classical symplectic Noether charges for preferred extremals connecting 3-surfaces at the ends of CD vanish. and this defines preferred extremal property. There would be n conformal gauge equivalence classes of preferred extremals which would correspond to n sheets of a covering of the space-time surface serving as base space. There is very close similarity with the Riemann surfaces. Therefore coverings would be generated dynamically and there is no need for actual coverings of the embedding space.

The gauge degeneracy corresponds to the non-determinism associated with the criticality having interpretation in terms of non-determinism of Kähler action and with strong form of holography. The extremely strong super-symplectic gauge conditions would guarantee that the continuation of string world sheets and partonic 2-surface to preferred extremals is possible at least for some value of p-adic prime. A good guess is that this is the case for the so called ramified primes associated with the algebraic extension in question. These ramified primes would characterize physical system and the weak form of NMP would allow to understand how p-adic length scale hypothesis follows [K137].

p-Adic continuations identifiable as imaginations would be due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K81]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes.

A further strong prediction is that the phase transitions increasing h_{eff} and thus reducing criticality (TGD Universe is like hill at the top of the hill at....) occur spontaneously [K31, K32, K33, K34]. This conforms with NMP and suggests that evolution occurs spontaneously. The state function reduction increasing h_{eff} means however the death of a sub-self so that selves are fighting to stay at the criticality. The metabolic energy bringing inNE allows to satisfy the needs of NMP so that the system survives and provides a garden in which subselves can are born and die and gradually generate negentropic entanglement. Living systems are thus negentropy gatherers and each death and re-incarnation generates new negentropy.

All particles in the vertices of Feynman diagrams have the same value of Planck constant so that the particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to h_{eff} changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory. These observations motivate the tentative identification of the macroscopic quantum phases in terms of dark matter and also of dark energy with gigantic "gravitational" Planck constant.

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by the following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of h_{eff} at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

Dark matter could be a key player in quantum biology.

1. Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the CD. For electron this time scale is.1 second, the fundamental bio-rhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $h_{eff}/h = n$-multiples of this time scale.

2. The predicted breaking of second law of thermodynamics chacterizing living matter - if identified as something in the intersection of real and p-adic words - would be always below the time scale of CD considered but would take place in arbitrary long time scales at appropriate levels of the hierarchy. The scaling up of h_{eff} also scales up the time scale for the breaking of the second law.

3. The hypothesis that magnetic body is the carrier of dark matter in large h_{eff} phase has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of [J70] [K37]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K65, K37]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K37].

5.2.4 Quantum Classical Correspondence

Quantum classical correspondence (QCI) has served as a guideline in the evolution of the ideas and the identification of the geometric correlates of various quantum notions at the level of embedding space and space-time surfaces has been an important driving force in the progress of ideas.

1. In ZEO causal diamonds (CDs) identified roughly as intersections of future and past directed light-cones are in key role. At embedding space level CD is a natural correlate for self and sub- CDs serve as correlates of sub-selves identified as mental images. At space-time level the space-time sheets having their ends at the light-like boundaries of CD serve as correlates for self. For a system characterized by a primary p-adic length scale $L_p \propto 2^{k/2}$ the size scale of CD is secondary p-adic scale $L_{p,2} = \sqrt{p}L_p \propto 2^k$. p-Adic length scale hypothesis follows if the proper time distance between the tips of CDs is quantized in powers of 2. This

quantization should relate directly to almost equivalence of octaves associated with music experience. It must be emphasized that this assumption is very probably too strong. If the distances come as integer multiples of CP_2 time, the U-matrices form a structure analogous to Kac-Moody algebra: the role of conformal weights is taken by the distances. NMP indeed selects preferred p-adic primes and thus also size scales for CDs.

2. At the level of space-time the identification of flux tubes (I called them earlier flux tubes) between space-time sheets (more precisely, between partonic 2-surfaces) as a correlate for bound state entanglement suggests itself. Flux tubes correspond typically to magnetic flux tubes in the TGD inspired quantum model of living matter. The size scale of the magnetic body of system is given by the size scale of CD and much larger than the size of the system itself.

3. The space-time sheets in the intersection of the real and p-adic WCWs characterized by the property that the mathematical representation of the partonic 2-surfaces at the ends representing holograpically the state allows interpretation in both real and p-adic sense would correspond to the correlates for negentropic entanglement. Rational and algebraic 2-surfaces defined by partonic 2-surfaces and string world sheets (in preferred coordinates) would be the common points of realities and p-adicities.

Quantum classical correspondence allows also to generate new views about quantum theory itself. Many-sheeted space-time and p-adic length scale hierarchy force to generalize the notion of sub-system. The space-time correlate for the negentropic and bound state entanglement is the formation of flux tubes connecting two space-time sheets. The basic realization is that two disjoint space-time sheets can contain smaller space-time sheets topologically condensed at them and connected by flux tubes. Thus systems un-entangled at a given level of p-adic hierarchy - that is in the measurement resolution defined by the level considered - can contain entanglement subsystems at lower level not visible in the resolution used.

In TGD inspired theory of consciousness this makes possible sharing and fusion of mental images by entanglement. The resolution dependence for the notions of sub-system and entanglement means that the entanglement between sub-systems is not "seen" in the length scale resolution of unentangled systems. This phenomenon does not result as an idealization of theoretician but is a genuine physical phenomenon. Obviously this generalized view about sub-system poses further challenges to the detailed formulation of NMP. Note that the resulting mental image should depend on whether sub-selves are entangled by bound state entanglement or NE.

5.2.5 Connection With Standard Quantum Measurement Theory

TGD allows to deduce the standard quantum measurement theory involving the notion of classical variables and their correlation with quantum numbers in an essential manner. WCW ("world of classical worlds" is a union over zero modes labelling infinite-dimensional symmetric spaces having interpretation as classical non-quantum fluctuating classical variables such as the pointer of a measurement apparatus essential for the standard quantum measurement theory [K30]. Quantum holography in its origimnal form states that partonic 2-surfaces at the light-like boundaries of CDs plus the corresponding distributions of 4-D tangent spaces of space-time surfaces at carry the information about quantum state and space-time sheet. The recent formulation talks about partonic 2-surfaces and string world sheets intersection them at discrete points with string connecting partonic 2-surfaces and string boundaries at their orbits carrying fermion number. The distribution of values of induced Kähler form of CP_2 at these surfaces defines zero modes whereas quantum fluctuating degrees of freedom correspond to the deformations of space-time surface by the flows induced by Hamiltonians associated with the degenerate symplectic structure of $\delta M^4_{\pm} \times CP_2$.

There exists no well-defined metric integration measure in the infinite-dimensional space of zero modes, which by definition do not contribute to the line element of WCW. This does not lead to difficulties if one assumes that a complete localization in zero modes occurs in each quantum jump. A weaker condition is that wave functions are localized to discrete subsets in the space of zero modes. An even weaker and perhaps the most realistic condition is that a localization to a finite-dimensional 2n-dimensional manifold with induced symplectic form defining a positive definite integration volume takes place.

The fundamental formulation of quantum TGD in terms of the Kähler action and Kähler-Dirac action [K139] containing measurement interaction terms guarantees quantum classical correspondence in the sense that the geometry of the space-time surface correlates with the values of conserved quantum numbers. The boundary term of Kähler-Dirac action (1-D massless Dirac action) implies that fermion line is light-like geodesic of $M^4 \times CP_2$ and carries light-like $M^4 \times E^4$ 8-momentum ($SO(4)$ quantum numbers when one uses partial wavs). The modes of embedding space spinor field carry four momentum and color ($SU(3)$) quantum numbers are also massless in 8-D sense and if the two four-momenta are identical one has Equivalence Principle (EP). The mass squared in E^4 degrees of freedom equals to the eigenvalue of spinor Laplacian in CP_2 degrees of freedom. This defines a more abstract form of EP: $SO(4)$ quantum numbers label hadrons and $SU(3)$ quantum numbers quarks and gluons so that one has dual representations.

The resulting correlation of zero modes with the values of quantum numbers can be interpreted as an abstract form of quantum entanglement reduced in quantum jump for the standard definition of the entanglement entropy.

That state function can occur at both boundaries of CD localizing the boundary in question reducing the part of zero energy state associated with it is the new element of TGD inspired quantum measurement theory and allows to understand how the arrow of experienced time emerges and precisely define self - observer - as a part of system interacting with it. Also the possibility that the arrow of time changes at some level of the self hierarchy is predicted. In living matter this is expected to occur routinely as already Fantappie speculated [J121]: the first state function reduction in the sequence of them and changing the arrow of time is indeed naturally identified as a correlate for the volitional act.

5.2.6 Quantum Jump As Moment Of Consciousness

Quantum jump between quantum histories identified as moment of consciousness was originally believed to be something irreducible and structureless. Gradually the view about quantum jump has however become more and more structured and a connection with the standard quantum measurement theory emerged. In what sense quantum jumps remains irreducible is that one cannot build any dynamical model for the non-deterministic steps appearing in quantum jump.

The general structure of quantum jump

It seems that TGD involves "holy trinity" of dynamics.

1. The dynamics defined by the preferred extremals of Kähler action corresponds to the dynamics of material existence, with matter defined as "res extensa", 3-surfaces. What preferred extremals really are has been a long standing open question. The recent formulation of the quantum theory using Kähler-Dirac action leads to the proposal that the preferred extremals are critical in the sense that they allow an infinite number of deformations for which the second variation vanishes. At the level of Kähler action this corresponds to the vanishing of classical Noether charges for a sub-algebra of super-symplectic algebra isomorphic with the entire algebra. This serves as space-time counterpart for quantum criticality of TGD Universe fixing the fundamental variational principle uniquely.

2. The dynamics defined by the sequence of state function reductions at fixed boundary of CD defining the life span of self at given level of hierarchy. This time evolution is a discrete counterpart of the ordinary Schrödinger time evolution $U \equiv U(-t,)$, $t \to \infty$ and can be regarded as "informational" time development occurring at the level of objective existence. It is un-necessary and in fact impossible to assign real Schrödinger time evolution with U. U defines the S-matrix of the theory. These reductions define the dynamics of sensory perception (passive aspects of consciousness) during which external world is regarded as unchanged in standard framework. Now the part of zero energy state at the fixed boundary of CD remains unchanged and un-entangled.

3. The dynamics of state function reductions at opposite boundary of CD defines the dynamics of volition (active aspects of consciousness).

Quantum jump was originally regarded as something totally irreducible. Gradually the structure of the complex formed by state function reductions and unitary process has revealed itself and led to the understanding how one can understand basic aspects of conscious experience in terms of this structure. Let us start with the original picture.

1. The first step in quantum jump was identified as "informational time development"

$$\Psi_i \to U\Psi_i \ ,$$

where U is the counterpart of the unitary process of Penrose. The resulting state is a completely entangled multiverse state, the entire sub-universe corresponding to a given CD being in a holistic state of "oneness".

In the recent picture Universe is replaced with CD and "informational time development" corresponds to a sequence of state function reductions keeping second boundary of CDand-states associated with it fixed. Repeated measurement having no effect on quantum state is the analog in standard quantum measurement theory. Self corresponds to this sequence.

Two subsequent reductions at same boundary of CD have unitary process between them tending to increase the size CD. The challenge is to identify the unitary process U. Self experiences the flow of time, which suggests that the unitary operator followed by localization in the moduli spaces of CDs corresponds to an integer shift for the tip of the active boundary of CD. No state function reduction can occur at the active boundary of CD during this period.

2. Next comes the TGD counterpart of state function in the ordinary sense of the word:

$$U\Psi_i \to \Psi_f^0 \ .$$

According to the recent view, the state function reduction in this sense corresponds to the state function at the opposite boundary of cD and leads to a change of the arrow of geometric time. Old self dies and new self is born. In this transition also the value of h_{eff} is expected to increase. This reduction is preceded by a scaling of by the integer ratio $h_{eff}(f)/h_{eff}(i)$ and realized as a unitary exponential of conformal scaling operator. Thus both Poincare and conformal time developments are realized.

3. The state function reduction for given CD is followed by a cascade of self measurements for sub-CDs in quantum fluctuating degrees of freedom

$$\Psi_f^0 \to .... \to \Psi_f \ ,$$

whose dynamics is governed by the Negentropy Maximization Principle (NMP). For a generic entanglement probabilities this process leads to bound states or negentropically entangled states. This process can be regarded as an analysis or even decay process. If entanglement probabilities define projection operator, the state function reduction leads or can laed to a negentropically entangled state: this depends on what form of NMP one assumes. Entanglement coefficients correspond to unitary matrix in this case.

Quantum measurement theory involves also the correlation between quantum degrees of freedom and classical degrees of freedom (the position of the pointer of the measurement apparatus correlates with the outcome of the measurement).

1. The assumption that localization occurs in zero modes of the WCW would pose very important consistency condition: there is one-one correlation between the quantum numbers in quantum fluctuating degrees of freedom in some state basis and the values of the zero modes. This in fact has interpretation in terms of holography: classical degrees of freedom in space-time interior correlate with fermionic degrees of freedom assignable to string world sheets and partonic 2-surfaces. This together with the fact that zero modes are effectively classical variables, implies that the localization in zero modes corresponds to a state function reduction.

2. Measurement theory requires an entanglement between zero modes and quantum jumps of the physical state. The addition of a measurement interaction term to the Kähler-Dirac action coupling to four-momentum and color quantum numbers of the state and also to more general conserved quantum numbers allows an explicit realization of this coupling and induces the addition of an analogous measurement interaction term to Kähler action [K139]. This term implies the entanglement of the quantum numbers of the physical states with zero modes.

A good metaphor for quantum jump is as Djinn leaving the bottle (informational time development), fulfilling the wish (quantum jump involving choice) and returning to, possibly new, bottle (localization in zero modes and subsequent state preparation process). One could formally regard each quantum jump as a quantum computation with duration defined by the life-time of corresponding self (the increase of the average temporal distance between the tips of CD in superposition of CDs) followed by halting meaning reduction to the opposite boundary of CD. Quantum jump to the opposite boundary could also be seen as an act of volition (or giving rise to experience of volition at some level of self hierarchy).

Is the complete localization in zero modes really necessary?

The detailed inspection of what happens in state function reductions forces to consider the possibility that state function reduction involves always a complete localization in zero modes. This was indeed the original proposal. It however seems that a localization modulo finite measurement resolution might be a more realistic assumption. Certainly it is enough to explain why the perceived Universe looks classical.

1. QFT picture strongly suggests that sub-system must be defined as a tensor factor of the space of WCW spinors at given point Y^3 of WCW . This suggests that subsystem should be defined as a function of Y^3 and should be a local concept. An important consequence of this definition is that entanglement entropy gives information about space-time geometry.

2. WCW spinor field can be formally expressed as superposition of quantum states localized into the reduced configuration space consisting of 3-surfaces belonging to light cone boundary. Hence WCW spinor field can be formally written as

$$\sum_{Y^3} C(Y^3)(n,N)|n\rangle|N\rangle$$

for any subsystem-complement decomposition defined in Y^3. Clearly, WCW coordinates appear in the role of additional indices with respect to which entanglement coefficients are diagonal. The requirement that final state is pure state would suggest that quantum jump reducing entanglement must involve complete localization of the WCW spinor field to some Y^3 plus further quantum jump reducing entanglement in Y^3. Complete localization in WCW is however not physically acceptable option since the action of various gauge symmetries on quantum states does not commute with the complete localization operation. In particular, the requirement that physical states belong to the representations of Super Virasoro and super-symplectic algebras, is not consistent with this requirement.

3. WCW has fiber space structure. WCW metric is non-vanishing only in the fiber degrees of freedom and since the propagator for small fluctuations equals to the contravariant metric, fiber degrees of freedom correspond to genuine quantum fluctuations. WCW metric vanishes in zero modes, which can be identified as fundamental order parameters in the spirit of Haken's theory of self organization. The requirement that various local symmetries act as gauge symmetries, provides good reasons to expect that *entanglement coefficients in the fiber degrees of freedom are gauge invariants and depend on the zero modes parametrically.* The one-one correlation between quantum numbers of the state assignable to fiber degrees of freedom and classical variables identified as zero modes would encourage the assumption the a complete localization occurs in zero modes. A weaker condition is that localization occurs only modulo a finite measurement resolution.

4. The original argument was that the non-existence of metric based volume element in zero modes forces the wave functions in zero modes to have a discrete locus. There however exists a symplectic measure defined by the symplectic form in zero modes. It does not however allow a complexification to Kähler form as it does in quantum fluctuating degrees of freedom. This symplectic from could define a hierarchy of integration measures coming as restrictions of $J \wedge J ... \wedge J$ with n factors to $2n$-dimensional sub-manifolds. Under some additional conditions- maybe the homological non-triviality of J and the orientability of the sub-manifold are enough, this measure would define a positive definite inner product and one would have a hierarchy finite-dimensional sub-spaces of zero modes. The maxima of Kähler function with respect to zero modes replace naturally the continuum with a discrete set of points and define the counterpart of the spin glass energy landscape consisting of the minima of free energy. Effective finite-dimensionality and even effective discreteness would be achieved.

5. The time development by quantum jumps in zero modes is effectively classical: Universe is apparently hopping around in the space of the zero modes. This looks very attractive physically since zero modes characterize the size, shape and classical Kähler fields associated with 3-surface. Therefore each quantum jump gives very precise conscious geometric information about space-time geometry and about WCW in zero modes. This also means that Haken's classical theory of self-organization generalizes almost as such to TGD context. The probability for localization to given point of zero mode space is given by the reduced probability density Q defined by the integral of the probability density R defined by WCW spinor field over fiber degrees of freedom. The local maxima of Q with respect to zero modes appear as attractors for the time development by quantum jumps. Dissipative time development could be regarded as a sequence of quantum jumps leading to this kind of local maximum.

6. Effective localization in zero modes is completely analogous to spontaneous symmetry breaking in which scalar field attains vacuum expectation value with the difference that the number of degrees of freedom is infinite unlike in typical models of symmetry breaking. Thus the general structure of the WCW spinor field together with TGD based quantum jump concept automatically implies spontaneous symmetry breaking in its TGD version (note however that particle massivation results from both p-adic thermodynamics and coupling to Higgs like field of purely geometric origin in TGD framework). TGD Universe is superposition of parallel classical universes (3-surfaces). Therefore quantum entangled state can can be regarded as a superposition of parallel entangled states, one for each 3-surface. Formally entanglement coefficients can be regarded as coefficients containing the WCW coordinates of 3-surfaces as additional index. The analogy with the spin glass also supports the localization in the zero modes.

7. Effective localization in the zero modes provides simple explanation for why the universe of conscious experience looks classical: moment of consciousness makes it classical. It also explains why the physics treating space-time as a fixed arena of dynamics has been so successful. As already found, a further important consequence is first principle description of the state function reduction.

5.2.7 NMP And Negentropic Entanglement

The evolution of NMP has been a process in which formulation has become gradually more accurate. The final outcome is surprisingly near to the original picture.

Information measures for entanglement

The attempts to formulate NMP in p-adic physics led to the realization that one can distinguish between three kinds of information measures.

1. In real physics the negative of the entanglement entropy defined by the standard Shannon formula defines a natural information measure, which is always non-positive. The formula for Shannon formula is given by $S = -\sum_n P_n log(P_n)$, where P_n are the probabilities identifiable

as eigenvalues of the density matrix for a pair of system and its complement. Density matrix is defined as $\rho = C^{dagger}C$, C is the matrix defined by the entanglement coefficients for the system and its complement. In the original formulation of NMP the state function it was assumed that ρ defines the universal observable measured in state function reduction so that the sub-system (its complement) goes to an eigen state of ρ. This assumption is still kept.

2. In p-adic physics one can generalize entanglement entropy as (dis-)information measure to p-adic valued information measure by replacing the logarithms of p-adic valued probabilities with the p-based logarithms $log_p(|P|_p)$ which are integer valued and can be interpreted as p-adic numbers. This p-adic valued entanglement entropy can be mapped to a non-negative real number by the so called canonical identification $x = \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n}$. In both cases a non-positive information measure results.

   When entanglement probabilities are rational numbers or at most finitely algebraically extended rational numbers one can still define logarithms of probabilities as p-based logarithms $log_p(|P|_p)$ and interpret the entropy as a rational or algebraic number. In this case the entropy can be however negative and positive definite information measure is possible. Irrespective of number field one can in this case define entanglement entropy as a maximum of number theoretic entropies S_p over the set of primes.

3. The consistency with quantum measurement theory forces to give up the most general identification of negentropic entanglement (NE). One could argue that it is not possible to distinguish between real and thus entropic entanglement and NE in any manner. One would need some signature for it. The internal consistency of quantum measurement theory indeed demands that the state function reduction occurs to an eigen space of density matrix, which in the most general case is characterized by an n-dimensional projector satisfying $P^2 = P$. Projector property of the final state density matriz would serve as a unique signature of negentropic entanglement.

It seems that the third choice is the correct one. NE would thus correspond to a density matrix proportional to a projector (identity matrix). What would be new that P is higher-dimensional projector. In real context one can argue that this situation is practically never met in reality. In TGD however hierarchy of Planck constants labelling quantum critical phases identified as dark matter would correspond to this kind of situations. Density matrix decomposes to a direct sum of terms proportional to higher-D projectors only at criticality. The interpretation could be in terms of measurement resolution: experimental resolution does not allow to discern between the n state pairs in the superposition and their probabilities are identical.

NE would result in the case of 2-particle system from entanglement coefficients defining a unitary matrix. This strongly suggests that quantum computing systems carry NE.

There has been also the question about whether NE could be identified as bound state entanglement. It is obvious that this cannot be the case for NE defined by projector treating all entangled state pairs democratically.

Does entanglement negentropy have a classical space-time correlate?

Quantum classical correspondence (QCC) suggests that number theoretic entanglement negentropy or entropy could have a classical counterpart at space-time level. The interpretation of Kähler function as the analog of thermodynamical free energy with Kähler coupling strength playing the role of critical temperature leads to ask whether the Kähler function could define the counterpart of entanglement entropy or - negentropy. The standard formula for the entropy in terms of free energy suggests that entropy is positive also now, and the interpretation as entropy would look more natural. One must of course be very cautious: also the negative of Kähler function could be identified as the analog of free energy and in this case entropy would be negative.

Kähler function is identified as Kähler action in the region of space-time with Euclidian signature and is non-negative. Kähler function is not present in GRT like theories so that it is a new concept. It is not yet clear whether also the Euclidian regions correspond to n-sheeted coverings.

What happens in Minkowkian regions, where $\sqrt{g_4}$ is imaginary and Kähler function is replaced with the analog of Morse function? In Minkowskian regions Kähler action can have also

negative sign. Could Kähler action in these regions have information theoretic interpretation? If so then the magnetic flux tubes would naturally correspond to negentropic regions and electric flux quanta to entropic ones. In Minkowskian regions magnetic flux tubes with $h_{eff} = n \times h$ correspond to n-fold coverings and give rise to n-fold value of Kähler action so that the interpretation in terms of negentropy might make sense. Note however that one can ask whether the flux tubes are actually Euclidian regions connecting Euclidian regions bounded by partonic 2-surfaces. This is possible since the string world sheet associated with the string like objects can have also Euclidian signature of metric.

An interesting question is how the negentropy assignable with the inclusions of hyperfinite factors and determined by the logarithm for the index of inclusion (to be discussed later) could relate to the value spectrum of Kähler function.

Bound state entanglement and NE

It is almost trivial that bound state entanglement must be kinematically stable against NMP became obvious. One can imagine that the state function reduction proceeds step by step by reducing the state to two parts in such a way that the reduction of entanglement entropy is maximal.

1. If a resulting subsystem corresponds to a bound state having no decomposition to free subsystems the process stops for this subsystem. The natural assumption is that subsystems lose their consciousness when U process leads to bound state entanglement whereas bound state itself can be conscious.

2. If the entanglement is negentropic (and thus rational or algebraic) a more natural interpretation consistent with the teaching of spiritual practices is that subsystems experience a fusion to a larger conscious entity. The negentropic entanglement between free states is stabilized by NMP and negentropically entangled states need not reside at the bottom of potential well forbidding the reduction of entanglement. This makes possible new kinds of correlated states for which binding energy can be negative. Bound state entanglement would be like the jail of organized marriage and NE like a love marriage in which companions are free to leave but do not what it. The existence of this kind of NE is especially interesting in living matter, where metabolism (high energy phosphate bond in particular) and the stability of DNA and other highly charged polymers is poorly understood physically: NE could be responsible for stabilization making possible the transfer of metabolic energy [K45, K46].

Strong and weak forms of NMP

The *strong form of NMP* would state that negentropy of the universe is maximal in each state function reduction: we would live in the best possible world. This does not seem to be the case however. This leads to the *weak form of NMP* stating that in the case that maximal negentropy gain corresponds to n-dimensional projector, also the reductions to $n-k$-dimensional sub-spaces are possible and for $n - k = 1$ one has ordinary reduction. Self can choose between different projector terms in ρ and for the chosen term choose lower- than maximal-dimensional sub-space.

The interpretation is that this brings to the theory of consciousness free will, ethics, and moral [K133]. Good means generation of NE, evolution. The choice in which outcome is 1-dimension sub-space means isolation, breaking of contact, as a punishment for not generating NE. The number of different choices in state function reduction for a given value of n is $2^n - 1$, which suggests am interpretation in terms of a Boolean algebra with n bits and an emotional realization of Boolean algebra - kind of emotional intelligence.

The weak form of NMP leads allows also to understand how preferred p-adic primes suggested by the p-adic length scale hypothesis emerged. The point is that NE per dimension of space is maximal when n is power of p. If n is power of p and $n-k$ is prime then the NE per dimension of subs-space is very large for it. For $p = 2$ this would explained preferred role of Mersenne primes.

What if the eigenvalues of the density matrix go outside the algebraic extension used?

The following argument suggests that also more general algebraic entanglement could be reasonably stable against NMP, namely the entanglement for which the eigenvalues of the density matrix and

eigenvectors are outside the algebraic extension associated with the parameters characterizing string world sheets and partonic 2-surfaces as space-time genes.

The restriction to a particular extension of rationals - a central piece of the number theoretical vision about quantum TGD - implies that density matrix need not allow diagonalization. In eigen state basis one would have has algebraic extension defined by the characteristic polynomial of the density matrix and its roots define the needed extension which could be quite well larger than the original extension. This would make state stable against state function reduction.

If this entanglement is algebraic, one can assign to it a negative number theoretic entropy. This negentropic entanglement is stable against NMP unless the algebraic extension associated with the parameters characterizing the parameters of string world sheets and partonic surfaces defining space-time genes is allowed to become larger in a state function reduction to the opposite boundary of CD generating re-incarnated self and producing eigenstates involving algebraic numbers in a larger algebraic extension of rationals. Could this kind of extension be an eureka experience meaning a step forwards in cognitive evolution?

If this picture makes sense, one would have both the unitary NE with a density matrix, which is projector and the algebraic NE with eigen values and NE for which the eigenstates of density matrix outside the algebraic extension associated with the space-time genes. Note that the entanglement characterized by a unitary matrix is "meditative" in the sense that any state basis is possible and therefore in this state of consciousness it is not possible to make distinctions. This strongly brings in mind koans of Zen buddhism. The more general algebraic entanglement could represent abstractions as rules in which the state pairs in the superposition represent the various instances of the rule.

Is NE experienced directly?

Does the NE at the passive boundary of CD give automatically rise to a conscious experience or must one "measure" it somehow?

1. The assumption that repeated state function reductions measure the NE and give rise to a conscious experience of it, looks natural. That NE is experienced consciously as an experience with a positive emotional coloring (love, compassion, understanding, experience of beauty,...) looks rather natural assumption since a repeated measurement of this state is in question although only the state at the active boundary changes. This experience would correspond to that part of experience which defines experiencer as something stable and unchanging (the original proposal was that self is a subsystem able to remain un-entangled and thus having self identity). The changing part of the experience would come from the active boundary of CD and give rise to an experience about flow of time due to the average increase of the distance between the tips of CD. Self would correspond to sequence of repeated reductions and would die when the first reduction to the opposite boundary of CD would occur. This would be an re-incarnation of self as a new conscious entity.

2. An alternative view is that NE as such gives rise to a conscious experience only in what is known as interaction free experiment [B1]. This idea looks un-necessary in the proposed framework. Interaction free measurement would be too complex a process to appear at the fundamental level.

It has turned that interaction free measurement could read bits (but not qubits) and might be involved with long term memory recall and reading of sensory and cognitive representations. The values of bits would remain unaffected in the interaction free measurement at idealized limit.

1. Interaction free measurement for which Elizur-Weizman bomb tester is an excellent representation (see `http://tinyurl.com/y9zenssv`) involves ordinary state function reduction. The outcome of state function reduction tells whether the bomb can act as quantum measurement apparatus or not (is it active or not) and at idealized limit the state of bomb is not changed (it does not explode). The reading of bits from memory is possible if bit 1 (say) can take the role of active state of bomb and bit 0 that of dud. In the bomb tester model the measured state corresponds to a superposition of two photon paths such that the other one traverses the bomb and induces explosion if state function reduction to this path takes place. The reduction to the other path does not induce explosion.

2. Interaction free measurement is useful if the bit can be represented as active/passive dichotomy. Active/passive dichotomy can be indeed represented in very simple manner physically. One has two state system in which lower energy state can be excited to a long lived higher energy state by photon absorption. System in higher energy state is passive and that in lower energy state active.

What happens to h_{eff} during state function reduction sequence?

What happens to h_{eff} during state function reduction sequence. Does it increase so that self would "become wiser" as it becomes older?

The natural assumption is that the value of h_{eff} stays constant during the life cycle of self and by NMP h_{eff} increasing phase transitions tend to occur as self dies and re-incarnates at opposite boundary of CD. In this process a state would be selected from the superposition of states having negentropic entanglement at the active boundary of CD.

The original idea about correlation between age and wisdom is not however wrong. h_{eff} increasing phase transitions can however occur for the sub-selves of self defining mental images of self. To these one can assign sub-CDs. Hence one can say that NE assignable to a given CD increases also during the repeated state function reductions.

It looks rather natural to assume that self does its best to stay alive by trying to gather somehow the NE needed to satisfy the demands of NMP: the easy solution is to eat other living beings! This is achieved by metabolic energy which has interpretation in terms of a transfer of NE carried by nutrients. Homeostasis in turn is a collection of mechanisms helping to stay at criticality.

Negentropic entanglement, NMP, braiding and TQC

Negentropic entanglement for which number theoretic entropy characterized by p-adic prime is negative so that entanglement carries information, is in key role in TGD inspired theory of consciousness and quantum biology.

1. The key feature of 2-particle negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is that density matrix is projector and thus proportional to unit matrix so that the assumption that state function reduction corresponds to the measurement of density matrix does not imply state function reduction to one-dimensional sub-space. This special kind of degenerate density matrix emerges naturally for the hierarchy $h_{eff} = n \times h$ interpreted in terms of a hierarchy of dark matter phases. I have already earlier considered explicit realizations of negentropic entanglement assuming that E is invariant under the group of unitary or orthogonal transformations (also subgroups of unitary group can be considered -say symplectic group). One can however consider much more general options and this leads to a connection with topological quantum computation (TQC).

2. Entanglement matrix E equal to $1/\sqrt{n}$ factor times unitary matrix U (as a special case orthogonal matrix O) defines a density matrix given by $\rho = UU^{\dagger}/n = Id_n/n$, which is group invariant. One has NE respected by state function reduction if NMP is assumed. This would give huge number of negentropically entangled states providing a representation for some unitary group or its subgroup (such as symplectic group). In principle any unitary representation of any Lie group would allow representation in terms of NE. In principle any unitary representation of any Lie group would allow a representation in terms of NE.

3. In physics as generalized number theory vision, a natural condition is that the matrix elements of E belong to the algebraic extension of p-adic numbers used so that discreted algebraic subgroups of unitary or orthogonal group are selected. This realizes evolutionary hierarchy as a hierarchy of p-adic number fields and their algebraic extensions, and one can imagine that evolution of cognition proceeds by the generation of negentropically entangled systems with increasing algebraic dimensions and increasing dimension reflecting itself as an increase of the largest prime power dividing n and defining the p-adic prime in question.

4. One fascinating implication is the ability of TGD Universe to emulate itself like Turing machine: unitary S-matrix codes for scattering amplitudes and therefore for physics and negentropically entangled subsystem could represent sub-matrix for S-matrix as rules representing "the laws of physics" in the approximation that the world corresponds to n-dimension Hilbert space. Also the limit $n \to \infty$ makes sense, especially so in the p-adic context where real infinity can correspond to finite number in the sense of p-adic norm. Here also dimensions n given as products of powers of infinite primes can be formally considered.

One can consider various restrictions on E.

1. In 2-particle case the stronger condition that E is group invariant implies that unitary matrix is identity matrix apart from an overall phase factor: $U = exp(i\phi)Id$. In orthogonal case the phase factor is ± 1. For n-particle NE one can consider group invariant states by using n-dimensional permutation tensor $\epsilon_{i_1,...i_n}$.

2. One can give up the group invariance of E and consider only the weaker condition that permutation is represented as transposition of entanglement matrix: $C_{ij} \to C_{ij}$. Symmetry/antisymmetry under particle exchange would correspond to $C_{ji} = \epsilon C_{ij}$, $\epsilon = \pm 1$. This would give in orthogonal case $OO^T = O^2 = Id$ and $UU^* = Id$ in unitary case.

   In the unitary case particle exchange could be identified as hermitian conjugation $C_{ij} \to C^*_{ji}$ and one would have $U^2 = Id$. Euclidian gamma matrices γ_i define unitary and hermitian generators of Clifford algebra having dimension 2^{2m} for $n = 2m$ and $n = 2m + 1$. It is relatively easy to verify that the squares of completely anti-symmetrized products of k gamma matrices representing exterior algebra normalized by factor $1/\sqrt{k!}$ are equal to unit matrix. For $k = n$ the anti-symmetrized product gives essentially permutation symbol times the product $\prod_k \gamma_k$. In this manner one can construct entanglement matrices representing negentropic bi-partite entanglement.

3. The possibility of taking tensor products $\epsilon_{ij..k...n}\gamma_i \otimes \gamma_j .. \otimes \gamma_k$ of k gamma matrices means that one can has also co-product of gamma matrices. What is interesting is that quantum groups important in topological quantum computation as well as the Yangian algebra associated with twistor Grassmann approach to scattering amplitudes possess co-algebra structure. TGD leads also to the proposal that this structure plays a central role in the construction of scattering amplitudes. Physically the co-product is time reversal of product representing fusion of particles.

4. One can go even further. In 2-dimensional QFTs braid statistics replaces ordinary statistics. The natural question is what braid statistics could correspond to at the level of NE. Braiding matrix is unitary so that it defines NE. Braiding as a flow replaces the particle exchange and lifts permutation group to braid group serving as its infinite covering.

   The allowed unitary matrices representing braiding in tensor product are constructed using braiding matrix R representing the exchange for two braid strands? The well-known Yang-Baxter equation for R defined in tensor product as an invertible element (`http://tinyurl.com/yax3j6mr`) expresses the associativity of braiding operation. Concretely it states that the two braidings leading from 123 to 321 produce the same result. Entanglement matrices constructed R as basic operation would correspond to unitary matrices providing a representation for braids and each braid would give rise to one particular NE.

   This would give a direct connection with TQC for which the entanglement matrix defines a density matrix proportional to $n \times n$ unit matrix: R defines the basic gate [B23]. Braids would provide a concrete space-time correlate for NE giving rise to "Akashic records". Note that in string theory-GRT framework this old idea of TGD has been recently introduced by Maldacena and Sussking as a proposal that wormholes connecting blackholes provide a description of entanglement.

   I have indeed proposed the interpretation of braidings as fundamental memory representations much before the vision about Akashic records. This kind of entanglement matrix need not represent only time-like entanglement but can be also associated also with space-like entanglement. The connection with braiding matrices supports the view that magnetic flux

tubes are carriers of negentropically entangled matter and also suggests that this kind of entanglement between -say- DNA and nuclear or cell membrane gives rise to TQC.

Some comments concerning the covering space degrees of freedom associated with $h_{eff} = n \times h$ viz. ordinary degrees of freedom are in order.

1. Negentropic entanglement with n entangled states would correspond naturally to $h_{eff} = n \times h$ and is assigned with "many-particle" states, which can be localized to the sheets of covering but one cannot exclude similar entanglement in other degrees of freedom. Group invariance leaves only group singlets and states which are not singlets are allowed only in special cases. For instance for $SU(2)$ the state $|j, m\rangle = |1, 0\rangle$ represented as 2-particle state of 2 spin 1/2 particles is negentropically entangled whereas the states $|j, m\rangle = |1, \pm 1\rangle$ are pure.

2. Negentropic entanglement associated with $h_{eff} = n \times h$ could factorize as tensor product from other degrees of freedom. Negentropic entanglement would be localised to the covering space degrees of freedom but there would be entropic entanglement in the ordinary degrees of freedom - say spin. The large value of h_{eff} would however scale up the quantum coherence time and length also in the ordinary degrees of freedom. For entanglement matrix this would correspond to a direct sum proportional to unitary matrices so that also density matrix would be a direct sum of matrices $p_n E_n = p_n Id_n/n$, $\sum p_n = 1$ correspond ing to various values of "other quantum numbers", and state function reduction could take place to any subspace in the decomposition. Also more general entanglement matrices for which the dimensions of direct summands vary, are possible.

3. One can argue that NMP in form does not allow halting of quantum computation. This is not true. The computation halts but in different manner since negentropic entanglement tends to be generated even for weak form of NMP. Weak form of NMP allows also ordinary state function reduction. State function reduction is not need if NE can be directly experienced and self represents this mental image as a kind of abstraction or rule with the state pairs in the superposition representing the instances of the rule.

   It might be also possible to deduce the structure of negentropically entangled state by an interaction free quantum measurement replacing the state function reduction with "externalised" state function reduction. One could speak of interaction free TQC. This TQC would be reading of "Akashic records".

4. One could also counter argue that NMP allows the transfer of NE from the system so that TQC halts. NMP allows this if some another system receives at least the negentropy contained by NE. The interpretation would be as the increase of information obtained by a conscious observer about the outcome of halted quantum computation.

   Metabolism could quite concretely correspond the transfer of NE associated with the NE between nutrient molecules and some system. This would satisfy the demands of NMP and make possible for the organism to avoid the first state function reduction to the opposite boundary of CD (death) In [K90] it is suggested that this system can be of astrophysical size, say gravitational Mother Gaia with magnetic flux tubes characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0 = \hbar_{eff} = n \times \hbar$, where v_0 is a parameter with dimensions of velocity. There is experimental evidence for dark matter shell around Earth [K112] and there are highly interesting connection to the hypothesis identifying bio-photons as decay products of dark photons located at magnetic flux tubes and having $h_{eff} = h_{gr}$.

The relationship to thermodynamics

The relationship with the ordinary thermodynamics is very interesting and my views about this have been fluctuating.

1. The basic point to notice is that entanglement (neg)entropy characterize the relationship of the system to its environment whereas thermodynamical entropy characterizes single particle in an ensemble. Hence these quantities are not directly comparable and NMP need not be in conflict with the second law. Ordinary state function reductions for an ensemble of

systems lead to a generation of thermodynamical entropy and this explains the second law of thermodynamics in the sector consisting of visible matter $h_{eff} = h$ provided that phase transitions generating negentropic entanglement and transforming ensembles to quantum coherent states are not too probable.

2. For the NE the outcome of the state function reduction ceases to be completely random as it is for the standard definition of entanglement entropy. For the strong form of NMP the outcome seems rather unique: the degenerate subspace for which number theoretic negentropy is maximal. For the weak form of NMP there is an additional randomness - one might speak about analog of thermodynamical fluctuations. The average increase of negentropy is positive if various choices for the dimension $n - k$ of the subspace are equally probable. Usually life is seen as a thermodynamical fluctuations, now its analog would prevent the world to be the best possible one.

   It can happen that the generation of NE transforms thermodynamical ensemble to a superposition of negentropically entangled subsystems and next state function reduction to the opposite boundary generates a negentropically entangled state. This could lead to the breaking of second law. The generation of NE means also phase transitions generating dark matter at magnetic flux tubes assumed to serve as correlates for entanglement. Since dark matter is not visible using the recent measurement technology, the breaking of second law could remain unseen. This could provide a new view to understand self-organization [K103] and evolution in living systems in which dark matter plays a key role according to the TGD inspired vision.

3. This suggests a weak formulation of the second law. In any process in which dark matter possibly created by phase transitions is observed by transforming it to ordinary matter second law holds true since the decay of dark matter to ordinary matter destroys macroscopic quantum coherence. If it is possible to develop technologies allowing to observe dark matter without this transformation, second law does not hold in the observable Universe. The decay of dark photons to ordinary photons identified as bio-photons would represent one example of this. Note also that one can transform only a small sample of dark matter to visible matter. By a book-keeping one can detect whether ordinary matter has transformed to dark matter and with some theory can deduce by taking this kind of samples about the distribution of dark matter.

NMP in adelic approach and two interpretational problems

There have been considerable progress in the understanding of NMP in Zero Energy Ontology (ZEO) and the latest progress is discussed in detail in [K123]. In adelic approach real and various p-adic sectors are combined to adelic structure at space-time level. State space is shared by all adelic sectors and corresponds to Hilbert space with a coefficient field, which is some extension of rationals. It defines an extension of p-adic numbers for all values of p. Algebraic extensions and also extensions by roots of e correspond to finite-dimensional extensions of p-adic numbers. Together these extensions define an adele.

At the level of WCW this means that the general coordinate - and Lorentz invariant coordinates of WCW have values in the algebraic extension making sense in all number fields. Strong form of holography means that string world sheets and partonic 2-surfaces (2-surfaces) serve as "space-time genes" determining the 4-D space-time surfaces so that these conformally invariant moduli parameters for these 2-surfaces serve as WCW coordinates.

In given p-adic sector entanglement entropy (EE) is defined by replacing the logarithms of probabilities in Shannon formula by the logarithms of their p-adic norms. The resulting entropy satisfies the same axioms as ordinary entropy but makes sense only for probabilities, which must be rational valued or in an algebraic extension of rationals. The algebraic extensions corresponds to the evolutionary level of system and the algebraic complexity of the extension serves as a measure for the evolutionary level. p-Adically also extensions determined by roots of e can be considered. What is so remarkable is that the number theoretic entropy can be negative.

A simple example allows to get an idea about what is involved. If the entanglement probabilities are rational numbers $P_i = M_i/N$, $\sum_i M_i = N$, then the primes appearing as factors of N

correspond to a negative contribution to the number theoretic entanglement entropy and thus to information. The factors of M_i correspond to negative contributions. For maximal entanglement with $P_i = 1/N$ in this case the EE is negative. The interpretation is that the entangled state represents quantally concept or a rule as superposition of its instances defined by the state pairs in the superposition. Identity matrix means that one can choose the state basis in arbitrary manner and the interpretation could be in terms of "enlightened" state of consciousness characterized by "absence of distinctions". In general case the basis is unique.

Metabolism is a central concept in biology and neuroscience. Usually metabolism is understood as transfer of ordered energy and various chemical metabolites to the system. In TGD metabolism could be basically just a transfer of NE from nutrients to the organism. Living systems would be fighting for NE to stay alive (NMP is merciless!) and stealing of NE would be the fundamental crime.

TGD has been plagued by a longstanding interpretational problem: can one apply the notion of number theoretic entropy in the real context or not. If this is possible at all, under what conditions this is the case? How does one know that the entanglement probabilities are not transcendental as they would be in generic case? There is also a second problem: p-adic Hilbert space is not a well-defined notion since the sum of p-adic probabilities defined as moduli squared for the coefficients of the superposition of orthonormal states can vanish and one obtains zero norm states.

These problems disappear if the reduction occurs in the intersection of reality and p-adicities since here Hilbert spaces have some algebraic number field as coefficient field. By SH the 2-D states states provide all information needed to construct quantum physics. In particular, quantum measurement theory.

1. The Hilbert spaces defining state spaces has as their coefficient field always some algebraic extension of rationals so that number theoretic entropies make sense for all primes. p-Adic numbers as coefficients cannot be used and reals are not allowed. Since the same Hilbert space is shared by real and p-adic sectors, a given state function reduction in the intersection has real and p-adic space-time shadows.

2. State function reductions at these 2-surfaces at the ends of CD take place in the intersection of realities and p-adicities if the parameters characterizing these surfaces are in the algebraic extension considered. It is however not absolutely necessary to assume that the coordinates of WCW belong to the algebraic extension although this looks very natural.

3. NMP applies to the total EE. It can quite well happen that NMP for the sum of real and p-adic entanglement entropies does not allow ordinary state function reduction to take place since p-adic negative entropies for some primes would become zero and net negentropy would be lost. There is competition between real and p-adic sectors and p-adic sectors can win! Mind has causal power: it can stabilize quantum states against state function reduction and tame the randomness of quantum physics in absence of cognition! Can one interpret this causal power of cognition in terms of intentionality? If so, p-adic physics seems be also physics of intentionality as originally assumed.

   One could also say that Einstein was rather near to truth when he said that God does not play dice. Conscious entities play dice only whey they die and re-incarnate as time-revered selves at the opposite boundary of CD - that is perform the first state function reduction at the opposite boundary of CD.

5.2.8 Wigner's friend and Schrödinger's cat

I encountered in Facebook discussion Wigner's friend paradox (see`http://tinyurl.com/jpnvtp5` and `http://tinyurl.com/ze6bmem`). Wigner leaves his friend to the laboratory together with Schrödinger's cat and the friend measures the state of cat: the outcome is "dead" or "alive". Wigner returns and learns from his friend what the state of the cat is. The question is: was the state of cat fixed already earlier or when Wigner learned it from his friend. In the latter case the state of friend and cat would have been superposition of pairs in which cat was alive and friend new this and cat was dead also now friend new this. Entanglement between cat and bottle would have been transferred to that between cat+bottle and Wigner's friend. Recall that this kind of

information transfer occur in quantum computation and quantum teleportation allows to transfer arbitrary quantum state but destroys the original.

The original purpose of Wigner was to demonstrate that consciousness is involved with the state function collapse.

TGD view is that the state function collapse can be seen as moment consciousness [K73, K10]. Or more precisely, self as conscious entity corresponds to a repeated state function reduction sequence to the same boundary of causal diamond (CD). One might say that self is generalized Zeno effect in Zero Energy Ontology (ZEO). The first reduction to the opposite boundary of CD means death of self and re-incarnation at opposite boundary as time reversed self. The experiencet flow of time corresponds to the shift of the non-fixed boundary of self reduction by reduction farther from the fixed boundary - also the state at it changes. Thus subjective time as sequence of reductions is mapped to clock time identifiable as the temporal distance between the tips of CD. Arrow of time is generated but changes in death-reincarnation.

In TGD inspired theory of consciousness the intuitive answer to the question of Wigner looks obvious. If the friend measured the state of cat, it was indeed dead or alive already before Wigner arrived. What remains is the question what it means for Wigner, the "ultimate observer", to learn about the state of the cat from his friend. The question is about what conscious communications are.

Consider first the situation in the framework of standard quantum information theory.

1. Quantum teleportation (see `http://tinyurl.com/omfkydh`) could make it possible to transfer arbitrary quantum state from the brain of Wigner's friend to Wigner's brain. Quantum teleportation involves generation of Bell state (see `http://tinyurl.com/z9g8rar` of qubits assignable with Wigner's friend (A) and Wigner (B).

2. This quantum state can be constructed by a joint measurement of component of spin in same direction at both A and B. One of the four eigenstates of (by convention) the operator $Q^z = J_x^{1)} \otimes J_y^{2)} - J_y^{1)} \otimes J_x^{2)}$ is the outcome. For spinors the actions of J_x and J_y change the sign of J_z eigenvalue so that it becomes possible to construct the Bell states as eigenstates of Q^z.

3. After that Wigner's friend measures both the qubit representing cat's state, which is to be communicated and the qubit at A. The latter measurement does not allow to predict the state at B. Wigner's friend communicates the two bits resulting from this measurement to Wigner classically. On basis of these two classical bits his friend performs some unitary operation to the qubit at his end and transforms it to qubit that was to be communicated.

This allows to communicate the qubit representing measurement outcome (alive/dead). But what about meaning? What guarantees that the meaning of the bit representing the state of the cat is the same for Wigner and his friend? One can also ask how the joint measurement can be realized: its seems to require the presence of system containing $A \otimes B$. To answer these questions one must introduce some notions of TGD inspired theory of consciousness: self hierarchy and subself=mental image identification.

TGD inspired theory of consciousness predicts that during communication Wigner and his friend form a larger entangled system: this makes possible sharing of meaning. Directed attention means that subject and object are entangled. The magnetic flux tubes connecting the two systems would serve as a correlate for the attention. This mechanism would be at work already at the level of molecular biology. Its analog would be wormholes in ER-EPR corresponence proposed by Maldacena and Susskind. Note that directed attention brings in mind the generation of the Bell entangled pair A-B. It would make also possible quantum teleportation.

Wigner's friend could also symbolize the "pointer of the measurement apparatus" constructed to detect whether cats are dead of alive. Consider this option first. If the pointer is subsystem defining subself of Wigner, it would represent mental image of Wigner and there would be no paradox. If qubit in the brain in the brain of Wigner's friend replaces the pointer of measurement apparatus then during communication Wigner and his friend form a larger entangled system experiencing this qubit. Perhaps this temporary fusion of selves allows to answer the question about how common meaning is generated. Note that this would not require quantum teleportation protocol but would allow it.

Negentropically entangled objects are key entities in TGD inspired theory of consciousness and the challenge is to understand how these could be constructed and what their properties could be. These states are diametrically opposite to unentangled eigenstates of single particle operators, usually elements of Cartan algebra of symmetry group. The entangled states should result as eigenstates of poly-local operators. Yangian algebras involve a hierarchy of poly-local operators, and twistorial considerations inspire the conjecture that Yangian counterparts of super-symplectic and other algebras made poly-local with respect to partonic 2-surfaces or end-points of boundaries of string world sheet at them are symmetries of quantum TGD [K48]. Could Yangians allow to understand maximal entanglement in terms of symmetries?

1. In this respect the construction of maximally entangled states using bi-local operator $Q^z = J_x \otimes J_y - J_x \otimes J_y$ is highly interesting since entangled states would result by state function. Single particle operator like J_z would generate un-entangled states. The states obtained as eigenstates of this operator have permutation symmetries. The operator can be expressed as $Q^z = f^z_{ij} J^i \otimes J^j$, where f^A_{BC} are structure constants of SU(2) and could be interpreted as co-product associated with the Lie algebra generator J^z. Thus it would seem that unentangled states correspond to eigenstates of J^z and the maximally entangled state to eigenstates of co-generator Q^z. Kind of duality would be in question.

2. Could one generalize this construction to n-fold tensor products? What about other representations of SU(2)? Could one generalize from SU(2) to arbitrary Lie algebra by replacing Cartan generators with suitably defined co-generators and spin 1/2 representation with fundamental representation? The optimistic guess would be that the resulting states are maximally entangled and excellent candidates for states for which negentropic entanglement is maximized by NMP [K73].

3. Co-product is needed and there exists a rich spectrum of algebras with co-product (quantum groups, bialgebras, Hopf algebras, Yangian algebras). In particular, Yangians of Lie algebras are generated by ordinary Lie algebra generators and their co-generators subject to constraints. The outcome is an infinite-dimensional algebra analogous to one half of Kac-Moody algebra with the analog of conformal weight N counting the number of tensor factors. Witten gives a nice concrete explanation of Yangian [B9] for which co-generators of T^A are given as $Q^A = \sum_{i<j} f^A_{BC} T^B_i \otimes T^C_j$, where the summation is over discrete ordered points, which could now label partonic 2-surfaces or points of them or points of string like object (see `http://tinyurl.com/y727n8ua`). For a practically totally incomprehensible description of Yangian one can look at the Wikipedia article (see `http://tinyurl.com/y7heufjh`).

4. This would suggest that the eigenstates of Cartan algebra co-generators of Yangian could define an eigen basis of Yangian algebra dual to the basis defined by the totally unentangled eigenstates of generators and that the quantum measurement of poly-local observables defined by co-generators creates entangled and perhaps even maximally entangled states. A duality between totally unentangled and completely entangled situations is suggestive and analogous to that encountered in twistor Grassmann approach where conformal symmetry and its dual are involved. A beautiful connection between generalization of Lie algebras, quantum measurement theory and quantum information theory would emerge.

5.3 Generalization Of NMP To The Case Of Hyper-Finite Type II_1 Factors

The intuitive notions about entanglement do not generalize trivially to the context of relativistic quantum field theories as the rigorous algebraic approach of [C2] based on von Neumann algebras demonstrates. von Neumann algebras can be written as direct integrals of basic building blocks referred to as factors [A33]. Factors can be classified to three basic types labelled as type I, II, and III. Factors of type I appear in non-relativistic quantum theory whereas factors of type III_1 in relativistic QFT [C2]. Factors of type II_1 [A25], believed by von Neumann to be fundamental, appear naturally in TGD framework [K138].

5.3.1 Factors

Factors of type I

The von Neuman factors of type I correspond to the algebras of bounded operators in finite or infinite-dimensional separable Hilbert spaces. In the finite-dimensional case the algebra reduces to the ordinary matrix algebra in the finite-dimensional case and to the algebra of bounded operators of a separable Hilbert space in the infinite-dimensional case. Trace is the ordinary matrix trace. The algebra of projection operators has one-dimensional projectors as basic building blocks (atoms), the notion of pure state is well-defined, and the decomposition of entangled state to a superposition of products of pure states is unique. This case corresponds to the ordinary non-relativistic quantum theory. Ordinary quantum measurement theory and also the theory of quantum computation has been formulated in terms of type I factors. Also the discussion of NMP has been formulated solely in terms of factors of type I.

Factors of type II_1

The so called hyper-finite type II_1 factors, which are especially natural in TGD framework, can be identified in terms of the Clifford algebra of an infinite-dimensional separable Hilbert space such that the unit operator has unit trace. Essentially the fermionic oscillator operator algebra associated with a separable state basis is in question. The theory of hyper-finite type II_1 factors is rich and has direct connections with conformal field theories [A45], quantum groups [A16], knot and 3-manifold invariants [A44, A20, A48], and topological quantum computation [K4], [B15].

Factors of type III

For algebras of type III associated with non-separable Hilbert spaces all projectors have infinite trace so that the very notion of trace becomes obsolete. The factors of type III_1 are associated with quantum field theories in Minkowski space.

The highly counter-intuitive features of entanglement for type III factors are discussed in [C2].

1. The von Neumann algebra defined by the observables restricted to an arbitrary small region of Minkowski space in principle generates the whole algebra. Expressed in a more technical jargon, any field state with a bound energy is cyclic for each local algebra of observables so that the field could be obtained in entire space-time from measurements in an arbitrary small region of space-time. This kind of quantum holography looks too strong an idealization.

   In TGD framework the replacement of Minkowski space-time with space-time sheet seems to restrict the quantum holography to the boundaries of the space-time sheet. Furthermore, in TGD framework the situation is nearer to the non-relativistic one since Poincare transformations are not symmetries of space-time and because 3-surface is the fundamental unit of dynamics. Also in TGD framework M^4 cm degrees of 3-surfaces are present but it would seem that they appear as labels of type II_1 factors in direct integral decomposition rather than as arguments of field operators.

2. The notion of pure state does not make sense in this case since the algebra lacks atoms and projector traces do not define probabilities. The generalization of the notion of pure state as in II_1 case does not make sense since projectors have infinite trace.

3. Entanglement makes sense but has very counter-intuitive properties. First of all, there is no decomposition of density matrix in terms of projectors to pure states nor any obvious generalization of pure states. There exists no measure for the degree of entanglement, which is easy to understand since one cannot assign probabilities to the projectors as their traces.

4. For any pair of space-like separated systems, a dense set of states violates Bell inequalities so that correlations cannot be regarded as classical. This is in a sharp contrast with elementary quantum mechanics, where "de-coherence effects" are believed to drive the states into a classically correlated states.

5. No local measurement can remove the entanglement between a local system and its environment. In TGD framework local operations would correspond to operations associated with a given space-time sheet. Irreducible type II_1 entanglement between different space-time sheets, if indeed present, might have an interpretation in terms of a finite resolution at state space level due to spin glass degeneracy.

On basis of these findings, one might well claim that the axiomatics of relativistic quantum field theories is not consistent with the basic physical intuitions.

5.3.2 NMP Hyper-Finite Factors Of Type II_1

In the following hyper-finite factors of type II_1 (HFFs) will be discussed since they are certainly emerge in TGD as operator algebra defined by the fermionic oscillator operators.

The origin of hyper-finite factors of type $\mathbf{II}_1$ in TGD

Infinite-dimensional Clifford algebra corresponds in TGD framework to the super-algebra generated by complexified WCW gamma matrices creating WCW spinor s from vacuum spinor which is the counterpart of Fock vacuum [K138]. By super-conformal symmetry also WCW degrees of freedom correspond to a similar factor. For type hyper-finite II_1 factors the trace is by definition finite and normalized such that the unit operator has unit trace. As a consequence, the traces of projection operators have interpretation as probabilities.

Finite-dimensional projectors have vanishing traces so that the notion of pure state must be generalized. The natural generalization is obvious. Generalized pure states correspond to states for which density matrix reduces to a projector with a finite norm. The physical interpretation is that physical measurements are never able to resolve completely the infinite state degeneracy identifiable in TGD framework as spin glass degeneracy basically caused by the vacuum degeneracy implying non-determinism of Kähler action. An equivalent interpretation is in terms of state space resolution, which can never be complete.

In TGD framework the relevant algebra can also involve finite-dimensional type I factors as tensor factors. For instance, the entanglement between different space-time sheets could be of this kind and thus completely reducible whereas the entanglement in configuration space spin and "vibrational" degrees of freedom (essentially fermionic Fock space) would be of type II_1. The finite state-space resolution seems to effectively replace hyper-finite type II_1 factors with finite-dimensional factors of type I.

Hyper-finite factors of type $\mathbf{II}_1$ and quantum measurement theory with a finite measurement resolution

The realization that the von Neumann algebra known as hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition.

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of WCW. Also the local Clifford algebra of the embedding space $H = M^4 \times CP_2$ in octonionic representation of gamma matrices of H is important and the entire quantum TGD emerges from the associativity or co-associativity conditions for the sub-algebras of this algebra which are local algebras localized to maximal associative or co-associate sub-manifolds of the embedding space identifiable as space-time surfaces.

The notion of inclusion for hyper-finite factors provides an elegant description for the notion of measurement resolution absent from the standard quantum measurement theory.

1. The included sub-factor creates in ZEO states not distinguishable from the original one and the formally the coset space of factors defining quantum spinor space defines the space of physical states modulo finite measurement resolution.

2. The quantum measurement theory for hyperfinite factors differs from that for factors of type I since it is not possible to localize the state into single ray of state space. Rather, the ray is replaced with the sub-space obtained by the action of the included algebra defining the measurement resolution. The role of complex numbers in standard quantum measurement theory is taken by the non-commutative included algebra so that a non-commutative quantum theory is the outcome.

3. This leads also to the notion of quantum group. For instance, the finite measurement resolution means that the components of spinor do not commute anymore and it is not possible to reduce the state to a precise eigenstate of spin. It is however perform a reduction to an eigenstate of an observable which corresponds to the probability for either spin state.

4. For HFFs the dimension of infinite-dimensional state space is finite and qual to $D = 1$ by convention. For included HFF $\mathcal{N} \subset \mathcal{M}$ the dimension of the tensor factor space containing only the degrees of freedom which are above measurement resolution is given by the index of inclusion $d = \mathcal{M} : \mathcal{N}$. One can say that the dimension associated with degrees of freedom below measurement resolution is $D = 1/d$. This number is never large than 1 for the inclusions and contains a set of discrete values $d = 4cos^2(2\pi/n)$, $n \geq 3$, plus the continuum above it. The fractal generalization of the formula for entanglement entropy gives $S = -log(1/D) = -log(d) \leq 0$ so that one can say that the entanglement negentropy assignable to the projection operators to the sub-factor is positive except for $n = 3$ for which it vanishes. The non-measured degrees of freedom carry information rather than entropy.

5. Clearly both HFFs of type I and II allow entanglement negentropy and allow to assign it with finite measurement resolution. In the case of factors its is not clear whether the weak form of NMP allows makes sense. Could the density matrix be expressed as a direct sum of projectors to subspaces multiplied by corresponding probabilities? Whether this is possible, is far from clear to me: in any case it would require new mathematics.

   A more natural looking option is that the decomposition of the density matrix to projectors is replaced with a particular hierarchy of inclusions and the state function reduction allows any finite sequence of inclusions. The negentropy gain would correspond to the total negentropy gain associated with the inclusion sequences obtained as sum of $S = -log(\prod_i d_i) = -\sum_i log(d_i)$. The larger the number of inclusions in the sequence, the larger the information gain. This makes sense since the measurement resolution would increase. The longer the sequence of inclusions, the higher the negentropy gain. This picture is different from that resulting from NE: in this case reduction to lower dimensional space tends to give smaller negentropy gain.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a way that unentangled systems can possess entangled sub-systems. One can say that the entanglement between sub-selves is not visible in the resolution characterizing selves. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a deeper justification from the quantum measurement theory for hyper-finite factors of type II_1 for which the finite measurement resolution is basic notion.

5.4 Some Consequences Of NMP

In the sequel the most obvious consequences of self measurement and NMP are discussed from the point of view of physics, biology, cognition, and quantum computing. The recent discussion differs considerably from the earlier one since several new elements are involved. ZEO and the hierarchy of CDs, the hierarchy of Planck constants and dark matter, and - perhaps most importantly - the better understanding NE as something genuinely new and making sense in the intersection of real and various p-adic worlds at which living matter is assumed to reside.

5.4.1 NMP And P-Adic Length Scale Hypothesis

The original form of the p-adic length scale hypothesis stated that physically most interesting p-adic primes satisfy $p \simeq 2^k$, k prime or power of prime. It has however turned out that all positive

integers k are possible. Surprisingly few new length scales are predicted by this generalization in physically interesting length scales. p-Adic length scale hypothesis leads to excellent predictions for elementary particle masses (note that the mass prediction is exponentially sensitive to the value of k) and explains also some interesting length scales of biology: for instance, the thicknesses of the cell membrane and of single lipid layer of cell membrane correspond to $k = 151$ and $k = 149$ respectively.

Various explanations for the origin of p-adic length scale hypothesis

The big problem of p-adic TGD is to derive this hypothesis from the basic structure of the theory.

1. One argument is based on black hole-elementary particle analogy [K82] leading to the generalization of the Hawking-Bekenstein formula: the requirement leading to the p-adic length scale hypothesis is that the radius of the so called elementary particle horizon is itself a p-adic length scale. This argument involves p-adic entropy essentially and it seems that information processing is somehow involved.

2. Zero energy ontology predicts p-adic length scale hypothesis if one accepts the assumption that the proper time distances between the tips of CDs come as powers of 2 [K82]. A more general highly suggestive proposal is that the relative position between tips forms a lattice at proper time constant hyperboloid having as a symmetry group discrete subgroup of Lorentz group (which could reduce to a subgroup of the group $SO(3)$ acting as isotropy group for the time-like direction defined by the relative coordinate between the tips of CD [K113].

   p-Adic length scale hypothesis could be understood as a resonance in frequency domain -most naturally for massless particles like photons. The secondary p-adic time scale for favored p-adic primes must be as near as possible to the proper time distance between the tips of CD. Mersenne primes $M_n = 2^n - 1$ (n is prime) satisfy this condition. Also $log(p)$ is in this case as near as possible to $log(2^n)$ and in the sense that the unit of negentropy defined as $log(2^n - m(n))/log(2^n)$ is maximized. This argument might work also for Gaussian Mersennes $G_n = (1+i)^n - 1$ (n is prime also now) if one restricts the consideration to Gaussian primes.

   A more general and more realistic looking hypothesis is that a given CD can have partonic light-like 3-surfaces ending at its boundaries for all p-adic length scales up to that associated with CD: powers of 2 would be favored by the condition of commeasurability very much analogous to frequency doubling.

3. An exciting possibility, suggested already earlier half seriously, is that evolution is present already at elementary particle level. This is the case if elementary particles reside in the intersection of real and p-adic worlds. The success of p-adic mass calculations and the identification of p-adic physics as physics of cognition indeed forces this interpretation. In particular, one can understand p-adic length scale hypothesis as reflecting the survival of the cognitively fittest p-adic topologies.

   I have discussed also other explanations.

1. A possible physical reason for the primes near prime powers of 2 is that survival necessitates the ability to co-operate, to act in resonance: this requirement might force commeasurability of the length scales for p-adic space-time sheet (p_1) glued to larger space-time sheet ($p_2 > p_1$). The hierarchy would state from 2-adic level having characteristic fractal length scales coming as powers of $\sqrt{2}$. When $p > 2$ space-time sheet is generated during cosmological evolution $L(p)$ for it must correspond to power of $\sqrt{2}$ so that one must have $p \simeq 2^n$.

2. A model for learning [K26] as a transformation of the reflective level of consciousness to proto level supports the view that evolution and learning occur already at elementary particle level as indeed suggested by NMP: the p-adic primes near power of prime powers of two are the fittest ones. The core of the argument is the characterization of learning as a map from 2^N many-fermion states to M association sequences. The number of association sequences should be as near as possible equal to 2^N. If M is power of prime: $M = p^K$, association sequences can be given formally the structure of a finite field $G(p, K)$ and p-adic length scale

hypothesis follows as a consequence of $K = 1$. NMP provides the reason for why $M = p^K$ is favored: in this case one can construct realization of quantum computer with entanglement probabilities $p_k = 1/M = 1/p^K$ and the negentropy gain in quantum jump is $Klog(p)$ while for M not divisible by p the negentropy gain is zero.

Generalization of p-adic length scale hypothesis suggested by NMP

The assumption that adelic physics has as its number theoretically universal core the physics for algebraic extensions of rationals inducing those of p-adic numbers fields allows to understand preferred p-adic primes as those which are ramified [K137]. Ramified prime decomposes into a product of primes involving higher powers of prime of the extension and maximally ramified primes correspond to irreducible extensions satisfying so called Eisenstein criterion.

In strong form of holography p-adic continuations of 2-surfaces to preferred extrmals identifiable as imaginations would be easy due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K81]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes. This does not yet explain p-adic length scale hypothesis [K82, K66] stating that p-adic primes near powers of 2 are favored.

A possible generalization of this hypothesis is that primes near powers of prime are favored. There indeed exists evidence for the realization of 3-adic time scale hierarchies in living matter [I49] (`http://tinyurl.com/jbh9m27`) and in music both 2-adicity and 3-adicity could be present, this is discussed in TGD inspired theory of music harmony and genetic code [K96].

The weak form of NMP might come in rescue here.

1. Entanglement negentropy for a NE [K73] characterized by n-dimensional projection operator is the $log(N_p(n)$ for some p whose power divides n. The maximum negentropy is obtained if the power of p is the largest power of prime divisor of p, and this can be taken as definition of number theoretic entanglement negentropy. If the largest divisor is p^k, one has $N = k \times log(p)$. The entanglement negentropy per entangled state is $N/n = klog(p)/n$ and is maximal for $n = p^k$. Hence powers of prime are favoured which means that p-adic length scale hierarchies with scales coming as powers of p are negentropically favored and should be generated by NMP. Note that $n = p^k$ would define a hierarchy of $h_{eff}/h = p^k$. During the first years of h_{eff} hypothesis I believe that the preferred values obey $h_{eff} = r^k$, r integer not far from $r = 2^{11}$. It seems that this belief was not totally wrong.

2. If one accepts this argument, the remaining challenge is to explain why primes near powers of two (or more generally p) are favoured. $n = 2^k$ gives large entanglement negentropy for the final state. Why primes $p = n_2 = 2^k - r$ would be favored? The reason could be following. $n = 2^k$ corresponds to $p = 2$, which corresponds to the lowest level in p-adic evolution since it is the simplest p-adic topology and farthest from the real topology and therefore gives the poorest cognitive representation of real preferred extremal as p-adic preferred extermal (Note that $p = 1$ makes formally sense but for it the topology is discrete).

3. Weak form of NMP [K73, K133] suggests a more convincing explanation. The density matrix of the state to be reduced is a direct sum over contributions proportional to projection operators. Suppose that the projection operator with largest dimension has dimension n. Strong form of NMP would say that final state is characterized by n-dimensional projection operator. Weak form of NMP allows free will so that all dimensions $n - k$, $k = 0, 1, ...n - 1$ for final state projection operator are possible. 1-dimensional case corresponds to vanishing entanglement negentropy and ordinary state function reduction isolating the measured system from external world.

4. The negentropy of the final state per state depends on the value of k. It is maximal if $n - k$ is power of prime. For $n = 2^k = M_k + 1$, where M_k is Mersenne prime $n - 1$ gives the maximum negentropy and also maximal p-adic prime available so that this reduction is favoured by NMP. Mersenne primes would be indeed special. Also the primes $n = 2^k - r$ near 2^k produce large entanglement negentropy and would be favored by NMP.

5. This argument suggests a generalization of p-adic length scale hypothesis so that $p = 2$ can be replaced by any prime.

This argument together with the hypothesis that preferred prime is ramified would correlate the character of the irreducible extension and character of super-conformal symmetry breaking. The integer n characterizing super-symplectic conformal sub-algebra acting as gauge algebra would depends on the irreducible algebraic extension of rational involved so that the hierarchy of quantum criticalities would have number theoretical characterization. Ramified primes could appear as divisors of n and n would be essentially a characteristic of ramification known as discriminant. An interesting question is whether only the ramified primes allow the continuation of string world sheet and partonic 2-surface to a 4-D space-time surface. If this is the case, the assumptions behind p-adic mass calculations would have full first principle justification.

5.4.2 NMP And Thermodynamics

The physical status of the second law has been a longstanding open issue in physics- in particular biophysics. In positive energy ontology the understanding of the origin of second law is simple. Quantum jumps involve state function reduction (or more generally, self measurement) with a random outcome and in the case of ensemble of identical system this leads to a probability distribution for the states of the members of the ensemble. This implies Boltzmann equations implying the second law. In TGD framework there are many elements which force to question this simple picture: zero energy ontology and CDs, effective four-dimensionality of the ensemble defined by states assignable to sub-CDs, hierarchy of Planck constants, and the possibility of negentropic entanglement.

Zero energy ontology and thermodynamical ensembles

Zero energy ontology means that the thermodynamics appears both at the level of quantum states and at the level of ensembles. At the level of quantum states this means that M-matrix can be seen as a complex square root of the density matrix: $\rho = MM^\dagger$, where M is expressible as a product of a positive and diagonal square root of density matrix and unitary S-matrix identifiable as the S-matrix used in quantum physics. U matrix can be seen as a collection of M-matrices as will be found later so that U-matrix fixes M-matrices contrary to what was believed originally. One can say that thermodynamics -at least in some sense- is represented at the level of single particle states. It is natural to assume that this density matrix is measured in particle physics experiment, and that this measurement corresponds to a state function reduction, which in standard physics picture corresponds to a preparation for the initial states and state function reduction for the final states.

The p-adic thermodynamics, which applies to conformal weights rather than energy, predicts successfully elementary particle masses [K79] and should reduce to this thermodynamics. That p-adic thermodynamics can be applied at all conforms with the view that even elementary particles (that is fermions serving as their basic building bricks) reside in the intersection of the real and p-adic worlds so that either p-adic thermodynamics or real thermodynamics with additional constraints on temperature implied by number theory applies.

M-matrix corresponds to a square root of density matrix, which suggests that also ordinary thermodynamics should be replaced with its square root bringing in phase factors. The imaginary part appearing in the exponent of the vacuum functional defined by Kähler action in Minkowskian regions could have interpretation in terms of a square root of thermodynamics. I have proposed this kind of description as a generalization of the model of cell membrane based on generalization of Josephson junction by bringing in dark currents flowing along magnetic flux tubes [K37].

Thermodynamical ensembles are 4-dimensional

The hierarchy of CDs within CDs defines a hierarchy of sub-systems and sub-CDs define in a natural manner 4-dimensional ensemble. If the state function reduction leads to unentangled states, the outcome is an ensemble describable by the density matrix assignable to the single particle states. The sequence of quantum jumps is expected to lead to a 4-D counterpart of thermodynamical ensemble and thermodynamics results when one labels the states by the quantum

numbers assignable to their positive energy part. Entropy is assigned with entire 4-D CD rather than to its 3-dimensional time=constant snapshots. The thermodynamical time is basically the subjective time and measured in terms of quantum jumps but has a correlation with geometric time as explained in [K10] and explained briefly below.

This picture differs from the standard views, and this might explain the paradoxical situation in cosmology resulting from the fact that the initial state of the universe in the standard sense of the word looks highly entropic whereas second law would suggest the opposite [K113]. The cosmological entropy is assigned with a CD of size scale defined by the value of the age of the universe. In this kind of situation each quantum jump replaces the zero energy state with a new one and also induces a drift in the space of CDs to the direction of larger CDs with size defined by the proper time distance between the tips of CD coming as power of 2. Entropy as a function of cosmic time corresponds in TGD framework to the increase of the 4-D entropy as a function of the quantized proper time distance between the tips of the CD.

In this framework it is possible to understand second law in cosmic time scales apart from the possible effects related to NE responsible for the evolution and breaking of second law in arbitrarily long time scales caused by the transformation of thermal ensembles to quantum coherent dark matter. For instance, the number of sub-CDs increases meaning the increase of the size of the ensemble and the emergence of new p-adic length scales as the size of cosmic CD increases. What is fascinating is that the TGD counterpart of cosmic time is quantized in powers of two. This might have predictable effects such as the occurrence of the cosmic expansion in a jump-wise manner. I have discussed an explanation of the accelerated cosmic expansion in terms of quantum jumps of this kind but starting from somewhat different picture [K113].

Does NMP replace second law?

In TGD NMP defines the fundamental law of evolution. If the maximal negentropy gain corresponds to n-dimensional projector and all outcomes for $m \leq n$ are equally probable (weak NMP) the average value of the dimension associated with the projector of the reduced sub-space is $n/2$. The average negentropy gain is average over the various values of m and has sensitive dependence on the prime number decomposition of m. If m is power of prime, the negentropy gain is large. Therefore the weak form of NMP makes it possible to have larger negentropy gain for $m < n$ than for n having factors if m is prime or has small number of factors.

Second law reflecting the non-determinism of state function reduction is expected to hold true when the reduction takes place to 1-D sub-space - dark matter is not generated in state function reductions. The process can have stages involving dark matter phases labelled by non-standard value of Planck constant but the system returns back to the state in which it consists of visible matter.

The generation of NE indeed breaks second law. Particles are not anymore independent members of a thermodynamical ensemble but form larger units. Since the number of particles is reduced also thermodynamical entropy is reduced and second law can be broken in the geometric time scale considered.

How second law must be modified?

Even in this case second law as such does not certainly apply in TGD framework without special restrictions. Many of these special prerequisites hold true also in the case of NMP.

1. The hierarchy of CDs forces to introduce a fractal version of the second law taking into account the p-adic length scale hypothesis and dark matter hierarchy. This means that the idea about quantum parallel Universes generalizes to that of quantum parallel dissipating Universes. For instance, the parton model of hadrons based on quarks and gluons relies on kinetic equations and is basically thermodynamical whereas the model for hadron applied at low energies is quantum mechanical. These two views are consistent if quantum parallel dissipation realized in terms of a hierarchy of CDs is accepted. p-Adic length scale hierarchy with p-adic length scale hypothesis stating that primes near powers of two are preferred corresponds to this dissipative quantum parallellism. Dark matter hierarchy brings in a further dissipative quantum parallelism.

2. Second law should always be applied only at a given level of p-adic and dark matter hierarchy and one must always take into account two time scales involved corresponding to the time scale assignable to the system identifiable as the time scale characterizing corresponding CD and the time scale in which the system is observed. Only if the latter time scale is considerably longer than the CD time scale, second law is expected to make sense in TGD framework - this provided one restricts the consideration to the entropic entanglement. The reason is that the Boltzmann equations implying the second law require that the geometric time scale assignable to quantum jump is considerably shorter than the time scale of observation: this guarantees that the random nature of quantum jump allows to use statistical approach.

3. The reduction of entanglement entropy at single particle level implies the increase of thermodynamical entropy at the level of ensemble in the case of entropic non-binding entanglement. This applies to bound state entanglement leading to a generation of entropy at the level of binding systems and a reduction of the contribution of the bound systems to the entropy of the entire system. Note however the emission of binding energy -say in form of photons- could take care of the compensation so that entropy would be never reduced for ensemble. For NE the situation is different.

4. One must be careful in distinguishing between geometric and subjective time. In the case of subjective time the negentropy increases in statistical sense forever unless the CD disappears in some quantum jump (highly non-probable for large enough CDs). If not, then endless evolution at the level of conscious experience is possible in the intersection of real and p-adic worlds and heat death is not the fate of the Universe as in ordinary thermodynamics.

   The arrow of geometric time changes in the state function reduction to the opposite boundary (act of free will of self leading to a death of sub-self) and negentropy increases. This implies that entropy increases in opposite time direction and behaves like syntropy.

5. In thermodynamics the breaking of second law must correspond to the breaking of ergodicity. Spin glasses are non-ergodic systems and TGD Universe is analogous to a 4-D quantum spin glass by the failure of strict non-determinism of Kähler action reflecting itself as vacuum degeneracy. Does the quantum spin glass property of the TGD universe imply the breaking of the second law? Gravitation has been seen as one possible candidate for the breaking second law because of its long range nature. It is indeed classical gravitational energy which distinguishes between almost degenerate spin glass states. The huge value of gravitational Planck constant associated with space-time sheets mediating gravitational interaction and making possible perturbative quantum treatment of gravitational interaction would indeed suggest the breaking of second law in cosmological time scales. For instance, black hole entropy which is inversely proportional to $GM^2/\hbar_{gr}$ would be for the values of gravitational Planck constant involved of the order of unity.

   This breaking of ergodicity implied by 4-D spin glass character of TGD might have an interpretation in terms of NE. The non-determinism implying the ergodicity is behind the hierarchy of quantum criticalities in turn realizing NE.

What do experiments say about second law?

That the status of the second law is far from settled is demonstrated by an experiment performed by a research group in Australian National University [D5]. The group studied a system consisting of 100 small beads in water. One bead was shot by a laser beam so that it became charged and was trapped. The container holding the beads was then moved from side to side 1000 times per second so that the trapped bead dragged first one way and then another. The system was monitored and for monitoring times not longer than.1 seconds second law did not hold always: entropy could also decrease.

1. What is remarkable that .1 seconds defines the duration τ of the memetic code word and corresponds to the secondary p-adic time scale $T_p(2) = \sqrt{p}L_p/c$ associated with Mersenne prime $p = M_{127}$ characterizing electron. This correspondence follows solely from the model of genetic code predicting hierarchy of codes associated with $p = 3, 7, 127$ (genetic code), $p = M_{127}$, ... τ should be the fundamental time scale of consciousness. For instance, average

alpha frequency 10 Hz corresponds to this time scale and "features" inside cortex representing sensory percepts have average duration of .1 seconds.

For electrons the CDs would have spatial size $L = 3 \times 10^7$ meters, which is slightly smaller than the circumference of Earth ($L = cT$, $T = .1$ s, the duration of sensory moment) so that they would have a strong overlap. One can of course ask whether this is an accident. For instance, the lowest Schumann frequency is around 7.8 Hz and not far from 10 Hz. What is interesting that Bohr orbit model [K112] predicts that Universe might be populated by Earth like systems having same distance from their Sun (stars with mass near that of Sun are very frequent). Bohr orbitology applied to Earth itself could also lead to the quantization of the radius of Earth.

2. The first observation was made for more than 15 years ago. Even more remarkable is the recent observation that the time scale of CD associated with electron is.1 seconds. Can one assign the breaking of the second law with the field bodies of electrons?

3. The experiment involves also a millisecond time scale. I do not know whether it is essential that the time scale is just this but one can play with the though that it is. Millisecond time scale is roughly the duration of seventh bit of the genetic codeword if its bits correspond to CDs with sizes coming as subsequent octaves of the basic time scale. Millisecond defines also the time scale for the duration of the nerve pulse and the frequency of kHz cortical synchrony.

   At the level of CDs millisecond time scale would correspond to a secondary p-adic time scale assignable to $k = 120$. Only u and d quarks, which appear with several p-adic mass scales in hadron physics and are predicted to be present as light variants also in nuclear physics as predicted by TGD, could correspond to this p-adic length scale: the prediction for their mass scale would be 5 MeV. Does this mean that the basic time scales of living matter correspond directly to the basic time scales of elementary particle physics?

4. A further interesting point is that neutrinos correspond to.1 eV mass scale. This means that the p-adic length scale is around $k = 167$ which means that the corresponding CD has time scale which is roughly 2^{40} times that for electron and corresponds to the primary p-adic length scale of 2.5 μm (size of cellular nucleus) and tothe time scale of 10^4 years. I have proposed that so called cognitive neutrino pairs consisting of neutrino and antineutrino assignable to the opposite throats of wormhole contact could play key a role in the formation of cognitive representations [K96]. This assumption looks now un-necessarily restrictive but one could quite well consider the possibility that neutrinos are responsible for the longest time scales assignable to consciousness for ordinary value of $\hbar$ (not necessarily our consciousness!). Large value of $\hbar$ could make also possible the situation in which intermediate gauge bosons are effectively massless in cell length scale so that electro-weak symmetry breaking would be absent. This would require $\hbar \simeq 2^{33}$. For this value of $\hbar$ the time scale of electronic CD is of the order of the duration of human of human life cycle. This would scale up the Compton length of neutrino to about 10 kilometers and the temporal size of neutrino CD to a super-cosmological time scale.

5.4.3 NMP And Biology

The notion of self is crucial for the understanding of bio-systems and consciousness. It seems that the NE is the decisive element of life and that one can say that in metaphorical sense life resides in the intersection of real and p-adic worlds.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

NMP and negentropic entanglement demanding entanglement probabilities which are equal to inverse of integer, is the starting point. Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that in some sense life and conscious intelligence reside in the intersection of the real and p-adic worlds.

What could be this intersection of realities and p-adicities?

1. The facts that fermionic oscillator operators are correlates for Boolean cognition and that induced spinor fields are restricted to string world sheets and partonic 2-surfaces suggests that the intersection consists of these 2-surfaces.

2. Strong form of holography allows a rather elegant adelization of TGD by a construction of space-time surfaces by algebraic continuations of these 2-surfaces defined by parameters in algebraic extension of rationals inducing that for various p-adic number fields to real or p-adic number fields. Scattering amplitudes could be defined also by a similar algebraic contination. By conformal invariance the conformal moduli characterizing the 2-surfaces would defined the parameters.

This suggests a rather concrete view about the fundamental quantum correlates of life and intelligence.

1. For the minimal option life would be effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world sheets partonic two-surfaces appears in U-matrix so that the data localizable to strings connecting partonic 2-surfaces would dictate the scattering amplitudes.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K3]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K103].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and also hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

That only algebraic extensions are possible is of course only a working hypothesis. Also finite-dimensional extensions of p-adic numbers involving transcendentals are possible and might in fact be necessary. Consider for instance the extension containing $e, e^2, .., e^{p-1}$ as units (e^p is ordinary p-adic number. Infinite number of analogous finite-dimensional extensions can be constructed by taking a function of integer variable such that $f(p)$ exists both p-adically and as a real transcendental number. The powers of $f(p)^{1/n}$ for a fixed value of n define a finite-dimensional transcendental extension of p-adic numbers if the roots do not exist p-adically.

Numbers like $log(p)$ and π cannot belong to a finite-dimensional extension of p-adic numbers [K49]. One cannot of course take any strong attitude concerning the possibility of infinite-dimensional extensions of p-adic numbers but the working hypothesis has been that they are absent. The phases $exp(i2\pi/n)$ define finite dimensional extensions allowing to replace the notion of angle in finite measurement resolution with the corresponding phase factors in finite measurement. The functions $exp(i2\pi q/n)$, where q is arbitrary p-adic integers define in a natural manner the physical counterparts of plane waves and angular momentum eigenstates not allowing an identification as ordinary p-adic exponential functions. They are clearly strictly periodic functions of q with a finite value set. If n is divisible by a power of p, these functions are continuous since the values of the function for q and $q + kp^n$ are identical for large enough values of n. This condition is essential and means in the case of plane waves that the size scale of a system (say one-dimensional box) is multiple of a power of p.

NMP and self-organization

NMP leads to new vision about self-organization about which adetailed vision is discussed in [K103]. Here only some key points are emphasized.

1. Dissipation selects the asymptotic self-organization patterns in the standard theory of self-organization and the outcomes are interesting in the presence of energy feed. The feed of energy can be generalized to feed of any kind of quantum numbers: for instance, feed of quantum numbers characterizing qualia. In fact, energy increment in quantum jump defines one particular kind of quale [K50]. Similar picture should apply now.

2. The fundamentally new element is that in ZEO basic objects are pairs of 3-D surfaces at the opposite boundaries of CDs. By holography the basic geometric objects are 4-dimensional or equivalently 3-dimensional. Strong form of holography allows also to identify the objects carrying information about quantum states as string world sheets and partonic 2-surfaces at the boundaries of CD. Self-organization leads to an asymptotic spatio-temporal pattern rather than spatial pattern, behavior or function. This picture is especially useful when one tries to understand morphogenesis and the emergence of functions and behaviors in biology and neuroscience [K93].

3. The notion of self relates very closely to self-organization in TGD framework [K103]. Self assignable to CD is a dissipative structure because it has sub-selves which dissipate quantum parallelly with it. Self as a perceiver maps the dissipation at the level of quantities in the external world to dissipation at the level of qualia in the internal world.

4. Dissipation leads to self-organization patterns and in the absence of external energy feed to thermal equilibrium. Thus thermodynamics emerges as a description for an ensemble of selves or for the time average behavior or single self when external energy feed to system is absent. One can also understand how the dissipative universe characterized by the presence of parameters like diffusion constants, conductivities, viscosities, etc.. in the otherwise reversible equations of motion, emerges. Dissipative dynamics is in a well defined sense the envelope for the sequence of reversible dynamical evolutions modelling the sequence of final state quantum histories defined by quantum jumps.

5. Quantum self-organization can be seen as iteration of the unitary process followed by state function reduction and leads to fixed point self-organization patterns analogous to the patterns emerging in Benard flow. Since selves approach "asymptotic selves", dissipation can be regarded as a Darwinian selector of both genes and memes. Thus not only surviving physical systems but also stable conscious experiences of selves, habits, skills, behaviors, etc... are a result of Darwinian selection.

6. In TGD one must distinguish between two kinds of self organizations corresponding to the entropic bound state entanglement and NE. Biological self-organization could be therefore fundamentally different from the non-biological one. The success of the p-adic mass calculations suggest that elementary particles reside in the intersection of real and p-adic worlds so that one should be very cautious in making strong conclusions. Certainly the intentional,

goal-directed behavior of the system in some time scale is a signature of negentropic self-organization but it is difficult to apply this criterion in time scales vastly different from human time scales. It is the field bodies (or magnetic bodies), which can be assigned naturally to CDs which suggests that the negentropic self organization occurs at this level. TGD based vision about living matter actually assumes this implicitly.

7. What is new that even quantum jump itself can be seen as a self-organization process analogous to Darwinian selection, which yields a state containing only bound state state entanglement or NE and representing analog of the self-organization patterns. By macro-temporal quantum coherence effectively gluing quantum jumps sequences to single quantum jump this pattern replicates itself fractally in various time scales. Thus self-organization patterns can be identified as bound states and states paired by a NE and the development of the self-organization pattern as a fractally scaled up version of single quantum jump. Second new element is that dissipation is not mere destruction of order but producer of jewels. A further new element is that dissipation can occur in quantum parallel manner in various scales.

8. The failure of the determinism in standard sense for Kähler action is consistent with the classical description of dissipation. In particular, the emergence of sub-selves inside self looks like dissipation from outside but corresponds to self-organization from the point of view of self. 4-dimensional spin glass degeneracy meaning breaking of ergodicity crucial for self-organization is highly suggestive on basis of the vacuum degeneracy of Kähler action, and this alone predicts ultra-metric topology for the landscape of the maxima of Kähler function defined in terms of Kähler action so that p-adicity emerges naturally also in this manner.

One particularly interesting concrete prediction is that the time scales assignable to CDs come as powers of two. This predicts fundamental frequencies coming as powers of two, and the hierarchy of Planck constants predicts rational or at least integer multiples of these frequencies. Could these powers of two relate to frequency doubling rather generally observed in hydrodynamical self-organizing systems?

Evolution and NMP

Evolution has many facets in TGD framework.

1. A key aspect of evolution relates to the hierarchy of Planck constants labelling a hierarchy of quantum criticalities. The phase transitions reducing criticality, increasing Planck constant, and generatic NE occur spontaneously so that evolution is unavoidable. This is in sharp conflict with the standard belief that life is a thermodynamical fluctuation.

2. In the adelic vision evolution reduce to the increase of the complexity of the algebraic extension of rationals defining the preferred primes which are primes near powers of prime by NMP. The value of n characterizing Planck constant would correspond to the product of ramified primes for a given extension. Infinite primes representing bound states in arithmetic quantum field theory could code for the irreducible polynomials characterizing the basic algebraic extension whose maximal Abelian extension is represented in terms of adeles [K137].

3. A further natural characterization of evolution is in terms of p-adic topology relating naturally to cognition. p-Adic primes near powers of two are favored if CDs have the proposed discrete size spectrum. From the point of view of self this would be essentially cosmic expansion in discrete jumps. CDs and can be characterized by powers of 2 and if partonic 2-surfaces correspond to effective p-adic p-adic topology characterized by a power of two, one obtains the commeasurability of the secondary p-adic time scale of particle and that of CD in good approximation.

4. The notion of infinite primes motivates the hypothesis that the many-sheeted structure of space-time can be coded by infinite primes [K118]. The number of primes larger than given infinite prime P is infinitely larger than the number of primes than P. The infinite prime P characterizing the entire universe decomposes in a well defined manner to finite primes and p-adic evolution at the level of entire universe is implied by local p-adic evolution at the

level of selves. Therefore maximum entanglement negentropy gain for p-adic self increases at least as $log(p)$ with p in the long run. This kind of relationship might hold true for real selves of p-adic physics is physics of cognitive representations of real physics as suggested by the success of p-adic mass calculations. Thus it should be possible to assign definite p-adic prime to each partonic 2-surface.

Just for fun one can play also with numbers.

1. The highest dark matter level associated with self corresponds to its geometric duration which can be arbitrarily long: the typical duration of the memory span gives an idea about the level of dark matter hierarchy involved if one assumes that the time scale.1 seconds assignable to electrons is the fundamental time scale. If the time scale T of human life cycle corresponds to a secondary p-adic time scale then $T = 100$ years gives the rough estimate $r \equiv \hbar/\hbar_0 = 2^{33}$ if this time scale corresponds to that for dark electron. The corresponding primary p-adic time length scale corresponds to $k = 160$ and is 2.2×10^{-7} meters.

2. If human time scale -taken to be $T = 100$ years- corresponds to primary p-adic time scale of electron, one must have roughly $r = 2^{97}$.

I have already discussed the second law in TGD framework and it seems that its applies only when the time scale of perception is longer than the time scale characterizing the level of the p-adic and dark matter hierarchy. Second law as it is usually stated can be seen as an unavoidable implication of the materialistic ontology.

Stable entanglement and quantum metabolism as different sides of the same coin

The notion of binding has two meanings. Binding as a formation of bound state and binding as a fusion of mental images to larger ones essential for the functioning of brain and regarded as one the big problems of consciousness theory.

Only bound state entanglement and NE are stable against the state reduction process. Hence the fusion of the mental images implies the formation of a bound entropic state- in this case the two interpretations of binding are equivalent- or a negentropic state, which need not be bound state.

1. In the case of NE bound state need not be formed and the interesting possibility is that the NE could give rise to stable states without binding energy. This could allow to understand the mysterious high energy phosphate bond to which metabolic energy is assigned in ATP molecule containing three phosphates and liberated as ATP decays to ADP and phosphate molecule. Negentropic entanglement could also explain the stability of DNA and other highly charged biopolymers. In this framework the liberation of metabolic (negentropic) energy would involve dropping of electrons to a larger space-time sheets accompanying the process $ATP \to ADP + P_i$. A detailed model of this process is discussed in [K45, K46].

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

2. The formation of bound state entanglement is expected to involve a liberation of the binding energy and this energy might be a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and formation of bound states are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enhanced oxidative metabolism [J100] (that is $ATP \to ADP$ process and its reversal). A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

If these interpretations are correct, there would be two modes of metabolism corresponding to two different kinds of fusion of mental images.

5.4.4 NMP, Consciousness, And Cognition

As already found NMP dictates the subjective time development of self and is therefore the basic law of consciousness. If p-adic physics is the physics of cognition, the most exotic implications of NMP relate to cognition rather than standard physics.

Thermodynamics for qualia

Concerning qualia one can consider two views.

1. If only entropic entanglement is assumed, second law would hold true also at the level of conscious experience of self, which can be seen as an ensemble of its sub-selves assignable to sub-CDs. The randomness of the state function reduction process implies that conscious experience involves statistical aspects in the sense that the experienced qualia correspond to the averages of quantum number and zero mode increments over the sub-selves assignable to sub-CDs. When the number of quantum jumps in the ensemble defining self increases, qualia get more entropic and fuzzy unless macro-temporal quantum coherence changes the situation.

2. ZEO and NE means departure from this picture if sub-CDs can generate NE. This is expected to be true if they overlap if one believes on standard argument for the formation of macroscopic quantum phases. In this case the flux tubes connecting space-time sheets assignable to the sub-CDs would serve as a space-time correlate for the NE.

The basic questions are whether sensory qualia can really correspond to the increments of quantum numbers in quantum jump and whether these quantum jumps are assignable to entropic or negentropic qualia. What is clear that the sensory qualia such as colors are assigned to an object of external world rather predictably. This is not obvious if this process is based on quantum jump.

1. The original view inspired by standard view about state function reduction (positive energy ontology) was that qualia are determined basically as increments of quantum numbers [K50]. In ordinary statistical physics measured quantities would correspond to quantum numbers basically. The basic function of sensory organs would be to map quantum numbers to quantum number increments so that our sensory perception is in reasonable approximation about world rather than changes of the world.

2. Entropic entanglement is reduced to zero in state function reduction for individual sensory receptor and the outcome involves all possible values of quale, say different fundamental colors for which I have proposed a model in terms of QCD color [K50]. If the probability of particular value of quale is much larger than others, one can have statistical ensemble giving rise to predictable quale as ensemble average.

What happens when ZEO based view about state function reduction is adopted?

1. Now sensory mental image corresponds to a sub-self, which in turn corresponds to a repeated state function reduction to a fixed (passive) boundary of sub-CD. Does sub-self without any sub-sub-selves correspond to conscious experience about quantum numbers instead of only change of quantum numbers? One cannot exclude this possibility. For instance, three colored states for quarks would correspond to three fundamental colors for this option.

   The alternative possibility is that quantum jumps of sub-selves give rise to the sensory mental images and the increments of quantum numbers define the qualia. Sub-selves without sub-selves would not give rise to sensory qualia. That consciousness involves always change could be seen as a support for this interpretation but one can ask what change is. Does change mean state function reduction in standard sense or does it mean a sequence of repeated state function reductions leaving the passive boundary of CD invariant but inducing sensation about flow of time and sensory experience?

2. In ZEO the increments must correspond to increments of quantum numbers for (say) positive energy part of the state. A sensation of (say) given color requires a continual feed of corresponding quantum number increment to the positive energy part of the system. Some kind of far from equilibrium thermodynamics seems to be necessary with external feed of quantum numbers generalizing the external feed of energy. The capacitor model of a sensory receptor [K50] realizes this idea in terms of generalized di-electric breakdown implying opposite charging of the capacitor plates in question. Note that in ZEO also the positive and negative energy parts of the zero energy state assignable to capacitor plates would be also analogous to a pair of oppositely charged capacitor plates and one can speak about capacitor also in time direction.

3. The flow of quantum numbers can be interpreted also in terms of feed of NE to the sub-CD of sub-self allowing it to satisfy the needs of NMP and avoid the lethal first state function reduction to the opposite boundary of its sub-CD. NE feed would accompany the feed of quantum numbers and would be accompanied by feed of metabolic energy and/or some other metabolite. Energy metabolism is indeed only one particular variant of metabolism. Metabolism would be always basically feed of NE assignable to system with quantum numbers producing the quale assignable to these quantum numbers. Each metabolite carrying NE would define its own quale. One can assign metabolites also to hearing and vision: the metabolite would be assigned with sound waves or photons and carry NE. Whether the metabolite could be identified with dark phonons or photons is an interesting question.

4. Note that in this picture quantum number increment corresponds to that for a subsystem due to the flow of quantum numbers to it rather than to the change of quantum numbers in state function reduction. Hence it is possible to assign qualia also to quantum numbers rather than their increments.

5. Also in this framework the analog of thermodynamical description is suggestive since chemical potentials provide natural thermodynamical description for the numbers of ions. In ZEO square root of thermodynamics is highly suggestive in order to take into account the macroscopic quantum coherence in living systems and I have proposed a model of cell membrane along these lines generalizing the usual thermodynamical model [K69]. Chemical potentials are in this framework replaced with the cyclotron energy differences over cell membrane.

The association of sensory qualia with the transfer of metabolites of various kinds is a powerful prediction and conforms at least in spirit with the early very naïve attempts to identify qualia in terms of biologically important charged particles assumed to form cyclotron condensates at dark magnetic flux tubes. If ATP (and GTP) are the universal carriers of metabolic energy and if energy quale must accompany any quale, one could try to identify the metabolites giving rise to qualia from the biochemistry of the sensory perception. The proposal that nutrients carry NE conforms with this picture.

3. "Final" solution to the problem of qualia

The TGD inspired theory of qualia [K50] has evolved gradually.

1. The original vision was that qualiaandother aspects of consciousness experience are determined by the change of quantum state in the reduction: the increments of quantum numbers would determine qualia. I had not yet realized that repeated state function reduction (Zeno effect) realized in ZEO is central for consciousness. The objection was that qualia change randomly from reduction to reduction.

2. Later I ended up with the vision that the rates for the changes of quantum numbers would determine qualia: this idea was realized in terms of sensory capacitor model in which qualia would correspond to kind of generalized di-electric breakdown feeding to subsystem responsible for quale quantum numbers characterizing the quale. The Occamistic objection is that the model brings in an additional element not present in quantum measurement theory.

3. The view that emerged while writing the critics of IIT of Tononi [K123] is that qualia correspond to the quantum numbers measured in the state function reduction. That in ZEO

the qualia remain the same for the entire sequence of repeated state function reductions is not a problem since qualia are associated with sub-self (sub-CD), which can have lifetime of say about .1 seconds! Only the generalization of standard quantum measurement theory is needed to reduce the qualia to fundamental physics. This for instance supports the conjecture that visual colors correspond to QCD color quantum numbers. This makes sense in TGD framework predicting a scaled variants of QCD type physics even in cellular length scales.

This view implies that the model of sensory receptor based on the generalization of dielectric breakdown is wrong as such since the rate for the transfer of the quantum numbers would not define the quale. A possible modification of the model simple: the analog of dielectric breakdown generates Bose-Einstein condensate and the quantum numbers for the BE condensate give rise to qualia assignable to sub-self.

Questions about various kinds of entropies and negentropies

In standard positive energy ontology and in absence of dark matter second law is natural for many-particle systems. In ZEO and accepting the hierarchy of dark matters NMP replaces second law and the modification of thermodynamics replaced entropy with negentropy is highly suggestive.

Consider first the situation in positive energy ontology. There are three kinds of entropies and the basic question is how these entropies relate.

1. Does the entropy characterizing the experience of self relate to the thermodynamical entropy of some system? The fact that non-geometric sensory qualia have a statistical interpretation, suggests that the entropy associated with the qualia of the mental image corresponds to the thermodynamical entropy for a system giving rise to the qualia via the sensory mapping. The thermodynamics of quantities in the external world would thus be mapped to the thermodynamics of qualia, increments of quantities, in the inner world. Selves could also represent the fundamental thermodynamical ensembles since they define also statistical averages of quantum numbers and zero modes although these are not directly experienced.

2. Could one interpret the entropies of the space-time sheets as entropies associated with the symbolic representations of conscious experiences of selves? Could one see the entire classical reality as a symbolic representation? Does the entropy of conscious experience correspond to the thermodynamical entropy of the perceived system, which in turn would correspond to the classical space-time entropy of the system representing the perceived system symbolically? Does this conclusion generalize to the case of p-adic entropy? Quantum-classical correspondence would encourage to cautiously think that the common answer to these questions might be yes.

One can repeat these questions almost as such for ZEO option. Now one would only speak about negentropy. Each quale would corresponding to its metabolite and to a chemical potential contribution to the differentials of thermodynamical functions. The thermodynamics of qualia could allow to have quantitative model correlating qualia with chemistry.

The arrow of psychological time and thermodynamics

In positive energy ontology and standard QM the arrow of psychological time is closely related to the second law and I have considered several alternative identifications for the arrow of psychological time. In ZEO [K133, K10] NMP replaces second law and the arrow of psychological time emerges as a prediction of the model for self as sequences of state function reductions to a fixed boundary of CD. The new element is that the arrow of geometric time chan change and that the moments for these changes define increases for the distance between the tips of CD defining a discrete flow of psychological time.

The latest option favored by ZEO involves two aspects. The one related to the arrow of time coordinate assignable to the space-time sheet and the other one to the relative proper time coordinate between the tips of CD. A simple argument show that this distance should increase gradually in statistical sense since the size of CD can also change in quantum jump. This would have have interpretation in terms of a flow of "cosmic time" (CD is analogous to big bang followed by

big crunch). Interestingly, CD with time scale of order 10^{11} years (age of the universe) corresponds primary p-adic length scale of only 10^{-4} meters, the size of a large neuron, and also the length scale in which the blob of water has Planck mass so that the quantization of gravitational Planck constant should become important [K112]. Could this mean that the CDs assignable to large neurons make possible to develop the idea about the cosmology and cosmology itself? Could it really be that our cognitive representations about Universe quite concretely have the size of the Universe itself as p-adic view about cognition requires?

Reductionism, holism and NMP

The fusion of sub-selves can take place in two ways: by real bound state entanglement and by NE. The resulting mental images must differ somehow, and the proposal is that the entanglement associated with the negentropic mental defines a conscious cognitive representation: kind of rule. Schrödinger cat negentropically entangled with the bottle of poison knows that it is not a good idea to open the bottle: open bottle-dead cat, closed bottle-living cat (note that thew weak form of NMP allows the cat to open the bottle so that the information is useful!). NE would generate rules and counterparts of conscious associations fundamental in brain functioning. For the mental image associated with bound state entanglement the information about bound systems would be lost. NE could give rise to stereo-consciousness essential for (say) stereo vision.

Analysis and conceptualization (synthesis) - formation of rules- could be seen as the reductionistic and holistic aspects of consciousness. The interpretation of quantum jump as a creation of a totally entangled holistic state, which is then analyzed to stable entangled pieces allows to interpret self measurement cascade as a conscious analysis. The resulting stable negentropic pieces give rise to experience of understanding and conceptualization - rules and abstractions. Perhaps the holistic character assigned to right brain hemisphere could be interpreted in terms of specialization to conceptualization and reductionist character of left brain to analysis to smallest possible pieces. This picture proposed originally in positive energy ontology makes sense also in ZEO.

Could one assume that left brain generates entropic bound state entanglement and right brain NE? This idea not so feasible as it looked originally. The reason is that only NE might be relevant for consciousness.

In ZEO the sequence of state function reductions at passive boundary of CD generates entangled holistic state at the active boundary and the reduction to opposite boundary generates the reductionistic state at it. The two boundaries of CD would seem to correspond to the reductionistic and analytic aspects of consciousness. Again one must be very cautious in making interpretations. One can also consider that holistic state corresponds to NE in long scales and with large h_{eff} whereas the reductionistic state would correspond to short scales and small values of h_{eff}.

If left and right brain work independently they should not differ unless their magnetic bodies are different in the sense that right brain correspond to a large magnetic body and to large values of h_{eff} and left brain to small values of h_{eff}. Could it be that the brain hemispheres work together quantum coherently and this allows specialization?

Could left brain produce less NE than right brain? Could left brain be the bad boy and right brain the saint? Or do both produce NE but that NE corresponds to short p-adic length scales in the case of left brain (dimension d of final state projectior is a large power of small prime p) and long p-adic length scales in the case of right brain hemisphere (d is a small power of large p)?

There are rather interesting connections with altered states of consciousness and states of macro-temporal quantum coherence.

1. Making mind empty of mental images could perhaps be interpreted as a mechanism of achieving irreducible self state. If self entangles negentropically with larger conscious entity this would lead to experiences characterized as expansion of consciousness, even cosmic consciousness. One could also consider the possibility the sub-selves representing mental images fuse to single long-lasting negentropic mental image. The absence of dissipation could relate to the reports of meditators about lowered metabolic needs.

2. The ordinary wake-up consciousness is identifiable as the analytical mode in which NE in short scales dominates. Together with weak form of NMP this would suggest that state

function reductions are carried out to rather sub-spaces with rather low dimension or alternatively to sub-spaces for which the dimension is larger power of small prime defining the p-adic length scale. The reason for this could be sensory input and motor activities, which would create effective heat bath destroying holistic mental images.

3. Krishnamurti has talked a lot about states of consciousness in which no separations and discriminations occur and timelessness prevails. These states could correspond to long-lived NE with large $\hbar$ with larger conscious entities giving rise to very long effective moments of consciousness. In this kind of situation NMP does not force cognitive self measurements to occur and analysis and separations can thus be avoided.

4. Sharing and fusion of mental images by entanglement of sub-selves of separate selves makes possible quantum realization of telepathy and could be a universal element of altered states of consciousness. Also this entanglement could be bound state entanglement or NE.

Cognitive codes

p-Adic length scale hypothesis leads to the idea that each $p \simeq 2^k$, k integer, defines a hierarchy of cognitive codes with code word having duration given by the n-ary p-adic time scale $T(n,k)$ and number of bits given by any factor of k. Especially interesting codes are those for which the number of bits is prime factor or power of prime factor of k. $n = 2$ seems to be in special position in ZEO. This is a strong quantitative prediction since the duration of both the code word and bit correspond to definite frequencies serving as signatures for the occurrence of commutations utilizing these codes.

If k is prime, the amount of information carried by the codon is maximal but there is no obvious manner to detect errors. If k is not prime there are several codes with various numbers of bits: information content is not maximal but it is possible to detect errors. For instance, $k = 252$ gives rise to code words for which the number of bits is $k_1 = 252, 126, 63, 84, 42, 21_2, 9, 7, 6_2, 4, 3_2, 2$: the subscript $_2$ tells that there are two non-equivalent ways to get this number of bits. For instance, $126 = 42 \times 3$-bit codon can have 42 -bit parity codon: the bits of this codon would be products of three subsequent bits of 126-bit codon. This allows error detection by comparing the error codon for communicated codon and communicated error codon.

The recent view about how NMP selects preferred primes [K137] supports this idea. The values of dimension for the sub-space defining the outcome of reduction which are primes near powers of prime p are favoured by NMP. $p = 2$ gives the p-adic length scale hypothesis. Large powers of small prime could give rise to cognitive codes. Not that the integers associated with code could also be in the range $[0, p^n]$. For instance, for microtubules $p = 13$ is suggestive. For genetic code $p = 127$ is suggestive.

Abstraction hierarchy and genetic code

Mersenne primes $M_n = 2^n - 1$, which seem to play fundamental role in elementary particle physics. This would put primes 3, 7, 31, 127, etc. in a special position. Primes appear frequently in various bio-structures and this might reflect the underlying p-adicity for the association sequences providing "plan" for the development of bio-system. For instance, we have actually 7 (!) fingers: two of them have degenerated during evolution but can be seen in the developing embryo. There are 31 subunits in our spinal chord, etc...

As already explained, the emergence of primes near powers of prime can be understood from NMP.

In the model of genetic code based on a simple model of abstraction process [K52] the so called Combinatorial Hierarchy $2, 3, 7, 127, 2^{127} - 1, ...$ of Mersenne primes emerges naturally. The construction for a model of abstraction process proceeds as follows.

1. At lowest level there are two digits. The statements Yes and No.

2. At the next level one considers all Boolean statements about these two statements which can be regarded as maps from 2-element set to 2-element set. There are 4 of them. Throw one away and you get 3 statements.

3. At the next level one considers all Boolean statements about these 3 statements and the total number of them is 2^3. Throw one away and you get 7 statements. And so on.

In this case one obtains what might be interpreted as a hierarchy of statements about statements about... The mystery is why one statement must be thrown away at each level of the construction. The answer might relate to a concrete model of quantum computation. The emotional realization of this code in terms of subs-spaces of n-dimensional space allows to understand this. The reason is that the outcome of the state function reduction corresponds to any $n-k$ dimensional sub-space for a fixed choices of basis with $k = 1, ..., n-1$. $k = 0$ is obviously excluded and the number of choices is $2^n - 1$ rather than 2^n.

An open problem is how the emotional realization of Boolean algebra is mapped to its fermionic representation. The task is to map in a natural manner the outcome of the state function reduction to a corresponding many-fermion state (in ZEO it would be pair of many-fermion states at opposite boundaries of CD having opposite quantum numbers). Is it really possible to map different levels (reductions and states) to each other?

Is the sum of p-adic negentropies equal to real entropy?

I ended almost by accident to a fascinating and almost trivial theorem. Adelic theorem for information would state that conscious information represented as sum of p-adic negentropies (entropies, which are negative) is equal to real entropy. The more conscious information, the larger the chaos in the environment as everyone can verify by just looking around.

This looks bad! Luckily, it turned out that this statement is true for rational probabilities only. For algebraic extensions it cannot be true as is easy to see. That negentropic entanglement is possible only for algebraic extensions of rationals conforms with the vision that algebraic extensions of rationals characterize evolutionary hierarchy. The rationals represent the lowest level at which there is zero amount of conscious information.

It is not completely obvious that the notion of p-adic negentropy indeed makes sense for algebraic extensions of rationals. A possible problem is caused by the fact that the decomposition of algebraic integer to primes is not unique. Simple argument however strongly suggests that the various p-adic norms of the factors do not depend on the factorization. Also a formula for the difference of the total p-adic negentropy and real entropy is deduced.

1. p-Adic contribution to negentropy equals to real entropy for rational probabilities but not for algebraic probabilities

The following argument shows that p-adic negentropy equals to real entropy for rational probabilities.

1. The fusion of real physics and various p-adic physics (identified as correlates for cognition, imagination, and intentionality) to single coherent whole leads to what I call adelic physics [K137]. Adeles associated with given extension of rationals are Cartesian product of real number field with all p-adic number fields extended by the extension of rationals. Besides algebraic extensions also the extension by any root of e is possible since it induces finite-dimensional p-adic extension. One obtains hierarchy of adeles and of corresponding adelic physics interpreted as an evolutionary hierarchy.

   An important point is that p-adic Hilbert spaces exist only if one restricts the p-adic numbers to an algebraic extension of rationals having interpretation as numbers in any number field. This is due to the fact that sum of the p-adic valued probabilities can vanish for general p-adic numbers so that the norm of state can vanish. One can say that the Hilbert space of states is universal and is in the algebraic intersection of reality and various p-adicities.

2. Negentropy Maximization Principle (NMP) [K73] is the variational principle of consciousness in TGD framework reducing to quantum measurement theory in Zero Energy Ontology assuming adelic physics. One can define the p-adic counterparts of Shannon entropy for all finite-dimensional extensions of p-adic numbers, and the amazing fact is that these entropies can be negative and thus serve as measures for information rather than for lack of it. Furthermore, all non-vanishing p-adic negentropies are positive and the number of

primes contributing to negentropy is finite since any algebraic number can be expressed using a generalization of prime number decomposition of rational number. These p-adic primes characterize given systen, say elementary particle.

NMP states that the negentropy gain is maximal in the quantum jump defining state function reduction. How does one define the negentropy? As the sum of p-adic negentropies or as the sum of real negative negentropy plus the sum of p-adic negentropies? The latter option I proposed for some time ago without checking what one obtains.

3. The adelic theorem says that the norm of rational number is equal to the product of the inverses of its p-adic norms. The statement that the sum of real and p-adic negentropies is zero follows more or less as a statement that the logarithms of real norm and the product of p-adic norms for prime factors of rational sum up to zero.

   The core formula is adelic formula stating that the real norm of rational number is product of its p-adic norms. This implies that the logarithm of the rational number is sum over the logarithms of its p-adic norms. Since in p-adic entropy assigned to prime p logarithms of probabilities are replaced by their p-adic norms, this implies that for rational probabilities the real entropy equals to p-adic negentropy.

   It would seem that the negentropy appearing in the definition of NMP must be the sum of p-adic negentropies and real entropy should have interpretation as a measure for ignorance about the state of either entangled system. The sum of p-adic negentropies would serve as a measure for the information carried by a rule with superposed state pairs representingt the instances of the rule. The information would be conscious information and carried by the negentropically entangled system.

4. What about probabilities in algebraic extensions? The probabilities are now algebraic numbers. The induced p-adic norm $N_p(x)$ for n-dimensional extension of Q is defined as the determinant $det(x)$ of the linear map defined by multiplication with x. $det(x)$ is rational number. The corresponding p-adic norm is defined as the n:th root $N_p(det(x))^{1/n}$ of the ordinary p-adic norm. Root guarantees that the norm coincides with the ordinary p-adic norm for ordinary p-adic integers. One must perform now a factorization to algebraic primes. Below an argument is given that although the factorization to primes is not always unique, the product of p-adic norms for given algebraic rational defined as ratio of algebraic integers is unique.

   The p-adic norms of probabilities are however always powers of primes so that the adelic formula *cannot* be true since on the real side one has logarithms of algebraic numbers and on the p-adic side only logarithms of primes.

   What could be the interpretation?

1. If conscious information corresponds to $N - P$, it accompanies the emergence of algebraic extensions of rationals at the level of Hilbert space.

2. If N corresponds to conscious information, then at the lowest level conscious information is necessary accompanied by entropy but for algebraic extensions $N - P$ could be positive since N is maximized.

Both interpretations conform with the number theoretic vision about evolution. One expects that the value of real entropy correlates strongly with the value of negentropy. This would conform with the observation that large entropy seems to be a prerequisite for life by providing large number of states with degenerate energies providing large representative capacity. For instance, Jeremy England has made this proposal [I59]: I have commented this proposal from [L35] (see `http://tinyurl.com/zjp3bp6`).

2. Formula for the difference of total p-adic negentropy and real entanglement entropy

Can one write an explicit formula the difference of total p-adic entanglement negentropy (positive) and real entanglement entropy using prime factorization in finite dimensional algebraic extension (note that for algebraic numbers defining infinite-dimensional extension of rationals

factorization does not even exist since one can write $a = \sqrt{a}\sqrt{a} = ...$)? This requires that total p-adic entropy is uniquely defined. There is a possible problem due to the non-uniqueness of the prime factorization.

1. For Dedekind rings, in particular rings of integers, there exists by definition a unique factorization of proper ideals to prime ideals (see `http://tinyurl.com/h3oufpp`). In contrast, the prime factorization in the extensions of Q is not always unique. Already for $Q(\sqrt{-5})$ one has $6 = 2 \times 3 = (1 + \sqrt{-5})(1 - \sqrt{-5})$ and the primes involved are not related by multiplication with units.

   Various factorizations are characterized by so called class group and class field theory (see `http://tinyurl.com/zdnw7j3`) is the branch of number theory studying factorizations in algebraic extensions of integer rings. Factorization is by definition unique for Euclidian domains. Euclidian domains allow by definition so called Euclidian function $f(x)$ having values in R_+ with the property that for any a and b one has either $a = qb$ or $a = qb + r$ with $f(r) < f(b)$. It seems that one cannot restrict to Euclidian domains in the recent situation.

2. Even when the factorization in the extension is not unique, one can hope that the product of various p-adic norms for the factors is same for all factorizations. Since the p-adic norm for the extensions of primes is induced by ordinary p-adic number this requires that the p-adic prime for which the induced p-adic norm differs from unity are same for all factorizations and that the products of p-adic norms differing from unity are same. This independence on the representative for factorization would be analogous to gauge invariance in physicist's conceptualization.

   The probabilities P_k belongs to a unique product of ideals labelled by primes of extension. The ideals are characterized by norms and if this norm is product of p-adic norms for any prime factorization as looks natural then the independence on the factorization follows. Number theorist can certainly immediately tell whether this is true. What is encouraging that for $Q(\sqrt{-5})$ $z = x + \sqrt{-5}y$ has determinant $det(z) = x^2 + 5y^2$ and for $z == 1 \pm \sqrt{-5}$ one has has $det(z) = 6$ so that for the products of p-adic norms for the factorizations $6 = 2 \times 3$ and $(1 + \sqrt{-5})(1 - \sqrt{-5})$ are equal.

3. If this this guess is true, one can write the the difference of total p-adic negentropy N and real entanglement entropy S as

$$N - S = \sum P_k log(\frac{P_k}{\prod_p N_p(P_k)}) \ . \tag{5.4.1}$$

   Here $\prod_p N_p(P_k)$ would not depend on particular factorization. The condition $\sum P_k = 1$ poses an additional condition. It would be nice to understand whether $N - S \geq 0$ holds true generally and if not, what are the conditions guaranteeing this. The p-adic numbers of numerators of rationals involved give positive contributions to $N - S$ as the example $P_k = 1/N$ in rational case shows.

3. An ansatz for entanglement probabilities guaranteeing $N - S > 0$

What about entanglement probabilities in algebraic extension of rationals? In this case real number based entanglement entropy is not maximal since entanglement probablities are different. What can one say about p-adic entanglement negentropies: are they still maximal under some reasonable conditions? The logarithms involved depend on p-adic norms of probabilities and this is in the generic case just inverse of the power of p. Number theoretical universality suggests that entanglement probabilities are of form

$$P_i = \frac{a_i}{N}$$

with $\sum_i a_i = N$ with algebraic numbers a_i not involving natural numbers and thus having unit p-adic norm.

With this assumption the p-adic norms of P_i reduce to those of $1/N$ as for maximal rational entanglement. If this is the case the p-adic negentropy equals to $log(p^k)$ if p^k divides N. The total adelic negentropy equals to $log(N)$ and is maximal and has the same value as for rational probabilities equal to $1/N$.

The real entanglement entropy is now in general however smaller than $log(N)$, which would mean that p-adic negentropy is larger than the real entropy as conjectured earlier [L48] (see `http://tinyurl.com/jozwqxk`). For *rational* entanglement probabilities the generation of entanglement negentropy - conscious information during evolution - would be accompanied by a generation of equal entanglement entropy measuring the ignorance about what the negentropically entangled states representing selves are.

This conforms with the observation of Jeremy England that living matter is entropy producer [L47] (see `http://tinyurl.com/jff33xk`). For algebraic extensions of rationals this entropy could be however smaller than the total negentropy. Second law follows as a shadow of NMP if the real entanglement entropy corresponds to the thermodynamical entropy. Algebraic evolution would allow to generate conscious information faster than the environment is polluted, one might concretize! The higher the dimension of the algebraic extension rationals, the larger the difference could be and the future of the Universe might be brighter than one might expect by just looking around! Very consolating! One should however show that the above described situation can be realized as NMP strongly suggests before opening a bottle of champaigne.

4. Cloning of maximally negentropic states is possible: DNA replication as cloning of this kind of states?

In Facebook discussion with Bruno Marchal and Stephen King the notion of quantum cloning as copying of quantum state popped up and I ended up to ask about approximate cloning and got a nice link about which more below. From Wikipedia article (see `http://tinyurl.com/oyvklde`) one learns some interesting facts cloning. No-cloning theorem states that the cloning of *all* states by unitary time evolution of the tensor product system is not possible. It is however possible clone *orthogonal basis of states*. Does this have some deep meaning?

As a response to my question I got a link to an article of Lamourex *et al* (see `http://tinyurl.com/zq4kgda`) showing that the *cloning of entanglement* - to be distinguished from the cloning of quantum state - is not possible in the general case. Separability - the absence of entanglement - is not preserved. Approximate cloning generates necessarily some entanglement in this case, and the authors give a lower bound for the remaining entanglement in case of an unentangled state pair.

The cloning of maximally entangled state is however possible. What makes this so interesting is that maximally negentropic entanglement for *rational* entanglement probabilities in TGD framework corresponds to maximal entanglement - entanglement probabilities form a matrix proportional to unit matrix- and just this entanglement is favored by Negentropy Maximization Principle. Could maximal entanglement be involved with say DNA replication? Could maximal negentropic entanglement for algebraic extensions of rationals allow cloning so that DNA entanglement negentropy could be larger than entanglement entropy?

The impossibility of cloning of entanglement in the general case makes impossible the transfer of information as any kind of entanglement. Maximal entanglement - and maybe be even negentropic entanglement maximal in p-adic sectors - could however make the communication without damaging the information at the source. Since conscious information is associated with p-adic sectors responsible for cognition, one could even allow the modification of the entanglement probabilities and thus of the real entanglement entropy in the communication process since the maximal p-adic negentropy depends only weakly on the entanglement probabilities.

NE is assigned with conscious experiences with positive emotional coloring: experience of understanding, experience of love, etc... There is an old finnish saying, which can be translated to "Shared joy is double joy!". Could the cloning of NE make possible generation of entanglement by loving attitude so that living entities would not be mere thieves trying to steal NE by killing and eating each other?

5.4.5 NMP And Quantum Computer Type Systems

In ZEO there are 3 basic matrices. U-matrix between zero energy states, M-matrices and defining entanglement coefficients between positive and negative energy states at opposite boundaries of CD. The mutually orthonormal M-matrices are assumed to be expressible as "square root" of a density matrix expressible as a product of a hermitian diagonal square root of density matrix and unitary S-matrix. Quantum theory can be see as a square root of thermodynamics in this framework.

The original mathematically attractive hypothesis that U-matrix has M-matrices as its rows turned out to be wrong. The physical picture about U-matrix as unitary matrix between states represented by M-matrices allowing also dispersion in the moduli space for the CDs with the passive boundary fixed leads with rather general assumptions to the identification of U-matrix as a representation for the unitary scalings of CDs [K78].

This is the original picture and every updating forces to challenge the earlier picture.

1. What about M-matrix? Can one really regard it as an orthonormal row of U or is M completely free? The defence for this assumption is that the orthonormality for hermitian square roots of density matrix is extremely powerful constraint. M-matrices could correspond to orthonormal basis of hermitian generators of some symmetry algebra. If symmetry algebra commutes with the S-matrix, the square roots of density matrices would be invariant under S-matrix. This assumption might be however physically unfeasible. Besides the hermitian basis one the degrees of freedom defined by the discrete moduli of CD with second (passive) boundary fixed would label M-matrices.

2. Weak form of NMP suggests that TGD Universe can be regarded as a quantum computer. CD as quantum computer is a local version of the same idea. Unitarity process U could relate closely to quantum computation. The state function reduction process represents a stepwise halting of the computation proceeding to shorter scales (sub-CDs) until the resulting states are either bound states or negentropically entangled states.

3. The question is whether it is U-matrix or M-matrix, which defines quantum computation. In other words, which kind of transitions do the repeated state functions leaving the passive boundary of CD and states at it invariant, correspond? It would seem that U-matrix is the correct identification since a repeated de-localization in the moduli space of CDs followed by a localization (but no reduction) is involved at the active boundary of CD. Note that the moduli of CD consist of discrete Lorentz boosts and proper time translations for CD. The argument of [K78] suggests that S-matrix reduces to a unitary representation for the scalings of CD by a power of S-matrix assignable to the CD with minimal size: $S(n) = S^n$, where n characterizes the size scale of CD as a temporal distance between its tips. This makes possible quantum computations.

4. In ZEO quantum computation can be associated with the sequence of repeated reductions at fixed boundary of CD defining self. NE would be realized in terms of an entanglement characterized by a multiple of unitary matrix for a two-body system at the passive boundary of CD and would be stable during computation. The computation would end with a state function reduction at opposite boundary giving the outcome of the process. It could be a state with higher entanglement negentropy but weak form of NMP allows also ordinary state function reduction. Strong form of NMP would make the halting of the quantum computation impossible. Bio-systems would be especially attractive candidates for performers of quantum computation like processes.

5. The action of U-matrix in this picture would be trivial at the passive boundary and affect only the moduli of the upper boundary and the M-matrices. U-matrix cannot be however the direct counterpart of the ordinary S-matrix since there is non-trivial action in the moduli space of CDs. The matrix elements of U-matrix are however expressible in terms of S-matrix and the orthonormal basis of hermitian square roots of density matrices.

It is useful to list the basic differences with respect to ordinary quantum computation. Ordinary quantum computation utilizes unitary evolution of quantum states in positive energy

ontology. In this case quantum coherence is extremely fragile. In TGD framework NMP and ZEO allow to circumvent this problem. The outcome of the computation is however realized at the level of dark matter unless ordinary state function reduction takes place. This means that n reductions from $2^n - 1$ correspond to computations, whose outcome can be verified with the existing technology. A further new element is that the computation is conscious and this aspect might be the important one in living matter.

How quantum computation in ZEO differs from ordinary quantum computation

Quantum computation in ZEO differs in several respects from ordinary quantum computation.

1. The time parameter defining quantum computation as a unitary time evolution in standard quantum physics disappears and corresponds to the U-matrix for single repeated reduction followed by a localization in moduli of the active boundary of CD (but no reduction at the active boundary). Large number of these steps occur. This process occurs for sub-CDs of given CD and the outcome of the quantum computation as seen by CD would be determined statistically from the distribution of the outcomes of state function reductions for over sub-CDs.

   One can assign to the quantum computation a duration equal to the increase of the proper time distance between the tips of CD. For instance, .1 seconds could be the time scale assignable to quantum computations possibly assignable to electrons.

   The hierarchies of CDs and Planck constants make possible zoomed up variants of quantum computations. This kind of zooming might be essential for intelligent behavior since it is useful to simulate dynamics of the external world in the time scales natural for brain and shorter than the time scale during which it is necessary to react in order to survive. The geometric duration of the shortest possible quantum computation is of order CP_2 time about 10^4 Planck times, if the simplest estimate is correct.

2. The classical space-time correlates for the quantum computation are four-dimensional unlike in the case of ordinary quantum computation. In living matter nerve pulses and EEG frequencies would be very natural correlates of this kind. The model for DNA as topological quantum computer [K3] has as its space-time correlates magnetic flux tubes connecting DNA nucleotides and lipids of nuclear and cell membranes defining the braiding coding for the topological quantum computation. Dynamical flow of lipids defines the braiding in time direction and the memory representation is in terms of the braiding of the flux tubes induced by this flow. A good metaphor is in terms of dancers connected to a wall by threads. Dancing is the correlate for the running quantum computer program and the geometric entanglement of threads the correlate for the storage of the program to computer memory.

3. The outcome of quantum computation is described statistically in terms of a large set of quantum computations. The statistical description of the conscious experience of ensemble of sub-selves implies that mathematically the situation is very much analogous with that encountered in the standard quantum computation and it is attractive to assume that conscious experience codes for the outcome of quantum computation via the average quantities assignable to the distribution of zero energy quantum states assignable to sub-CDs.

4. A further new element is macro-temporal quantum coherence involving several aspects. One of these aspects is that the time scale of CD defines macrotemporal quantum coherence at least at the level of the field body assignable to the physical system such as electron. It is not quite clear whether electrons correspond to distinct overlapping CDs of size scale defined by.1 second time scale and of the order of Earth circumference and thus satisfying the basic criterion of quantum coherence or whether one should speak about anyonic many particle states assignable to single CD or whether both interpretations can make sense depending on situation.

   In living matter also millisecond time scale is important and would correspond naturally to the CDs assignable to u and d quarks in nuclei and perhaps also with the ends of magnetic flux tubes in the model of DNA as topological quantum computer. In the proposed model quarks

and antiquarks at the ends of flux tubes represent genetic codons and their entanglement is responsible for the realization of the program at quantum level. The millisecond time scale of synchronous cortical firing and of nerve pulse could correspond to the time scale of CDs associated with u and d quarks at the ends of the flux tube. Note that larger value of $\hbar$ would scale up this time scale. Quantum parallel dissipation taking place at various size scales for CD is a further new element.

5. One must generalize the standard quantum computer paradigm since ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. This suggests that qubits must be replaced by qupits since for algebraic entanglement two-state systems are naturally replaced with p-state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which would mean gigantic quantum computational resources. The secondary p-adic time scale $T_2(127) \simeq .1$ seconds basic bit-like unit corresponds to $M_{127} = 2^{127}-1$ M_{127}-qupits making about 254 bits. The size of neuron corresponds to CD with time scale equal to the age of the universe and in this case the maximum the number of pinary digits is 171.

   The finite measurement resolution for qubits of course poses strong limitations to the actual number of bits since the negentropic zero energy qubits must be in reasonable approximation pure qubits distinguishable from each other and could correspond CDs with time scales coming as powers of two from $n = k_{min}$ to k so that the effective number of qubits would go like 2-based logarithm of the p-adic prime. For instance, electron could correspond to six bits assignable to genetic code plus parity bit corresponding to time scale range from 1 ms to 100 ms. In any case the idea about neuron as a classical bit might be completely wrong!

6. Spin glass degeneracy also provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the flux tubes -say magnetic flux tubes- and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis suggests itself. The space-time sheets mediating gravitational interaction are predicted to have a huge gravitational Planck constant $\hbar_{gr} = GMm/v_0$, $v_0/c < 1$, particles at these space-time sheets are predicted to have huge Compton wavelengths and the plausible looking identification is in terms of dark energy [K112, K87]. This would make quantum computation like activities possible in super-astronomical time scales.

Negentropic quantum computations, fuzzy qubits, and quantum groups

1. The possibility of NE is certainly the basic distinction making in the intersection of real and p-adic worlds possible a conscious process at least analogous to a quantum computation and accompanied by a conscious understanding. What makes this possible is the fact that the negentropically entangled states of N basic states have permutation of the basis states as a symmetry. For instance, states for which bit 1 appears with almost unit probability gives by permutation a state for which bit 0 appears with almost unit probability. This suggests that the outcome of quantum computation is expressed in terms of almost bits with a small mixing implying that the outcome has interpretation both as a rule and as almost bit in the ordinary sense. The conscious quantum computation would utilize states with NE in time direction. Also the analogies of bound states for time-like entanglement are possible and might make possible the counterpart of ordinary quantum computation without the higher level conscious experience about rules defined by the entangled states.

2. NE for positive and negative energy parts of bits stable and pinary digits stable under NMP means that the logic is always fuzzy. I have proposed the mathematical description of this in terms of quantum spinors for which the components do not commute anymore implying that only the probability for either spin state is is an observable [K138]. This suggests that NE might be describable in terms of quantum spinors and that it would be the unavoidable fuzziness which would make possible the representation conscious rules. What is interesting that for quantum spinors the spectrum of the probabilities for given spin is universal and depends only on the integers characterizing the quantum phase $q = exp(i2\pi/n)$. An alternative interpretation is that fuzzy logic relates to a finite measurement resolution. These interpretation need not be in conflict with each other. Since quantum groups are

associated with anyonic systems, this suggests that negentropic quantum computations take place in anyonic systems assignable to phases with large value of $\hbar$. This encourages to consider the possibility that quantum phases define algebraic extensions of p-adic numbers.

3. In living systems it might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macro-temporal quantum coherence replace the unitary time evolutions at the gates of the quantum computer as the basic information processing units and entanglement bridges between selves act as basic quantum communication units with the sharing of mental images providing a communication mode not possible in standard quantum mechanics.

5.4.6 Quantum Measurement And Quantum Computation In TGD Universe

It is interesting to test how the view about quantum computation must be modified in TGD Universe. There are considerable deviations from the standard view. Zero Energy Ontology (ZEO), weak form of NMP dictating the dynamics of state function reduction [K73], negentropic entanglement, and hierarchy of Planck constants [K31, K32, K33, K34] define the basic differences between TGD based and standard quantum measurement theory. TGD suggests also the importance of topological quantum computation (TQC) like processes with braids represented as magnetic flux tubes/strings along them.

The natural question is how NMP and Zero Energy Ontology (ZEO) could affect the existing view about TQC. The basic observation is that the phase transition to dark matter phase reduces dramatically the noise affecting quantum quits. This together with robustness of braiding as TQC program raises excellent hopes about TQC in TGD Universe. The restriction to negentropic space-like entanglement (NE) defined by a unitary matrix is something new but does not seem to have any fatal consequences as the study of Shor's algorithm shows.

NMP strongly suggests that when a pair of systems - the ends of braid - suffer state function reduction, the NE must be transferred somehow from the system. How? The model for quantum teleportation allows to identify a possible mechanism allowing to achieve this. This mechanism could be fundamental mechanism of information transfer also in living matter and phosphorylation could represent the transfer of NE according to this mechanism: the transfer of metabolic energy would be at deeper level transfer of negentropy.

NE defines an excellent candidate for an analog of error correcting code. If only the diagonal form of the unitary entanglement matrix carries information, the quantization of phases as roots of unity provides a scenario in which Nature itself would take care of error correction.

ZEO based quantum measurement theory

Consider first the quantum measurement theory based on ZEO.

1. Sub-system–complement pair defining larger system defines the counterpart for the pair observer-measured system in standard quantum measurement theory. In TGD framework density matrix for a sub-system–complement pair defines the universal observable. As a matter of fact, for a given system all sub-system-complement pairs defining possible splitting of this kind and the state function reduction is realized for the pair giving rise to maximum of maximal negentropy gain (NMP). A further essential assumption is that the reduction proceeds from a system inside CDE to subsystems as a cascade obeying this basic rule.

2. ZEO implies that state function reductions occur at either boundary of causal diamond (CD) - the active boundary. The sequence of reductions leaving passive boundary and state at it unaffected gives rise to a conscious entity - self. What is new that at the active boundary the state changes. Even the active boundary itself drifts to the geometric future so that the size of CD increases. This gives rise to the experience about flow of time.

   This is the TGD counterpart for the unitary time evolution and its duration corresponds to the increases of the proper time distance between the tips of CD. Eventually NMP forces the first state function reduction to the opposite boundary: this corresponds to a genuine state

function reduction. The self dies and re-incarnates at the opposite boundary as time reversed self since CD increases after than at the opposite boundary to the direction of geometric past.

In the standard quantum models for quantum computation one assumes that measurement can be realized by some interaction Hamiltonian: the state of entangled system-observer pair develops to an eigen state of the interaction Hamiltonian. The time development by this interaction Hamiltonian gives entangled state defined by the density matrix. This description can be seen as an approximation to TGD based description in which one can assign definite duration to the analog of the unitary evolution.

3. Negentropic entanglement (NE) is possible for entanglement coefficients in algebraic extension of rationals since in this case number theoretic entropy having negative values is well-defined. If the density matrix does not belong to the same algebraic extension, state function reduction requires a phase transition extending the algebraic extension of rationals used and could be seen as kind of evolutionary jump. This kind of NE could be therefore rather stable and could be interpreted as a kind of cognitive entanglement representing a rule with instances represented as state pairs in the superposition. If the state function reduction occurs it leads to a ray of state space if density matrix is non-degenerate.

   If the density matrix contains as a direct summand a higher-dimensional projector, a reduction giving rise to a projector to this sub-space is allowed by the interpretation as measurement of density matrix producing its eigen space. The state remains negentropically entangled by the unitary matrix giving rise to the projector. Weak form of NMP [K73] however allows reductions also to the subspaces of this sub-space assuming preferred state basis so that also the reduction to a ray of state space is possible as a special case. In this case any state basis is eigenbasis for the sub-space and this suggests an interpretation in terms of meditative states in which distinctions disappear.

TQC in TGD

How could (topological) quantum computation be realized in TGD framework?

1. In standard quantum theory unitary time evolution realizes the quantum computation. Unitary time evolution is engineered in terms of gates performing standardized operations for qubits. For TQC braiding defines the space-time entanglement between the systems A and B at the ends of the braid. Call this system $A \otimes B$. One can speak about evolution a kind of "space-like" topological quantum computer program with negentropically entangled "initial" and "final" states at the ends of the braid. Basic braiding operation defines the basic gate in terms of so called R-matrix and the desired NE can be build using an appropriate braiding. For the sake of concreteness the following considerations assume TQC. In fact, if there is entanglement between ends, it must be unitary entanglement since only this entanglement is respected by NMP.

2. In TQC the program is defined by braid and is robust against perturbations. The quantum states at the ends of the braid are however sensitive to noise and this requires complex error correction procedures to eliminate the errors, which are basically spin flip changing the value of qubit and change of its phase. If only phase ± 1 is allowed phase change actually reduces to spin flip in suitable basis.

   In standard quantum computation the small value of Planck constant is the basic problem. Coherence times tend to be very short and the control of external noise is a tough challenge. In TGD quantum criticality gives rise to phases of matter with effective value $h_{eff} = n \times h$ of Planck constant identified as dark matter. These phases are involved also with NE. Only systems with same value of $h_{eff} = n \times h$ have direct interactions with each other. This should dramatically reduce the noise since visible matter particle must transform to dark matter particle to interact directly with dark matter to produce noise. Also the scaling up of interaction time scales gives hopes that quantum coherence times are long enough to perform TQC.

3. The value of h_{eff} is expected to correlate with the duration of self defined as the increase ΔT of the temporal distance during the sequence of state function reductions to the same

passive boundary of CD. ΔT could be interpreted as quantum coherence time. Coherence time for classical fields could be identified as the temporal distance between the tips of CD increasing during quantum computation.

4. TGD promises to guarantee the reduction of noise in terms of darkness of the particles involved with the computation: this instability is the weakness of TQC although TQC program itself is robust. TGD also promises the understanding of the role of quantum criticality in quantum measurement. The very fact that quantum measurements necessarily involve the amplification of small quantum effects to macroscopic "classical" effect, indeed strongly suggests quantum criticality.

5. The key challenge is to prepare a desired kind of negentropically entangled state - say a dark many-particle state associated with a braid system. One should be able to manipulate of dark matter, which we are not yet able to even detect! That dark matter appears at quantum criticality could be extremely helpful in the attempts to get grasp on the dark matter. A simple clue is that the disappearance of visible matter could serve as a signature for the emergence of dark matter.

One should somehow be able to perform state function reduction of the negentropically entangled system to one of the eigenstates of the density matrix associated with an entanglement matrix proportional to a unitary matrix (in the following I will speak of unitary entanglement). This requires TGD counter part of time evolution. One can imagine two options.

1. One can couple the negentropically entangled system pair AB to a measurement apparatus C, whose function is to develop ordinary entanglement with both systems during the repeated sequence of state function reductions at fixed boundary. In the state function reduction to the opposite boundary a time reversed reduced state results and gives rise to rays of state space for both A and B. One can however argue that the situation cannot be so simple: NMP requires that entanglement negentropy increases so that NE should be transferred somewhere. This will be discussed below.

2. The measurement interaction must be able to achieve ordinary state function reduction by generating entanglement with the system formed by negentropically entangled system. One must have interaction between ordinary and dark matter and this requires transformation of ordinary matter to dark matter with the same value of h_{eff}. Quantum criticality allows the transformation of ordinary matter to dark matter so that the measuring system should be quantum critical [K31, K32, K33, K34].

3. Could one do without a third system? Weak form of NMP allows also a reduction to the lower dimensional sub-spaces of the N-D sub-space considered and also 1-D ray is possible. This process corresponds to a duration of single self, which dies when the first reduction to the opposite boundary of its CD occurs. If the braid system is not changed in the state function to the opposite boundary one can hope that a reduction to a 1-D ray can occur with some probability. By waiting long enough one can obtain state function reductions which determine the probabilities for the reduction to a given ray or sub-space. The important difference to the standard picture would be that the system does it itself. No external measurements at the end of braid would be carried out. This is however too good to be true. Only one of the two quantum measurements required by Shor algorithm can be both carried out in his manner.

The interpretation in terms of consciousness theory allows also to consider the possibility that the measurement corresponds at deeper level to transfer of negentropic entanglement.

1. One has besides AB also the third system C. The NE for AB is transferred to NE for AC and can be transferred further - say to entanglement to NE for CD. In TGD framework the iteration of this process makes possible a transfer of conscious information associated with NE for AB to that of conscious observer.

2. If the state of C is eigenstate of spin in the basis used, the final state of B is also an eigenstate of spin. Hence the transfer of NE could be thus interpreted as a measurement of the state of B or as the measurement of state of AC in Bell basis. This conforms with the fact that state function reduction for a subsystem can be interpreted as a state function reduction for its complement. Could the deeper interpretation of quantum measurement be as a transfer of NE so that essentially quantum information theory would be in question.

3. The measurement is performed for the negentropically entangled Bell states for the pair AC and performs the transfer of entanglement inducing a unitary rotation. Since in the case of NE defined by a unitary matrix any state basis is allowed, one could ask whether the outcomes are equivalent from the point of view of consciousness theory at least. The knowledge of the final state of B allows to deduce the unitary rotation needed to rotate AC state to the original AB state so that this information is enough to realize a faithful NE transfer. Since the conscious experience is dictated both by the bit telling the state of B and by the state of AC one can ask whether the conscious experience and is same for all four outcomes.

Where and how the NE could be transferred?

NMP demands that entanglement negentropy increases. An interesting question is, where and how the entanglement negentropy is transferred.

1. Does NE correspond to information transferred to the performer of quantum measurement? If so, the quantum measurement process would be basically transfer of information realized as NE. Living systems would be carrying out this all the time and ATP-ADP transformation defining the basic step of energy metabolism would be just this kind of transfer. The transfer corresponds at the level of space-time geometry the transfer of the end of magnetic flux tubes plus particles from a donor to the acceptor.

2. A possible manner to carry out the transfer of negentropic entanglement is inspired by the quantum teleportation protocol (`http://tinyurl.com/omfkydh`). In the simplest situation this protocol is as follows. Alice wants to send qubit C to Bob. A Bell state (`http://tinyurl.com/z9g8rar`) is shared between Alice and Bob by mutual agreement in advance so that both know it. Alice can achieve the teleportation by a quantum measurement in the tensor product of the qubit C with the AB Bell state.

   Alice reduces the system AC to one of the four Bell states and communicates the result classically to Bob. The factored out state of B is the original state or one of three states related to it by unitary rotation. Alice sends classically two bits telling what the measurement outcome was. If the outcome was the original state to be sent, Bob does nothing. If it was one of the three remaining states, Bob performs a unitary rotation giving as a result the original state.

3. What makes this protocol so interesting is that in the reduction the NE for AB is transferred to NE for AC as such or modified by a unitary rotation so that four different outcomes are possible. Since the states of C and AB are in 1-1-correspondence it is indeed obvious that the information about the state of B resulting from the measurement of Alice allows the rotation of the Bell state AC to the original state AB. For instance, if the state of B is the original state of C, the state is the original state AB.

   One can apply this procedure by introducing four system D - call it Doris - so that AC NE is transferred to CD NE and AB is now product state. This kind of transfer of negentropic entanglement might be a key event in in phosphorylation and in the utilization of metabolic energy coming from nutrients. The NE between phosphate P of ATP ==B and third system A would be transferred to NE between acceptor molecule and C and A. Also the NE between nutrient B and third system A could bnd third system A could be transferred to NE between phosphate and A.

Shor's algorithm from TGD point of view

Is the unitary of the entanglement matrix guaranteeing NE too strong an assumption? Just for fun I m (`http://tinyurl.com/ppxvcsd`) for the factorization of a given integer, call it N, which has been shown to work for $N = 15$. It turns out that unitary entanglement is not a problem. Furthermore, ordinary quantum measurements are needed for the two systems involved and require interaction coupling negentropically entangled pair of systems to external world so that both negentropically entangled systems generate entanglement with external world.

Consider now the Shor's algorithm. The genuinely quantal step of algorithm is that of finding the period r of the function $f(x) = a^x \ mod \ N$, for integers $1 < a < N$ and $1 < x < N$.

1. According to the Wikipedia article , the computation involves the construction of quantum function $f(x) = a^x$ as

$$\frac{1}{Q}\sum_x |x, f(x)\rangle \ .$$

   Here Q is normalization factor. Since $a^r = 1 \ mod \ N$, $f(x)$ is not a bijection. Unless r divides Q (we do not however know r!), the number $N(z)$ of values of x satisfying $f(x) = z$ varies and the variation is one unit at most. Therefore the entanglement is not unitary and the density matrix of the state is not unit matrix since the norms of states

$$|Z| = \sum_x |x, f(x) = z\rangle$$

   is given by $N(z)$- the number of x mapped to z and varies somewhat. NE would be obtained by normalizing the states $|Z\rangle$ to unit norm and replacing Q by the the number $N(Z)$ of points z to get

$$\frac{1}{\sqrt{N(Z)}}\sum_z \frac{1}{\sqrt{N(z)}}\sum_x |x, f(x) = z\rangle \ .$$

2. Second step in the computation is discrete quantum Fourier transform using as counterparts of plane waves powers of the root of unity defined as $\omega = exp(i2\pi/Q)$, where Q satisfies $N^2 \leq Q < 2N^2$. This operation is unitary and gives rise to entanglement matrix proportional to a unitary matrix. Since the entire entanglement matrix is product of unitary matrices, it is also unitary. The action of unitary transformation is given for given value of z by the following formula.

$$\sum_x |x, f(x) = z)\rangle \rightarrow \sqrt{1}\sqrt{N}\sum_y \sum_{z=f(x)} \omega^{xy}|y, z = f(x)\rangle \ .$$

   The entire state is transformed to

$$\frac{1}{\sqrt{N(Z)}}\frac{1}{\sqrt{N}}\sum_z \frac{1}{\sqrt{N(z)}}\sum_y \omega^{xy}\sum_x |y, z = f(x)\rangle \ .$$

   In this expression the state paired $|Z\rangle$ is a superposition of several values of y since the number of different values of z is smaller than those of y by a factor which in ideal situation is the sought four value of r.

3. Quantum measurement should reduce this state to a state with fixed values of y and z. This implies that the normalization factors do not matter. Weak NMP allows a self-reduction a state Z with fixed value of z. The self reduction of the system is however not able to reduce the state Z to $|y, z\rangle$.

   One must couple at least the "y" part of the system to external measurement apparatus generating ordinary or negentropic entanglement with non-degenerate density matrix belonging

to the extension used and having $|y\rangle$ as eigenstates. This would force y-reduction. One can of course perform the same for both y and z. The ordinary quantum measurement theory seems to be a necessary part of the picture. In TGD framework additional constraints come from the condition that the measurement involves negentropy transfer. This requires explicit introduce of systems C and D receiving the NE.

About negentropic entanglement as an analog of error correction code

In classical computation, the simplest manner to control errors is to take several copies of the bit sequences. In quantum case no-cloning theorem prevents this. Error correcting codes (`http://tinyurl.com/oq7hl37`) code n information qubits to the entanglement of $N > n$ physical qubits. Additional contraints represents the subspace of n-qubits as a lower-dimensional sub-space of N qubits. This redundant representation is analogous to the use of parity bits. The failure of the constraint to be satisfied tells that the error is present and also the character of error. This makes possible the automatic correction of the error is simple enough - such as the change of the phase of spin state or or spin flip.

Negentropic entanglement (NE) obviously gives rise to a strong reduction in the number of states of tensor product. Consider a system consisting of two entangled systems consisting of N_1 and N_2 spins. Without any constraints the number of states in state basis is $2^{N_1} \times 2^{N_2}$ and one as $N_1 + N_2$ qubits. The elements of entanglement matrix can be written as $E_{A,B}$ $A \equiv \otimes_{i=1}^{N_1}(m_i, s_i)$, $B \equiv \otimes_{k=1}^{N_2}(m_k, s_k)$ in order to make manifest the tensor product structure. For simplicity one can consider the situation $N_1 = N_2 = N$.

The un-normalized general entanglement matrix is parametrized by 2×2^{2N} independent real numbers with each spin contributing two degrees of freedom. Entanglement matrix proportional to a unitary matrix is characterized by 2^{2N} real numbers. One might perhaps say that one has $2N$ real bits instead of almost $2N + 1$ real qubits. If the time evolution according to ZEO respects the negentropic character of entanglement, the sources of errors are reduced dramatically.

The challenge is to understand what kind of errors NE eliminates and how the information bits are coded by it. NE is respected if the errors act as unitary transformations $E \to UEU^\dagger$ of the entanglement matrix unitary apart from a normalization factor. One can consider two interpretations.

1. The unitary automorphisms leave information content unaffected only if they commute with E. In this case unitary automorphisms acting non-trivially would give rise genuine errors and an error correction mechanism would be needed and would be coded to quantum computer program.

2. One can also consider the possibility that the unitary automorphisms *do not affect* the information content so that the diagonal form of entanglement matrix coded by N phases would carry of information. Clearly, the unitary automorphisms would act like gauge transformations. Nature would take care that no errors emerge. Of course, more dramatic things are in principle allowed by NMP: for instance, the entanglement matrix proportional to unitary matrix could reduce to a tensor product of several unitary matrices. Negentropy could be transferred from the system and is indeed transferred as the computation halts.

   By number theoretic universality the diagonalized entanglement matrix would be parametrized by N roots of unity with each having n possible values so that n^N different NEs would be obtained and information storage capacity would be $I = log(n)/log(2) \times N$ bits for $n = 2^k$ one would have $k \times N$ bits. Powers of two for n are favored. Clearly the option for which only the eigenvalues of E matter, looks more attractive realization of entanglement matrices. If overall phase of E does not matter as one expects, the number of full bits is $k \times N - 1$. This option looks more attractive realization of entanglement matrices.

   In fact, Fermat polygons for which cosine and sine for the angle defining the polygon are expressible by iterating square root besides basic arithmetic operations for rationals (ruler and compass construction geometrically) correspond to integers, which are products of a power of two and of different Fermat primes $F_n = 2^{2^n} + 1$. 1

   This picture can be related to much bigger picture.

1. In TGD framework number theoretical universality requires discretization in terms of algebraic extension of rationals. This is not performed at space-time level but for the parameters characterizing space-time surfaces at the level of WCW. Strong form of holography is also essential and allows to consider partonic 2-surfaces and string world sheets as basic objects. Number theoretical universality (adelic physics) forces a discretization of phases and number theoretically allowed phases are roots of unity defined by some algebraic extension of rationals. Discretization can be also interpreted in terms of finite measurement resolution. Notice that the condition that roots of unity are in question realizes finite measurement resolution in the sense that errors have minimum size and are thus detectable.

2. Hierarchy of quantum criticalities corresponds to a fractal inclusion hierarchy of isomorphic sub-algebras of the super-symplectic algebra acting as conformal gauge symmetries. The generators in the complement of this algebra can act as dynamical symmetries affecting the physical states. Infinite hierarchy of gauge symmetry breakings is the outcome and the weakening of measurement resolution would correspond to the reduction in the size of the broken gauge group. The hierarchy of quantum criticalities is accompanied by the hierarchy of measurement resolutions and hierarchy of effective Planck constants $h_{eff} = n \times h$.

3. These hierarchies are argued to correspond to the hierarchy of inclusions for hyperfinite factors of type II_1 labelled by quantum phases and quantum groups. Inclusion defines finite measurement resolution since included sub-algebra does induce observable effects on the state. By Mac-Kay correspondence the hierarchy of inclusions is accompanied by a hierarchy of simply laced Lie groups which get bigger as one climbs up in the hierarchy. There interpretation as genuine gauge groups does make sense since their sizes should be reduced. An attractive possibility is that these groups are factor groups G/H such that the normal subgroup H (necessarily so) is the gauge group and indeed gets smaller and G/H is the dynamical group identifiable as simply laced group which gets bigger. This would require that both G and H are infinite-dimensional groups. An interesting question is how they relate to the super-symplectic group assignable to "light-cone boundary" $\delta M^4_{\pm} \times CP_2$. I have proposed this interpretation in the context of WCW geometry earlier.

4. Here I have spoken only about dynamical symmetries defined by discrete subgroups of simply laced groups. I have earlier considered the possibility that discrete symmetries provide a description of finite resolution, which would be equivalent with quantum group description.

Summarizing, these arguments boil down to the conjecture that discrete subgroups of these groups act as effective symmetry groups of entanglement matrices and realize finite quantum measurement resolution. A very deep connection between quantum information theory and these hierarchies would exist.

Gauge invariance has turned out to be a fundamental symmetry principle, and one can ask whether entanglement matrices proportional to unitary matrices assuming that only the eigenvalues matter, could give rise to a simulation of discrete gauge theories. The reduction of the information to that provided by the diagonal form be interpreted as an analog of gauge invariance?

1. The hierarchy of inclusions of hyper-finite factors of type II_1 suggests strongly a hierarchy of effective gauge invariances characterizing measurement resolution realized in terms of hierarchy of normal subgroups and dynamical symmetries realized as coset groups G/H. Could these effective gauge symmetries allow to realize entanglement matrices proportional to unitary matrics invariant under these symmetries?

2. A natural parametrization for single qubit errors is as rotations of qubit. If the error acts as a rotation on *all* qubits, the rotational invariance of the entanglement matrix defining the analog of S-matrix is enough to eliminate the effect on information processing.

   Quaternionic unitary transformations act on qubits as unitary rotations. Could one assume that complex numbers as the coefficient field of QM is effectively replaced with quaternions? If so, the multiplication by unit quaternion for states would leave the physics and information content invariant just like the multiplication by a complex phase leaves it invariant in the standard quantum theory.

One could consider the possibility that quaternions act as a discretized version of local gauge symmetry affecting the information qubits and thus reducing further their number and thus also errors. This requires the introduction of the analog of gauge potential and coding of quantum information in terms of SU(2) gauge invariants. In discrete situation gauge potential would be replaced with a non-integrable phase factors along the links of a lattice in lattice gauge theory. In TGD framework the links would correspond the fermionic strings connecting partonic two-surfaces carrying the fundamental fermions at string ends as point like particles. Fermionic entanglement is indeed between the ends of these strings.

3. Since entanglement is multilocal and quantum groups accompany the inclusion, one cannot avoid the question whether Yangian symmetry crucial for the formulation of quantum TGD [K126] could be involved.

5.5 p-Adic physics and consciousness

p-Adic physics as physics of cognition and imagination is an important thread in TGD inspired theory of consciousness. In the sequel I describe briefly the basic of TGD inspired theory of consciousness as generalization of quantum measurement theory to ZEO (ZEO), describe the definition of self, consider the question whether NMP is needed as a separate principle or whether it is implied is in statistical sense by the unavoidable statistical increase of $n = h_{eff}/h$ if identified as a factor of the dimension of Galois group extension of rationals defining the adeles, and finally summarize the vision about how p-adic physics serves as a correlate of cognition and imagination.

5.5.1 From quantum measurement theory to a theory of consciousness

The notion of self can be seen as a generalization of the poorly defined definition of the notion of observer in quantum physics. In the following I take the role of skeptic trying to be as critical as possible.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. The density matrix was assumed to define the universal observable. Note that a density matrix, which is power series of a product of matrices representing commuting observables has in the generic case eigenstates, which are simultaneous eigenstates of all observables. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

The precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO (ZEO) only rather recently (2014).

1. Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant - "small" state function reductions. The parts of zero energy states at second boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.

2. The first quantum jump to the opposite boundary corresponds to the act of "free will" or birth of re-incarnated self. Hence the act of "free will" changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means "death" of self and "re-incarnation" of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.

3. This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

One can identify several rather abstract state function reductions selecting a sector of WCW.

1. There are quantum measurements inducing localization in the moduli space of CDs with passive boundary and states at it fixed. In particular, a localization in the moduli characterizing the Lorentz transform of the upper tip of CD would be measured. The measured moduli characterize also the analog of symplectic form in M^4 strongly suggested by twistor lift of TGD - that is the rest system (time axis) and spin quantization axes. Of course, also other kinds of reductions are possible.

2. Also a localization to an extension of rationals defining the adeles should occur. Could the value of $n = h_{eff}/h$ be observable? The value of n for given space-time surface at the active boundary of CD could be identified as the order of the smallest Galois group containing all Galois groups assignable to 3-surfaces at the boundary. The superposition of space-time surface would not be eigenstate of n at active boundary unless localization occurs. It is not obvious whether this is consistent with a fixe value of n at passive boundary.

   The measured value of n could be larger or smaller than the value of n at the passive boundary of CD but in statistical sense n would increase by the analogy with diffusion on half line defined by non-negative integers. The distance from the origin unavoidably increases in statistical sense. This would imply evolution as increase of maximal value of negentropy and generation of quantum coherence in increasingly longer scales.

3. A further abstract choice corresponds to the replacement of the roles of active and passive boundary of CD changing the arrow of clock time and correspond to a death of self and re-incarnation as time-reversed self.

Can one assume that these measurements reduce to measurements of a density matrix of either entangled system as assumed in the earlier formulation of NMP, or should one allow both options. This question actually applies to all quantum measurements and leads to a fundamental philosophical questions unavoidable in all consciousness theories.

1. Do all measurements involve entanglement between the moduli or extensions of two CDs reduced in the measurement of the density matrix? Non-diagonal entanglement would allow final states states, which are not eigenstates of moduli or of n: this looks strange. This could also lead to an infinite regress since it seems that one must assume endless hierarchy of entangled CDs so that the reduction sequence would proceed from top to bottom. It looks natural to regard single CD as a sub-Universe.

   For instance, if a selection of quantization axis of color hypercharge and isospin (localization in the twistor space of CP_2) is involved, one would have an outcome corresponding to a quantum superposition of measurements with different color quantization axis!

   Going philosophical, one can also argue, that the measurement of density matrix is only a reaction to environment and does not allow intentional free will.

2. Can one assume that a mere localization in the moduli space or for the extension of rationals (producing an eigenstate of n) takes place for a fixed CD - a kind of self measurement possible for even unentangled system? If there is entanglement in these degrees of freedom between two systems (say CDs), it would be reduced in these self measurements but the outcome would not be an eigenstate of density matrix. An interpretation as a realization of intention would be approriate.

3. If one allows both options, the interpretation would be that state function reduction as a measurement of density matrix is only a reaction to environment and self-measurement represents a realization of intention.

4. Self measurements would occur at higher level say as a selection of quantization axis, localization in the moduli space of CD, or selection of extension of rationals. A possible general rule is that measurements at space-time level are reactions as measurements of density matrix whereas a selection of a sector of WCW would be an intentional action. This because formally the quantum states at the level of WCW are as modes of classical WCW spinor field single particle states.

5. If the selections of sectors of WCW at active boundary of CD commute with observables, whose eigenstates appear at passive boundary (briefly *passive observables*) meaning that time reversal commutes with them - they can occur repeatedly during the reduction sequence and self as a generalized Zeno effect makes sense.

   If the selections of WCW sectors at active boundary do not commute with passive observables then volition as a choice of sector of WCW must change the arrow of time. Libet's findings show that conscious choice induces neural activity for a fraction of second before the conscious choice. This would imply the correspondences *"big" measurement changing the arrow of time - self-measurement at the level of WCW - intentional action* and *"small" measurement - measurement at space-time level - reaction.*

   Self as a generalized Zeno effect makes sense only if there are active commuting with passive observables. If the passive observables form a maximal set, the new active observables commuting with them must emerge. The increase of the size of extension of rationals might generate them by expanding the state space so that self would survive only as long at it evolves.

   Otherwise there would be only single unitary time evolution followed by a reduction to opposite boundary. This makes sense only if the sequence of "big" reductions for sub-selves can give rise to the time flow experienced by self: the birth and death of mental images would give rise to flow of time of self.

A hierarchical process starting from given CD and proceeding downwards to shorter scales and stopping when the entanglement is stable is highly suggestive and favors self measurements. What stability could mean will be discussed in the next section. CDs would be a correlate for self hierarchy. One can say also something about the anatomy and correlates of self hierarchy.

1. Self experiences its sub-selves as mental images and even we would represent mental images of some higher level collective self. Everything is conscious but consciousness can be lost or at least it is not possible to have memory about it. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.

2. By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J148] could be understood as a sharing of mental images between brain hemispheres, which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.

3. At the level of 8-dimensional embedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by

sensory qualia. For instance .1 second time scale defining sensory chronon corresponds to the secondary p-adic time scale characterizing the size of electron's CD (Mersenne prime M_{127}), which suggests that Cooper pairs of electrons are essential for the sensory qualia.

5.5.2 NMP and self

The view about Negentropy Maximization Principle (NMP) [K73] has co-evolved with the notion of self and I have considered many variants of NMP.

1. The original formulation of NMP was in positive energy ontology and made same predictions as standard quantum measurement theory. The new element was that the density matrix of sub-system defines the fundamental observable and the system goes to its eigenstate in state function reduction. As found, the localizations at to WCW sectors define what might be called self-measurements and identifiable as active volitions rather than reactions.

2. In p-adic physics one can assign with rational and even algebraic entanglement probabilities number theoretical entanglement negentropy (NEN) satisfying the same basic axioms as the ordinary Shannon entropy but having negative values and therefore having interpretation as information. The definition of p-adic negentropy (real valued) reads as $S_p = -\sum P_k log(|P_k|_p)$, where $|.|_p$ denotes p-adic norm. The news is that $N_p = -S_p$ can be positive and is positive for rational entanglement probabilities. Real entanglement entropy S is always non-negative.

   NMP would force the generation of negentropic entanglement (NE) and stabilize it. NNE resources of the Universe - one might call them Akashic records- would steadily increase.

3. A decisive step of progress was the realization is that NTU forces all states in adelic physics to have entanglement coefficients in some extension of rationals inducing finite-D extension of p-adic numbers. The same entanglement can be characterized by real entropy S and p-adic negentropies N_p, which can be positive. One can define also total p-adic negentropy: $N = \sum_p N_p$ for all p and total negentropy $N_{tot} = N - S$.

   For rational entanglement probabilities it is easy to demonstrate that the generalization of adelic theorem holds true: $N_{tot} = N - S = 0$. NMP based on N_{tot} rather than N would not say anything about rational entanglement. For extensions of rationals it is easy to find that $N - S > 0$ is possible if entanglement probabilities are of form X_i/n with $|X_i|_p = 1$ and n integer [L47]. Should one identify the total negentropy as difference $N_{tot} = N - S$ or as $N_{tot} = N$?

   Irrespective of answer, large p-adic negentropy seems to force large real entropy: this nicely correlates with the paradoxical finding that living systems tend to be entropic although one would expect just the oppositecite [L47]: this relates in very interesting manner to the work of biologists Jeremy England [I59]. The negentropy would be cognitive negentropy and not visible for ordinary physics.

4. The latest step in the evolution of ideas NMP was the question whether NMP follows from number theory alone just as second law follows form probability theory! This irritates theoretician's ego but is victory for theory. The dimension n of extension is positive integer and cannot but grow in statistical sense in evolution! Since one expects that the maximal value of negentropy (define as $N - S$) must increase with n. Negentropy must increase in long run.

Number theoretic entanglement can be stable

Number theoretical Shannon entropy can serve as a measure for genuine information assignable to a pair of entanglement systems [K73]. Entanglement with coefficients in the extension is always negentropic if entanglement negentropy comes from p-adic sectors only. It can be negentropic if negentropy is defined as the difference of p-adic negentropy and real entropy.

The diagonalized density matrix need not belong to the algebraic extension since the probabilities defining its diagonal elements are eigenvalues of the density matrix as roots of N:th order polynomial, which in the generic case requires n-dimensional algebraic extension of rationals. One

can argue that since diagonalization is not possible, also state function reduction selecting one of the eigenstates is impossible unless a phase transition increasing the dimension of algebraic extension used occurs simultaneously. This kind of NE could give rise to cognitive entanglement.

There is also a special kind of NE, which can result if one requires that density matrix serves a universal observable in state function reduction. The outcome of reduction must be an eigen space of density matrix, which is projector to this subspace acting as identity matrix inside it. This kind NE allows all unitarily related basis as eigenstate basis (unitary transformations must belong to the algebraic extension). This kind of NE could serve as a correlate for "enlightened" states of consciousness. Schrödingers cat is in this kind of state stably in superposition of dead and alive and state basis obtained by unitary rotation from this basis is equally good. One can say that there are no discriminations in this state, and this is what is claimed about "enlightened" states too.

The vision about number theoretical evolution suggests that NMP forces the generation of NE resources as NE assignable to the "passive" boundary of CD for which no changes occur during sequence of state function reductions defining self. It would define the unchanging self as negentropy resources, which could be regarded as kind of Akashic records. During the next "re-incarnation" after the first reduction to opposite boundary of CD the NE associated with the reduced state would serve as new Akashic records for the time reversed self. If NMP reduces to the statistical increase of $h_{eff}/h = n$ the consciousness information contents of the Universe increases in statistical sense. In the best possible world of SNMP it would increase steadily.

Does NMP reduce to number theory?

The heretic question that emerged quite recently is whether NMP is actually needed at all! Is NMP a separate principle or could NMP reduced to mere number theory [K73]? Consider first the possibility that NMP is not needed at all as a separate principle.

1. The value of $h_{eff}/h = n$ should increase in the evolution by the phase transitions increasing the dimension of the extension of rationals. $h_{eff}/h = n$ has been identified as the number of sheets of some kind of covering space. The Galois group of extension acts on number theoretic discretizations of the monadic surface and the orbit defines a covering space. Suppose n is the number of sheets of this covering and thus the dimension of the Galois group for the extension of rationals or factor of it.

2. It has been already noticed that the "big" state function reductions giving rise to death and reincarnation of self could correspond to a measurement of $n = h_{eff}$ implied by the measurement of the extension of the rationals defining the adeles. The statistical increase of n follows automatically and implies statistical increase of maximal entanglement negentropy. Entanglement negentropy increases in statistical sense.

   The resulting world would not be the best possible one unlike for a strong form of NMP demanding that negentropy does increaes in "big" state function reductions. n also decrease temporarily and they seem to be needed. In TGD inspired model of bio-catalysis the phase transition reducing the value of n for the magnetic flux tubes connecting reacting bio-molecules allows them to find each other in the molecular soup. This would be crucial for understanding processes like DNA replication and transcription.

3. State function reduction corresponding to the measurement of density matrix could occur to an eigenstate/eigenspace of density matrix only if the corresponding eigenvalue and eigenstate/eigenspace is expressible using numbers in the extension of rationals defining the adele considered. In the generic case these numbers belong to N-dimensional extension of the original extension. This can make the entanglement stable with respect to state the measurements of density matrix.

   A phase transition to an extension of an extension containing these coefficients would be required to make possible reduction. A step in number theoretic evolution would occur. Also an entanglement of measured state pairs with those of measuring system in containing the extension of extension would make possible the reduction. Negentropy could be reduced but higher-D extension would provide potential for more negentropic entanglement and NMP would hold true in the statistical sense.

4. If one has higher-D eigen space of density matrix, p-adic negentropy is largest for the entire subspace and the sum of real and p-adic negentropies vanishes for all of them. For negentropy identified as total p-adic negentropy SNMP would select the entire sub-space and NMP would indeed say something explicit about negentropy.

Or is NMP needed as a separate principle?

Hitherto I have postulated NMP as a separate principle [K73]. Strong form of NMP (SNMP) states that Negentropy does not decrease in "big" state function reductions corresponding to death and re-incarnations of self.

One can however argue that SNMP is not realistic. SNMP would force the Universe to be the best possible one, and this does not seem to be the case. Also ethically responsible free will would be very restricted since self would be forced always to do the best deed that is increase maximally the negentropy serving as information resources of the Universe. Giving up separate NMP altogether would allow to have also "Good" and "Evil".

This forces to consider what I christened weak form of NMP (WNMP). Instead of maximal dimension corresponding to N-dimensional projector self can choose also lower-dimensional sub-spaces and 1-D sub-space corresponds to the vanishing entanglement and negentropy assumed in standard quantum measurement theory. As a matter fact, this can also lead to larger negentropy gain since negentropy depends strongly on what is the large power of p in the dimension of the resulting eigen sub-space of density matrix. This could apply also to the purely number theoretical reduction of NMP.

WNMP suggests how to understand the notions of Good and Evil. Various choices in the state function reduction would correspond to Boolean algebra, which suggests an interpretation in terms of what might be called emotional intelligence [K133]. Also it turns out that one can understand how p-adic length scale hypothesis - actually its generalization - emerges from WNMP [K137].

1. One can start from ordinary quantum entanglement. It corresponds to a superposition of pairs of states. Second state corresponds to the internal state of the self and second state to a state of external world or biological body of self. In negentropic quantum entanglement each is replaced with a pair of sub-spaces of state spaces of self and external world. The dimension of the sub-space depends on which pair is in question. In state function reduction one of these pairs is selected and deed is done. How to make some of these deeds good and some bad? Recall that WNMP allows only the possibility to generate NNE but does not force it. WNMP would be like God allowing the possibility to do good but not forcing good deeds.

   Self can choose any sub-space of the subspace defined by $k \leq N$-dimensional projector and 1-D subspace corresponds to the standard quantum measurement. For $k = 1$ the state function reduction leads to vanishing negentropy, and separation of self and the target of the action. Negentropy does not increase in this action and self is isolated from the target: kind of price for sin.

   For the maximal dimension of this sub-space the negentropy gain is maximal. This deed would be good and by the proposed criterion NE corresponds to conscious experience with positive emotional coloring. Interestingly, there are $2^k - 1$ possible choices, which is almost the dimension of Boolean algebra consisting of k independent bits. The excluded option corresponds to 0-dimensional sub-space - empty set in set theoretic realization of Boolean algebra. This could relate directly to fermionic oscillator operators defining basis of Boolean algebra - here Fock vacuum would be the excluded state. The deed in this sense would be a choice of how loving the attention towards system of external world is.

2. A map of different choices of k-dimensional sub-spaces to k-fermion states is suggestive. The realization of logic in terms of emotions of different degrees of positivity would be mapped to many-fermion states - perhaps zero energy states with vanishing total fermion number. State function reductions to k-dimensional spaces would be mapped to k-fermion states: quantum jumps to quantum states!

The problem brings in mind quantum classical correspondence in quantum measurement theory. The direction of the pointer of the measurement apparatus (in very metaphorical sense) corresponds to the outcome of state function reduction, which is now 1-D subspace. For ordinary measurement the pointer has k positions. Now it must have $2^k - 1$ positions. To the discrete space of k pointer positions one must assign fermionic Clifford algebra of second quantized fermionic oscillator operators. The hierarchy of Planck constants and dark matter suggests the realization. Replace the pointer with its space-time k-sheeted covering and consider zero energy energy states made of pairs of k-fermion states at the sheets of the n-sheeted covering? Dark matter would be therefore necessary for cognition. The role of fermions would be to "mark" the k space-time sheets in the covering.

The cautious conclusion is that NMP as a separate principle is not necessary and follows in statistical sense from the unavoidable increase of $n = h_{eff}/h$ identified as dimension of extension of rationals define the adeles if this extension or at least the dimension of its Galois group is observable.

5.5.3 p-Adic physics as correlate of cognition and imagination

The items in the following list give motivations for the proposal that p-adic physics could serve as a correlate for cognition and imagination.

1. By the total disconnectedness of the p-adic topology, p-adic world decomposes naturally into blobs, objects. This happens also in sensory perception. The pinary digits of p-adic number can be assigned to a p-tree. Parisi proposed in the model of spin glass [B16] that p-adic numbers could relate to the mathematical description of cognition and also Khrennikov [J40] has developed this idea. In TGD framework that idea is taken to space-time level: p-adic space-time sheets represent thought bubbles and they correlate with the real ones since they form cognitive reprentations of the real world. SH allows a concrete realization of this.

2. p-Adic non-determinism due to p-adic pseudo constants suggests interpretation in terms of imagination. Given 2-surfaces could allow completion to p-adic preferred extremal but not to a real one so that pure "non-realizable" imagination is in question.

3. Number theoretic negentropy has interpretation as negentropy characterizing information content of entanglement. The superposition of state pairs could be interpreted as a quantum representation for a rule or abstracted association containing its instances as state pairs. Number theoretical negentropy characterizes the relationship of two systems and should not be confused with thermodynamical entropy, which characterizes the uncertainty about the state of single system.

The original vision was that p-adic non-determinism could serve as a correlate for cognition, imagination, and intention. The recent view is much more cautious. Imagination need not completely reduce to p-adic non-determinism since it has also real physics correlates - maybe as partial realizations of SH as in nerve pulse pattern, which does not propagate down to muscles.

A possible interpretation for the solutions of the p-adic field equations would be as geometric correlates of cognition, imagination, and perhaps even intentionality. Plans, intentions, expectations, dreams, and possibly also cognition as imagination in general could have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is the characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

The most feasible view is that the intersections of p-adic and real space-time surfaces define cognitive representations of real space-time surfaces (PEs, [K16, K11, K13]). One could also say that real space-time surface represents sensory aspects of conscious experience and p-adic space-time surfaces its cognitive aspects. Both real and p-adics rather than real or p-adics.

The identification of p-adic pseudo constants as correlates of imagination at space-time level is indeed a further natural idea.

1. The construction of PEs by SH from the data at 2-surfaces is like boundary value problem with number theoretic discretization of space-time surface as additional data. PE property in

real context implies strong correlations between string world sheets and partonic 2-surfaces by boundary conditions a them. One cannot choose these 2-surfaces completely independently in real context.

2. In p-adic sectors the integration constants are replaced with pseudo-constants depending on finite number of pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces. The fixing of the discretization of space-time surface would allow to fix the p-adic pseudo-constants. Once the number theoretic discretization of space-time surface is fixed, the p-adic pseudo-constants can be fixed. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets, partonic 2-surfaces, and number theoretic discretization but not allowed in real context.

   Could these p-adic PEs correspond to imaginations, which in general are not realizable? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could one identify non-realistic imaginations as the modes of WCW spinor fields for which 2-surfaces are not extendable to real space-time surfaces and are localized to 2-surfaces? Could they allow only a partial continuation to real space-time surface. Could nerve pulse pattern representing imagined motor action and not proceeding to the level of muscles correspond to a partially real PE?

   Could imagination and problem solving be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real PEs? If so, p-adic physics would be there as an independent aspect of existence and this is just the original idea. Imagination could be realized in state function reduction, which always selects only those 2-surfaces, which allow continuation to real space-time surfaces. The distinction between only imaginable and also realizable would be the extendability by using strong form of holography.

3. An interesting question is why elementary particles are characterized by preferred p-adic primes (primes near powers of 2, in particular Mersenne primes). Could the number of realizable imaginations for these primes be especially large?

I have the feeling that this view allows respectable mathematical realization of imagination in terms of adelic quantum physics. It is remarkable that SH derivable from - you can guess, SGCI (the Big E again!), plays an absolutely central role in it.

5.6 Negentropy Maximization Principle and Second Law

This article was inspired by a birthday gift. The gift was a highly inspiring book "Lifespan" by David Sinclair and Matthew LaPlante [I25]. The book tells about the recent understanding concerning aging. The general vision about aging represented in the book can be summarized as follows.

1. The key idea is that genes do not determine everything. DNA has also continuum degrees of freedom characterized by its shape. These degrees of freedom are related to epigenesis which is higher level control activity controlling what genes are expressed. The basic mechanisms are prevention and allowance of gene expression. Acetylization [I2], methylation [I14] and many other modifications affect the gene expression by attaching to proteins known as histones forming kind of pearls in the necklace defined by DNA: genes follow nucleosomes in the DNa strand. Also the reversals of these processes - for instance, deacetylation [I7, I33]and demethylation [I14] are essential for the control of gene expressions.

2. Aging involves the emergence of various diseases. Usually the attention is directed to dealing with these diseases. Now the view is however more general. Aging is seen as a gradual approach to chaos manifesting as various diseases. In order to prevent the diseases one should slow down the approach to chaos.

3. Epigenetic chaos hypothesis suggests that some control systems associated with information molecules and related to the control of DNA transcription and translation by epigenesis must

approach chaos. This is seen as the gradual randomization of DNA conformations causing problems in the transcription of DNA: DNA becomes loopy. The DNA coding for the ribosome acting as the translation machinery of DNA is of special importance and becomes also loopy. What comes first in physicist's mind, is an approach to thermal equilibrium. Is there some system controlling epigenesis which approaches thermal equilibrium with the environment? In standard chemistry it is difficult to identify this kind of system.

4. Biology has invented ingenious mechanisms to slow down aging. For instance, there are molecules having two functions. There are proteins making the translation of the genes related to cell replication possible.

   When the DNA coding for the ribosome gets loopy their function changes. The translation of genes ceases as the proteins leave the histone molecules and enter the damaged DNA and freeze it so that it can be prepared. This however slows down cell replication and also causes other problems leading to various diseases related to aging. One can say that a cell is like a hospitalized patient.

   The slowing down of aging would be in this framework basically fighting against the thermo-dynamical arrow of time. Is it really possible to understand the processes involved in the framework of standard bio-chemistry with a single arrow of time?

   Even the understanding of the biocatalysis is difficult: how the reacting molecules are able to find each other in the molecular soup and how the huge increase for the rate of these processes is possible. The TGD based solution of these problems will be discussed later.

What could TGD inspired theory of consciousness and quantum biology rely on zero energy ontology (ZEO) inspired biology allow to say about the mechanism behind aging?

1. Negentropy Maximization Principle (NMP) as the variational principle of consciousness replaces the second law and implies it for ordinary matter. State function reduction (SFR) means a reduction of the entanglement for a pair $S_a - S_b$ of sub-system S_a and its complement S_b in S. Measurement cascade proceeding from long to short scales decomposes at each step a system to a pair of unentangled subsystems is in question. NMP as a variational principle of consciousness states that negentropy gain in these reductions is maximized and selects the pair $S_a - S_b$ at given step.

   In adelic physics [L70, L69] the negentropy $N = -S_1 - S_2$ is sum of real and various p-adic negentropies but p-adic negentropy can be positive so that for non-trivial extensions of rationals one can have $N > 0$. This kind of entanglement is stable against NMP so that the process stops. One can assign positively colored emotions to this kind of entanglement and it distinguishes between living and inanimate matter and also between dark and ordinary matter.

2. TGD inspired theory of consciousness is basically an extension of quantum measurement theory allowing to get rid of the basic paradox of quantum measurement theory. There are two kinds of state function reductions (SFRs) "big" SFR and "small" SFR (briefly BSFR and SSFR) [L108].

   SSFRs are counterparts of "weak" measurements which are much like classical measurements and do not involve any dramatic changes. The sequence of SSFRs gives rise to a conscious entity -self - as a sequence of moments of consciousness. Subjective time as a sequence of SSFRs correlates with the geometric time. BSFRs are counterparts of ordinary quantum measurements and have a dramatic effect: in a very general sense one can say that self dies and reincarnates with an opposite arrow of geometric time.

3. There is a hierarchy of magnetic bodies carrying dark matter as phases of ordinary matter with effective value $h_{eff} = nh_0$ of Planck constant. n corresponds to the dimension of an extension of rationals. The extensions define evolutionary hierarchies with increasing complexity. n serves as a measure of algebraic complexity and as a universal IQ, and also characterizes the scale of quantum coherence. For instance, genes are characterized by the value of h_{eff} associated with their MB.

Since MBs have higher universal IQ than ordinary biomatter, they control the biochemistry. In particular, they would control DNA and DNAs MB would actually realize genetic codons in terms of dark proton triplets. Also dark photon triplets would provide this kind of realization crucial for control of and communication with ordinary biomatter.

4. ZEO implies a theory of self-organization [L104] and of self-organized quantum criticality (SOQC) relying on time reversal [L194]. The dissipation of a system looks like in reversed time direction extraction of energy from the environment. Also SOQC becomes possible since criticality, since a state, which is a repeller, becomes an attractor in reversed time direction. The system seems to tend to criticality for an observer with an opposite arrow of time.

5. In this framework the aging could be seen as the approach of the system formed by MBs of the information molecules and of ordinary biomatter to a thermal equilibrium. The temperature of MB gradually grows and eventually reaches a maximal temperature (due to the stringy character of flux loops) known as Hagedorn temperature and identifiable as the physiological temperature. System dies.

5.7 Very brief summary about some aspects of aging?

The book of Sinclair and LaPlante [I25] is about aging and how to slow down it. The basic hypothesis is that aging need not mean getting sicker and sicker all the time. Biology has developed molecular tools for slowing down aging and there are longevity genes analogs to SPs taking care of this. It might be possible to help them by a healthy lifestyle.

The books represents a vision involving the following pieces.

1. Aging is information loss and molecular level, in particular DNA level. Ribosomal DNA seems to be in a special role assignable to nucleolus. Physicist could try to understand this from the second law: entropy un-avoidably increases . Entropy increases for isolated system but it is perhaps not so simple.

2. It has been learned that damage to DNA alone cannot explain aging. There must be additional degrees of freedom assignable to epigenesis as a control of genome. Besides genetic code there should exist additional continuous information carrying degrees of freedom.

   Epigenesis involves these degrees of freedom and DNAs conformation (involving coilings of coilings of ..) represents these degrees of freedom. Histones appear tangles along the DNA double strand selecting which genes are expressed. Acetyl tag in the histome allows gene expression to take place. When acetyl is absent, nothing happens. The effect of acetyl tag can be also silenced.

3. There are enzymes Sirn, $n = 1, 2, ..7$, called sirtuins [I19, I47] (`https://cutt.ly/Hjkh0ia`). In particular, Sir2 silences so-called mating type genes so that the cell replicates normally. If Sir2 is not present in mating type genes, they are expressed and replication does not take place normally. I understood that for yeast, the cell loses its sexual identity and does not replicate.

   During this non-replication period the cell would concentrate on maintenance. Under stress situations this would occur quite generally and make survival possible. If you cannot eat and replicate, sleep, and generate metabolic energy from thermal energy for instance. Also SPs would be at work. On the basis of [L194], one could guess that a kind of hibernation state with a reversed arrow of time could be in question. To live longer it is good to die sufficiently often!

4. This is not the only function of Sir2. When DNA double strand is broken, Sir2 must leave its job and hurry to the broken DNA and catalyze expression of SIRn coding for histone deacetylase HDAC, which removes acetyl tags from histones and deactivates DNA. After this the broken DNA is prepared. This is like putting a victim of a traffic accident to a hospital bed or even artificial coma.

As cells get older, this kind of DNA breaks occur more often and Sir2 must leave its basic job more often and the cell loses its ability to replicate more often. It can also happen that Sir2 does not find its original position in the mating gene and starts to silence a wrong gene. This leads to epigenetic noise inducing aging.

5. In particular, ribosomal DNA in the nucleolus, the largest structure of the nucleus, can end up with chaos. Loops are formed and recombination between portions of the same strand can occur (remember the reconnection mechanism and time reversal). Ribosome plays a fundamental role in translation so that there is no wonder that difficulties emerge. Important class of damage consists of breaking DNA double strands. This leads to a chaotic conformation involving loops. Sir2 must rush to the nucleolus and this means that mating genes activate and the replication stops. When these accidents occur too often, the cell becomes senescent.

The first cognitive measurement leads to a product decomposition in $F(G/(G_2...G_n)) \times F(G_2..G_n)$ if the entanglement coefficients between $G_1 = G/(G_2...G_n)$ and $F(G_2..G_n)$ are in the extension of rationals considered. Same can happen at the next step and leads to a similar decomposition of $F(G_2, ...G_n)$. The maximal cognitive measurement cascade leads to a product of wave functions in $F(G_i)$ but it can happen that there is no measurement cascade at all.

Suppose that the time evolution following SSFR for individual mutually unentangled subsystems is in good approximation unitary (their interactions with other such subsystems can be neglected) so that they do not entangle, the density matrix of an individual system suffers a unitary automorphism so that entanglement entropies remain unaffected and the negentropy gain vanishes. One could speak of "asymptotic freedom" as a condition for the cognitive fixed point.

The cognitive fixed point would define the "silent wisdom" of the re-incarnate having the formerly active boundary of CD as a passive boundary of CD. What would be learned during life would help during the next life cycle.

5.8 Negentropy Maximization Principle (NMP) and Second Law

The natural expectation is that second law relates to aging. This motivates a section devoted to the recent view about Negentropy Maximization Principle (NMP) [K73] defining the variational principle of consciousness in the TGD framework and implying in adelic physics [L69, L70] second law in the case of non-negentropic entanglement (in standard physics entanglement is always non-negentropic).

Mathematically NMP is analogous to the second law in that it is not deterministic like the variational principles of classical physics. For a given entangled system NMP allows state function reduction (SFR) for that sub-system-complement pair for which the negentropy gain is maximal. The state function reduction can occur to any eigenstate of the density matrix of the selected subsystem in accordance with standard quantum measurement theory. This would lead to a product of pure states and the negative entanglement negentropy of the initial state would become vanishing in the final state so that negentropy would increase. The inclusion of p-adic contribution to negentropy identifiable in terms of cognitive information assignable to entanglement changes the situation and the entanglement can be stable against NMP and state function reduction cascade stops to entangled state representing cognitive fixed point. Since negentropy gain is not anymore popssible in SSFRs, death is bound to take place.

5.8.1 General observations about second law

First some general observations about second law.

1. Second law is an empirical fact. Second law forces the increase of entropy in statistical sense. Thermo-dynamical equilibrium is the most probable equilibrium. Second law in the standard form assumes a fixed arrow of time. Zero energy ontologuy (ZEO) forces to give up this assumption and allow both arrows of time.

2. Quantum physics is certainly behind second law. If you have an entangled system state, SFRs occur for subsystems with reduction probabilities determined by its entanglement with the environment. This eventually leads to a loss of entanglement and quantum coherence and one must apply statistical using density matrix for individual sub-system and eventually justifies thermo-dynamical description. It is important to notice that in SFR the entanglement entropy of an individual system is reduced in SFR but that in the case of ensemble of identical systems this generates entanglement entropy identical to the entanglement entropy of single particle giving thermo-dynamical entropy as a special case.

   One can consider two interpretations: a) the generation of entanglement generates single particle entropy although actually the entropy of the entire system does not increase in unitary evolution or b) the transformation of this entropy to ensemble entropy corresponds to second law. Option b) looks more realistic.

This is however only a description for what happens. One can ask what is behind second law. Is there some deeper principle as one might suspect because quantum measurement is so poorly defined theory. For instance, von Neumann proposed that only humans cause SFRs. It is often assumed that decoherence occurs without making any proposal how this happens. What is known and well-tested is that reduction probabilities for a measurement reducing the entanglement are coded by the measured density matrix, and one can say that the system goes to an eigenstate of the density matrix as the entanglement is reduced. For an ensemble of identical particles this process transforms entanglement entropy to ensemble entropy with the same value.

Negentropy Maximization Principle (NMP) is the TGD based proposal for the variational principle behind SFRs.

5.8.2 The new physics elements involved with NMP

NMP involves several new physics elements.

1. What is new is the hierarchy of systems having the hierarchy of space-time sheets as a geometric correlate. At the level of consciousness theory it would have self hierarchy as a correlate. Quantum measurements are assumed to correspond to SFR cascades proceeding from higher to lower levels of the hierarchy.

2. ZEO brings in the notions of "small" SFR (SSFR) as counterpart of "weak" measurement and "big" SFR (BSFR) as counterpart of ordinary quantum measurement [L108] and forces giving up the assumption about a fixed arrow of time. This modifies standard thermodynamics and leads to a new view about self-organization self-organized quantum criticality [L104, L194].

3. In the standard physics framework there is no definition of negentropy as a measure of conscious information. Negentropy can be only defined as the negative of ordinary entropy and is therefore non-positive. The best that one could have would be vanishing negentropy. This failure is understandable since standard physics does not even try to describe cognition. One manner to solve the problem is to claim that only entropy gradients, whose sign can be also negative matter and thus consider only information flows. In TGD different view is adopted.

4. To bring in conscious information one must introduce cognition. In the TGD framework it is assumed to be described by adelic physics [L70, L69]. This brings in p-adic space-time surfaces as correlates of cognition. Real space-time surfaces are replaced with their adelic counterparts forming a kind of Cartesian product of real and various p-adic space-time surfaces obeying the same algebraic equations.

   By $M^8 - H$ duality [L127, L128] one can regard space-time surfaces as surfaces in M^8 or in $H = M^4 \times CP_2$. M^8 is a subspace of the space of complexified octonions O_c and space-time surface is determined as a 4-D "root" of a real polynomial algebraically continued to an octonionic polynomial. If the coefficients of the polynomial are rational numbers, the polynomial makes sense for both real and p-adic number fields implying number theoretical universality. The dynamical principle is simple: the normal space of the space-time surface is associative/quaternionic.

$M^8 - H$-duality maps these 4-surfaces to 4-surfaces in H. In both cases one has minimal surfaces. Also the notion of cognitive representation emerges and is essential for the number theoretical universality. It is also crucial for the construction of the scattering amplitudes [L135, L127, L128].

5.8.3 Detailed formulation of NMP

Consider now the formulation of NMP [K73] in this conceptual framework.

1. In adelic physics cognition is described in terms of p-adic degrees of freedom. Entropy is a sum of two terms: $S = S_1 + S_2$.

   S_1 is the ordinary entropy describing the amount of ignorance of the observer about the state of either entangled system - say Schrödinger cat and the bottle of poison.

   S_2, as the p-adic variant of entropy (also real valued) assignable to cognitive information has an analogous formula and similar defining properties but can be *negative*(!) and is interpreted as a measure for the information carried by entanglement.

   Thr possibility of having negative sign is basically due to the fact that the logarithms $log(p_k)$ of probabilities p_k in the Shannon formula $S = -\sum_k p_k log(p_k)$ for entropy are replaced by the logarithms of their p-adic norms $|p_k|_p$ given by p^{-n} for $p_k = p^n(a_0 + a_1 p + ...)$ (note that the exponent changes sign!): $log(p_k) \to log(|p_k|_p)$. Entropy remains additive since the p-adic norm of product is product of p-adic norms.

   A more general formula for the real Shannon entropy S_1 is as $S_1 = -Tr(\rho log(\rho))$ (ρ is the density matrix). Even in the case that the matrix elements of ρ are in the extension of rationals used, this formula need not generalize for S_2 since also $log(\rho)$ should have this property. The manner to avoid the problem is to diagonalize ρ. This is possible if the eigenvalues of ρ - having an interpretation as entanglement probabilities p_k (equivalently reduction probabilities) - belong to the extension of rationals considered.

   At the fundamental level this extension is defined by the space-time surface determined by a polynomial with rational coefficients ($M^8 - H$ duality [L127, L128]): the roots of the polynomial determine the extension and space-time surface (number theoretic holography). If the entanglement probabilities are not in the extension, one might argue that the entanglement is stable - note however that NMP alone could make it stable.

   Quantum coherence involves stable entanglement carrying cognitive information measured by S_2. The destruction of coherence if allow by NMP destroys information defined as the sum $N = -S = -S_1 - S_2$. In absence of cognition one would have $N = -S_1$ and NMP would transform to second law.

2. The cascade of "small" state function reductions (SSFRs) eventually leads to a state in which the remaining entanglement is stable. There is no subsystem-complement pair for which SSFR could take place in such a way that negentropy $N = -S = -S_1 - S_2$ would increase. The resulting states are analogous to bound states.

3. Remarkably, in its adelic formulation NMP states that the total entropy, which tends to be negative for extensions of rationals, gets smaller and negative: information is generated! The pessimistic second law transforms to an optimistic NMP! The gloomy character of second law would be due to the neglect of cognition from physics.

   Cognitive entropy gets more and more negative but real entropy which is closely related to it but tending to have a smaller magnitude than p-adic entropy for extensions of rationals also increases [K73] [L108]. Hence their sum tends to increase with the dimension $n = h_{eff}/h_0$ of the extension.

What makes entanglement stable against SSFR? One can consider two mechanisms.

1. Adelic physics allows negentropic entanglement, which tends to be stable against SSFRs since it can only become even more negentropic.

2. One can also consider another stabilization mechanism. The rule would state that if the density matrix of the subsystem-complement pair does not allow eigenvalues in the extension of rationals considered, the reduction is not possible. For a stable entanglement density matrix would not allow eigenvalues in the extension of rationals considered. One can of course criticize this rule as somewhat *ad hoc* and the first option might be enough. One can also ask whether this mechanism is equivalent with the first mechanism.

3. What could be the interpretation of the negentropic entanglement? I have assigned positive emotions like love to this entanglement, also experience of understanding, etc...

One can raise an objection against entanglement coefficients in an extension of rationals, call it E.

1. Entanglement coefficients would be in E characterizing the polynomial determining space-time surface in M^8 and by $M^8 - H$-duality this would be the case also in $H = M^4 \times CP_2$. The problem is that this does not seem to allow smooth time evolution of entanglement coefficients.

2. At the level of M^8 the construction of scattering amplitudes relies on discretization - cognitive representation [L127, L128]. M^8 is analogous to momentum space and dynamics is purely algebraic at the level of M^8. The algebraic view about solutions of Dirac equation is analogous to momentum space view about ordinary Dirac equation: the spinor mode is localized to a point of momentum space. Many-fermion state corresponds naturally to a cognitive representation. This allows getting rid of the problems since no such evolutions exist at M^8 level.

3. What about the situation at the level of $H = M^4 \times CP_2$? Should one only assume that entanglement coefficients for many-fermion state are transformable to a number theoretic entanglement by a unitary matrix leaving the eigenvalues of the density matrix representing entanglement invariant? Since the induced spinors in H satisfy partial differential equations, this seems to be a reasonable option.

   Algebraic entanglement coefficients are needed only at the level of the scattering amplitudes. $M^8 - H$ duality allows to map cognitive representation in M^8 to H. This also applies to entanglement coefficients so that they would be in an extension of rationals at the points of cognitive representation containing point-like fermions at both sides.

NMP implies increase of ordinary entanglement entropy

NMP implies increase of the ordinary entanglement entropy. The hasty conclusion would be that this implies also increase of thermal entropy and thus second law. Here one must be however cautious.

1. Second law as an increase of ordinary entropy would still hold true but the increase of cognitive information would be larger than the increase of the real entropy for non-trivial extensions of rationals (this is always the case).

   The asymptotic states with maximum negentropy and with stable entanglement would have maximal real and minimal p-adic entanglement entropy and their sum would be negative - and $N = -S$ would therefore serve as a measure for the amount of conscious information.

2. One might argue that intelligent systems tend to pollute their environment: they are entanglement entropy generators and by witnessing what has been happening to our environment, it would be easy to agree.

   One must be however extremely cautious with formulas. The stability of negentropic entanglement means that the real entanglement entropy cannot transform to ensemble entropy and cannot therefore actualize! Is this what distinguishes loving attention as something unique and positive: the entanglement is stable and cannot transform to ordinary entropy?

Could NMP allow the failure of second law in some situations?

The dream about eternal youth seems to be in conflict with the second law. For physicist second law is usually the absolute authority. Working with the details of NMP however force to challenge this view.

A generalization of second law taking into account time reversals is required in ZEO and already this implies apparent breakings of second law. Furthermore, NMP implies second law as the increase of entanglement entropy. NMP does not allow SFRs transforming negentropic entanglement entropy to thermodynamic ensemble entropy unless the SFRs occurs at higher level of hierachy so that the local reduction of negentropy is compensated by its increase in a longer scale. The implications of this fact remain to be understood.

Could NMP break the second law? Can this be consistent with empirical facts? Could the breaking of second law occur at the level of dark matter only? Second law would apply only to the entropy transformable to thermal entropy. The sum $N = -S_1 - S_2$ is what matters: for a trivial extension one has $N = 0$ so that this transformation is possible. $N = 0$ can be however true also for non-trivial extensions. Could the total entanglement negentropy assignable to the ordinary matter satisfy $N = 0$ and be therefore transformable to thermal entropy whereas "dark" entanglement negentropy satisfying $N > 0$ would not allow this. Could one identify dark/living matter as negentropic matter and ordinary/inanimate matter as non-negentropic thermalizable matter? Note that also the phases with $h_{eff}/h_0 = n$ could in principle have $N = 0$. The stability of dark entanglement could directly relate to the failure to observe dark matter.

Comparison with the proposal of Jeremy England

Jeremy England [I59] has noticed that living systems increase entropy and has proposed it as a basic principle of biology. England's proposal is discussed from TGD point of view in [**?**]. I did not however realize in this article the fact, that negentropic entanglement entropy need not allow a transformation to thermal entropy.

One can represent several objections against England's idea.

1. Second law cannot force or even allow the generation of life. Second law relates to the occurrence of SFRs but we do not have a real theory of quantum measurement.

2. Second law assumes preferred arrow of time and there is a lot of support for its violation in living matter as realized first by Fantappie [J121]: in particular, self-organization processes could involve dissipation with reversed arrow of time.

3. To understand life one must take it seriously. Living system is somehow different from inanimate matter. The emergence of life means the generation of conscious information but in the framework of standard physics there is no definition of conscious information.

These objections raise several questions. Why the emergence of life would be accompanied by a generation of entropy? What could serve as a measure for conscious information? How to describe cognition? To these questions adelic physics provides a possible answer. If entropy that England talks about is identified as the entropy produced in SFRs of systems having $N = 0$, TGD view is consistent with the proposal of England.

Cognitive fixed point instead of thermal equilibrium?

The analogy with the second law strongly suggests that the system approaches a cognitive fixed point (negentropy maximum) during the sequence of SSFRs followed by the analog of unitary time evolution. SSFRs cannot generate negentropy anymore. Since the system does not learn anymore, BSFR is bound to occur. A possible number theoretic formulation for the fixed point could be following.

1. The time evolution following SSFR generates entanglement. This entanglement is maximally reduced in measurements of observables, which correspond to operators, whose action does not affect the states at the passive boundary.

2. Cognitive measurements define an important class of such measurements [L134]. The cognitive quantum states correspond to wave functions in the Galois group G of the extension - that is elements of the group algebra $F(G)$ of G. G can be decomposed to a product $G = \prod G_i$ of subgroups defined by the hierarchy of normal subgroups of G defined by the representation of the extension as an extension of an extension of ... of rationals.

   Elements of $F(G)$ decompose to superpositions of products of functions in G_i and the factors are entangled. Note that the order of G_i matters and is induced by the inclusion hierarchy for the extensions considered: the largest extension is at the top of the hierarchy. One has "ordered" entanglement. This is analogous to the directedness of attention which is difficult to understand in the standard physics framework.

   Eastern philosophies speak also of states of consciousness in which there is no distinction between observer and observed and not division. Could this kind of attention involve negentropic entanglement between systems, which correspond to the same extension of rationals so that the. attention cannot be directed? Or could it correspond to negentropic cognitive entanglement allowing cognitive SSFRs?

5.9 TGD based model for aging

In this section the TGD based view about aging is discussed. The king idea is that the magnetic bodies (MBs) of information molecules and linear molecules formed from them (DNA,RNA, amino-acids,tRNA) are at very low temperature in the beginning. The temperature of MB starts to raise and approach the physiological temperature. The entropy of MB increases. Since the MB of the molecule controls the molecule, the control by MB starts to fail and this leads to the diseases accompanying aging.

5.9.1 Aging as approach of MB and BB to thermal equilibrium

Ordinary entropy increases for an isolated system, it approaches thermal equilibrium - thermalizes. Aging must correspond to thermalization in some sense. There are two views about this.

1. The weak form of the proposal making sense in the standard physics context would identify aging as thermalization. For ordinary biomatter, which already is in thermal equilibrium in good approximation, this idea does not lead to anything interesting.

2. Ordinary matter and the dark matter at MBs carrying dark matter as phases of ordinary matter with $h_{eff} = nh_0$ have widely different temperatures at the moment of birth. Aging means that these systems approach thermal equilibrium in the sense that temperatures become identical . MB has infinite number of degrees of freedom and therefore maximal temperature known as Hagedorn temperature identifiable naturally as physiological temperature [L194]. This option will be considered in the sequel.

   Consider the situation in TGD.

1. What are the continuous degrees of freedom whose entropy growth would lead to aging. In the TGD framework they would be naturally the geometric degrees of freedom associated with the flux tubes of dark DNA controlling ordinary DNA. Their number is infinite implying that temperature is below Hagedorn temperature around physiological temperature. One can assign a temperature to the flux tubes and also to these degrees of freedom and this is below Hagedorn temperature. When temperature at flux tubes increases, the geometric shape starts to thermally fluctuate and the overall size increases. Cells indeed increase in aging as do also we!

2. For information molecules the temperature of MB must be very low: dark DNA flux tubes have a very precise shape and therefore also ordinary DNA. For SPs the situation is different and this makes possible their basic functions.

3. Aging could simply mean that the dark genome approaches thermal equilibrium with ordinary biomatter at physiological (Hagedorn) temperature and entropy of dark genes and magnetic flux tubes increases. Flux tubes get more and more irregular shaped and induce a development of loops for ordinary DNA and breaks DNA double strand. Nucleosomes are loop like structures associated with histones and also these are known to be lost. Epigenetic chaos is induced. When thermal equilibrium is achieved death as heat death occurs and changes the arrow of time at the level of the entire body which is left in the geometric past of the standard observer to continue life with an opposite arrow of time.

4. There is a connection to the article [L192] about DNA and arrow of time. One can argue as follows. As the electric field along DNA double strand decreases by the shortening of the sticky ends, the string tension as density of electric energy per length decreases, the stiffness of DNA decreases, and the fluctuations start to develop. Second possibility is that the shortening of telomeres and sticky ends is a controlled process causing a programmed aging.

5. There are molecules devoted to preparation of the damaged DNA. The epigenetic tags on histones of mating genes could control the arrow of time for the gene involved. If the tag is present, the gene is expressed. If not or if inhibited by say Ser2, the arrow of time is reversed.

Objections related to metabolism

Metabolic energy feed is needed to keep the distribution of h_{eff}:s and even increase the values of h_{eff} - defining universal IQ and characterizing quantum coherence scale. This relates to the second important aspect of life: quantum coherence in long length scales is needed to generate the coherent behavior of ordinary biomatter and is not possible in standard bio.chemistry framework. aging would be a gradual reduction of this quantum coherence by thermalization of MBs of the basic information molecules, in particular the dark variants of the basic biomolecules. If you want to live long, take care of your personal quantum coherence!

One can develop some objections against the vision about aging as thermalization of the MBs of information molecules.

1. Aging is viewed as changes of the body after birth. What about the processes before birth? When sperm and gametes inoculate and divide and divide and form some distinguished organs, this process needs a high amount of energy; that is why mothers get to eat more during pregnancy.

   Fetus generates new structures - parts of MBs containing dark matter as $h_{eff} = n \times h_0$ phases of ordinary matter with increasing value of h_{eff}. This requires high metabolic energy feed provided by mother. Information molecules are however still very far from thermal equilibrium and the gradual increase of the temperature of MBs has practically no effects. The situation remains the same also at the young age. At later age MBs approach thermal equilibrium and problems with the bio-control by MB emerge.

2. Reactive Oxygen Species (ROS) cause also damage for DNA: the more ROS, the shorter the life of the cell. That is why food with low calories content or fastings or low carbohydrates (which need less oxygen to burn) diets are good for longevity.

   ROS have been also seen as a cause of aging and one could argue that they should cause a lot of damage during the fetus period involving intense metabolism. The repair mechanisms of MB work almost optimally for fetus and at young age and allow handling of the problems due to ROS. The authors of [I25] argue that it is now known that ROS are not the basic reason for aging. As a matter of fact, ROS are essential for the demethylation [I9].

Is apoptosis as programmed cell death consistent witht he proposal?

Also programmed cell death - apoptosis - could be treated as an objection against aging as approach to thermal equilibrium. Apoptosis as a programmed cell death cannot be purely thermal event. It could be induced by MB at the higher level of hierarchy as BSFRs. Perhaps

by MB of cell group as in the development of fingers from the cell mass. Apoptosis could have several motivations.

1. The basic prediction is that giving systems are intentional systems having free will at all levels. MB at the higher level could act like dictator and destroy quantum coherence locally leading to the death of the cells but generating quantum coherence and generation of structures in longer scales which would also take the metabolic energy resources used by the dead cells.

   Negentropy Maximization Principle (NMP) would be the deeper principle behind the second law. Apoptosis would be consistent with the NMP which implies second law as a by-product and as its name tells, implies negentropy increase. Therefore thermalization would not the only cause of cell death.

   Apoptosis would indeed generate more complex structures when fingers develop from tissue. Destruction of lower level structure would be the price paid for the generation of a higher level structure and negentropy gain in longer scales.

2. Evolution means steps in which h_{eff} increases in BSFRs and longer scales of quantum coherence at the level of MB emerge. Extinction of cells and sauri would be part of evolution.

A controlled BSFR causing the analog of death/hibernation of a subsystem could be also represented as an objection. The BSFR would have the survival of a larger system as a motivation [L194]. In fact, all motor actions can be seen as BSFRs at some lower level so that life is continual dying! Death/hibernation of a subsystem means savings of metabolic energy and can be seen as one manner to fight against second law since the dead subsystem lives with the opposite arrow of time: living system is basically 4-D entity in ZEO - not just the time slice which corresponds to conscious experience!

Is the biochemical approach trying to describe dissipation as a controlled process?

A general comment related to the distinction of the standard approach and the TGD approach relying on ZEO is in order. Standard approach does its best to identify control mechanisms leading from state A to state B. Huge amount of information exists about reaction pathways and one can only admire these data mountains.

This approach is very natural as long as time reversal is not involved. If this is the case, there are processes, basically healing and repair processes, that occur in a reversed time direction as dissipative processes and each BSFR leading to a time reversed state involves its own reaction pathways. The tragedy would be that the standard approach tries desperately to understand loss of order as a controlled process inventing endlessly reaction pathways!

Of course, this work would not be useless. The problem is however that a deeper understanding is missing and prevents seeing how incredibly simple the picture is at the fundamental level.

1. The increase of entropy in reverse time direction apparently breaks second law in the standard time direction. Stress proteins (SPs) discussed in [L194] are involved with this battle. The magnetic bodies of SPs can extract heat energy from the environment in heat shock and heat DNA and proteins in cold shock, and also act as heat engines for molecular motors.

2. As also the authors of [I25] emphasize: diseases are a consequence of a loss of information. Disorder increases as quantum coherence is lost, and manifests as numerous diseases. Quite concretely, the h_{eff} distribution flattens in the sequence of SSFRs. System gets less intelligent and is unable to cope with the hard reality! Second law would eventually win although this process can be slowed down by BSFRs of subsystems.

3. Things can go wrong in very many ways: as Tolstoy said, families can be unhappy in myriads of different ways but there are very few ways to be a happy family! Therefore the disease centered thinking of medicine is perhaps not the best approach. One should do something which helps to prevent all diseases simultaneously. One can avoid diseases by choosing a healthy lifestyle. Also a medicine relying on the idea that BSFRs for subsystems could

help. BSFR could be seen also as falling sleep and resting and gathering metabolic energy - even from thermal energy.

4. Time reversed dissipative evolution looks like healing in the reversed arrow of time. If this is the case, the tragedy of biology would be the attempt to understand time reversed dissipation in terms of complex control actions based on complex reaction pathways or even as some kind of computer programs.

5. MB would be in a key role since most diseases would be problems in the control performed by MB and basically due to the reduction of h_{eff} and therefore of information contents. About detailed criteria for when one has a disease this approach cannot say much.

Loss of the control of housekeeping genes causes vicious circle leading to death

The basic problem from the point of view of longevity would be that during aging MB gradually loses control of not only methylation, acetylation and their reversals but also other modification processes.

A possible explanation for hypermethylation is that the control actions inducing demethylation fail. The observed hypomethylation in the complement of CpG islands could be due the failure of methylation so that the state becomes stable. More generally, this suggests that the loss of control of all modifications is the mechanism leading to the situation in which the modifications cannot be changed. For instance, the differential methylation of hippocampus is known to be relevant for memory recall, which could relate to the emergence of memory problems at the old age.

CpG:s which are hypermethylated appear in the promoter regions of almost all housekeeper genes so that housekeeping [I12] (`https://cutt.ly/2jQgOSD`), in particular transcription and translation machineries, metabolism, functioning of stress proteins, etc.... becomes difficult.

The enzymes responsible for the methylation and demethylation are especially important for housekeeping genes [I12] whose promoter regions contain CpG islands. Metabolism related enzymes like Cytochrome P450 are involved also with demethylation as enzymes. Methylation of the promoter region of housekeeping genes means also methylation of genes coding for demethylase. This vicious circle - not so positive positive feedback - leads to death.

What causes the loss of the control of these modifications? The mechanisms leading to the loss of control would relate to modifications of the chromatin and DNA organization. These include reduced global heterochromatin, nucleosome remodeling and loss, changes in histone marks, global DNA hypomethylation with CpG island hypermethylation, and the relocalization of chromatin modifying factors [I55, I22, I35]. In the TGD framework these changes would be caused by the thermalization of the MBs of DNA and chromosomes.

Also cancer induces these changes about which the appearance of additional chromosomes in the mitochondrial DNA in cancer is an example. It has been found that a very weak oscillating magnetic field with strength in nanotesla range and with oscillation frequency around 60 Hz (Schumann frequency) leads to the disappearance of additional chromosomes [I72]. The loss of quantum coherence is the general explanation but it is not clear whether this can be due to thermalization at the level of DNA in this case. A possible explanation is that the control by MB at a higher level of hierarchy is lost and the presence of magnetic field re-establishes a connection with this MB in turn re-establishing quantum coherence [L81].

MB controls the conformations of DNA and chromosomes. MB is identifiable as a flux tube network and its control relies on its motor actions involving reconnections and shortenings of the flux tubes by a temporary reduction of h_{eff}. These motor actions of MB would become fuzzy by the thermal motion. The precise motor performance of MB is crucial for the realization of modifications occurring at the promoter regions near histones and at histone tails. Therefore the thermalization of the flux tube degrees of freedom of MB could be the basic reason for the problems.

When does death occur?

Aging could simply mean that the dark genome approaches thermal equilibrium with ordinary biomatter at physiological (Hagedorn) temperature [L194] and entropy of dark genes and magnetic

flux tubes increases. Flux tubes get more and more irregular shaped and induce a development of loops for ordinary DNA and breaks DNA double strand. Epigenetic chaos is induced. When thermal equilibrium is achieved death as an analog of heat death occurs and changes the arrow of time at the level of the entire body which is left in the geometric past of the standard observer to continue life with an opposite arrow of time.

BSFR means death and death is bound to occur. But when? TGD proposes a general criterion: at a given step either SSFR or BSFR occurs and the SFR that means maximum negentropy gain takes place. This SFR is not unique. It can be either SSFR or BSFR and in both cases there are a lot of options for the final state.

When would BSFR win in the comparison?

1. Total entropy can be defined as the sum of p-adic and real Shannon entropies. p-Adic Shannon entropies involving p-adic norms $N_p(p_k)$ of probabilities p_k in the logarithmic factors $log(N_p(p_k))$ can be negative. In this case they characterize the information (associated with cognition) assignable to the entanglement.

2. Real entropy characterizes the lack of information about the state of either entangled system and is associated with sensory input (is the cat dead or alive?). The sum of the real and p-adic entropies can be negative for non-trivial extensions of rationals so that one would have genuine cognitive information. One could also speak of mere cognitive information as the p-adic contribution to the entropy and this can be negative.

3. Intuitively it seems obvious that thermalization meaning that the temperature difference between MBs and systems such as genes is reduced, means loss of information defined in this manner. Information molecules cease to be information molecules at least in the geometric degrees of freedom.

4. BSFR becomes the winner if SSFRs can give only very small negentropy gain or if the negentropy gain becomes negative. The fact that we do not learn much anymore at the old age, could reflect the reduction of the negentropy gain in SSFRs.

Also the distribution of $h_{eff} = n \times h_0$ values could reduce IQ. As found in [L134], a complete cognitive measurement inducing maximal reduction of entanglement for an extension with dimension n would reduces the state to a product state with state space with dimensions n. which are factors of n and thus smaller than n: instead of single MB with high IQ several with lower IQs. It might happen that the next SSFRs are not anymore able to regenerate larger values of n and the system becomes less intelligent.

An objection against this picture is that there are also situations when resurrection seems to occur: this has happened for people having had near-death experiences. One can also slow down the process of aging by a appropriate diet.

1. The slowing down of the aging process is possible by the reversal of the arrow of time at lower levels so that time reversed dissipative processes at these levels look like self-organization and generate order from the point of view of the organism. This would be a general. mechanism used by living matter to slow down the approach of MB to thermal equilibrium with MB.

2. This does not however explain resurrection. The opposite BSFR can however occur at the level of the entire organism but with a suitable stimulation like resuscitation opposite BSFR can take place. Taking into account the fact that also the organism is only one level in the hierarchy of conscious entities, this reduces to the first option.

   The analog of resuscitation occurs at the atomic level in the experiments of Minev *et al* [L99]. Although the deterministic process apparently leading to the final state of BSFR had already occurred, it could be stopped by a suitable stimulus. In TGD framework the interpretation is that the BSFR had already occurred and the time reversed time evolution apparently leading to the final was observed. A suitable stimulation however induced the opposite BSFR so that the process apparently stopped [L99].

DNA and the arrow of time

There is a connection with the article about DNA and arrow of time by Rastmanesh and Pitkänen [L193]. The proposal is as follows. As the electric field along DNA double strand (with dark DNA strands included) decreases by the shortening of the sticky ends, the string tension as density of electric energy per unit length decreases, the stiffness of DNA is reduced, and thermal fluctuations start to develop.

Biologist might wonder how various biological and homeostatic maneuvers like weakening of acetylation/phosphorylation/methylation eventually translate to a decrease of the electric field strength along DNA! In the TGD framework one can see the situation in a different manner: chemistry is not the boss now but is controlled by MB.

1. Modifications (or rather, the loss of the control of modifications) are not the primary cause of the weakening of the electric field. What happens at the control level, at MB, is the primary cause. The weakening of the electric field along DNA would correlate with the shortening of the sticky ends carrying electric charges creating the longitudinal electric field.

   This would also correlate with the reduction of the level of consciousness at the level of DNA if one is ready to generalize Becker's findings [J45] about the correlation of the strength of the longitudinal electric field along the body axis with the level of consciousness. Similar correlation with consciousness can be assigned to the electric field directed from visual cortex to frontal lobes.

2. The reduction of the electric field strength reduces energy density of DNA and therefore string tension. DNA begins to fluctuate geometrically, which generates epigenetic noise. Initially dark DNA is like a tense guitar string but transforms gradually to spaghetti. Basically the reduction of string tension reflects the dissipation accompanying the approach of MB to thermal equilibrium with the ordinary bio-matter.

   One could perhaps say that the reduction of string tension of MB flux tubes forces the reduction of electric field strength and the internal consistency (Maxwell equations) requires reduction of the sticky end lengths proportional to the charges generating the electric field along DNA. Note that also charge separations tend to disappear in the approach to thermal equilibrium.

3. An interesting question is whether hyper-methylation accompanying aging [I31, I71, I65] could be seen as an attempt to minimize the effects of DNA damage - analogous to an amputation of a leg to prevent necrosis. Hyper-methylation accompanies also cancer [I24, I54].

   Second view is that hypermethylation is due to the loss of control of MB caused by the approach to thermal equilibrium. Hyper-methylation could be seen as the failure of demethylation caused by the low level of demethylase activated by MB and caused by methylation of the genes coding for demethylase! This positive feedback loop would lead to the failure of the control of MB.

Is the shortening of the telomeres a controlled process or due to thermalization? The first option could be argued to be realistic since otherwise the population would end up to fight about metabolic resources. Second law could of course solve the problem without any need for a controlled action. If the length of telomeres correlates with the charges of the sticky ends proportional to its length which in turn would be proportional to the length of the telomere as proposed in [L193], the conclusion would be that the shortening is not a controlled process.

5.10 Epigenesis and aging in TGD framework

In the TGD framework epigenesis would be control of the biological body by MB consisting of ordinary biomatter. The basic control tool would be dark photon 3N-plets coupling resonantly to the dark proton sequences of proteins serving as enzymes and RNAs serving as ribozymes. The coupling would be precise and based on the addresses defined by dark proton 3N-sequences defining emitting dark 3N-photons.

These would in turn catalyze the basic biochemical processes and here TGD suggests a mechanism explaining why the reactants find each other and where the energy needed to overcome the energy barrier to make reaction fast enough come. The reduction of h_{eff} for flux tubes would be the needed mechanism.

Also other catalysts than enzymes and ribozymes can be considered. For these catalysts and organic and non-organic molecules in general, the coupling with MB could be single photon resonant coupling transforming 3N-photon to bio-photon.

5.10.1 How MB could control biochemistry

How does the general biochemistry picture involving biomolecules and reaction pathways relate to the multi-resonance vision about how MB controls ordinary biomatter? Can one reduce this picture to a description in terms of multir-resonance frequencies - that is to the level of MB and MB-BB communications alone.

1. Suppose that MB of DNA, RNA, or protein controls DNA, RNA or protein by signals from dark genes using multi-resonance mechanism allowing to select the target and use modulation of dark photon signal to code control signals. Also the MB of DNA, RNA, or protein can be controlled by a higher level of the hierarchy.

   If all control takes place in this manner, epigenetic control would be control of proteins acting as enzymes, of RNA, in particular ribozymes, and of DNA. MB would also activate genes coding for various enzymes, in particular housekeeping enzymes.

   The controlled proteins would be naturally enzymes catalyzing various biochemical reactions.

2. Could the MB of DNA just change its geometric conformation inducing change of DNA conformation and changing also the epigenetic patterns determined by methylation, etc...? This would represent something new: in TGD one has a network of molecules connected by flux tubes, in biochemistry approach one has only molecules.

   The first basic mechanism for the change of the conformation would be the reduction of h_{eff} leading to the shortening of the flux tubes and liberation of energy and its reversal. The reduction of h_{eff} is crucial in the TGD based model of bio-catalysis. The opposite process would feed metabolic energy to MB. The formation of reconnection would be another key process and allow to change the topology of the flux tube network. This would be the basic mechanism of the immune system and also of biocatalysis in which the U-shaped flux tubes associated with the reacting molecules would reconnect.

   For instance, the actions of cells during say catastrophic events mean typically that proteins like Sir2 come in rescue by travelling along flux tubes or pairs of them serving as highways: these highways do not exist in standard biology. The existing pattern of flux tubes determines the road network. MB would control the topology of this network by reconnecting and by controlling the lengths of the flux tubes by h_{eff} changing transitions: motor actions of MB would be in question.

3. TGD leads to a view about emotions as sensory perceptions of MB. The model for genetic code emerging from a model of bio-harmony [L30, L98, L131, L154] based on icosahedral and tetrahedral geometries and the observation that music expresses and induces emotions leads to the proposal that the bio-harmony characterized by 64 allowed 3-chords in one-one correspondence with DNA codons has 3N-resonances assignable to the 3-chords of the harmony as a correlate. These resonant interactions induce transitions of selected bio-molecules and possibly also specific transitions of a given biomolecule characterizing the harmony. Could epigenesis be regarded as expressions of emotions by music of light?

BSFR would create a superposition of deterministic time evolutions leading to the geometric past. It would define an average time evolution described in terms of reaction pathways. Could the final state of MB in BSFR dictate also the epigenetic patterns - say bio-harmony determined by frequencies of cyclotron transitions of protons? They are indeed determined by the strengths of the magnetic fields at flux tubes. This would conform with the proposal that the outcome

of volitional action as BSFR dictates what happens in the brain of geometric past explaining the findings of Libet [J44] [L99].

SSFRs give rise to an approximately classical time evolution and generation of entropy, and therefore aging. h_{eff} distribution becomes flatter and MBs of information molecules and ordinary matter approaches thermal equilibrium. The distribution for the conformations of the magnetic flux tubes thermalizes and cell size increases. Basically string tensions decrease since the electric fields involved weaken and the electric and also magnetic contribution to the tension weakens.

What could be the general mechanism of bio-catalysis? The MB of the enzyme could activate the enzyme when the value of h_{eff} of a flux tube connecting it to other reactants is reduced and induces the shortening of the flux tube and liberation of energy.

Depending in what direction energy flows, one can imagine two scenarios for what happens.

1. The energy could flow from higher levels of hierarchy to lower levels. The flux tube at the highest level would be shortened and liberate energy transferred to a lower level. At the lowest level enzyme would be excited and return to the ground state and liberate the energy needed to overcome the potential wall making reaction slow. Now the shortening of the flux tube of enzyme's MB does not seem to be necessary energetically.

   The process would proceed from higher to lower levels in the hierarchy of MBs by this kind of excitations and de-excitations transferring the energy to the lower level, somewhat like in photosynthesis. The flow of money from top towards bottom in a big project serves as a second metaphor for the course of events.

2. If the process is a generalized motor action involving BSFRs and time reversals, the higher levels in the hierarchy of MBs extract energy from shorter scales (very much like higher levels extract work of lower levels in the social hierarchies!). One could also say that negative energy is sent to the lower levels of the hierarchy.

   The lower level would provide the energy by reducing its h_{eff} so that its energy is reduced and energy is liberated and taken by the higher level. This would induce the shortening of magnetic flux tubes at all levels. The cascade would proceed down to the level of MBs of proteins and also the U-shaped flux tubes connecting the protein to the other reactants would shorten and bring the reactants together. The reduction of the flux tube length should provide energy to overcome the potential wall, not only the energy going to the higher level of hierarchy.

It is not quite clear which option is realized. Motor actions involve transfer of metabolic energy from short to length scales giving rise to macroscopic coherent motion: time reversal would be natural from this point of view.

Methylation and acetylation

The figures of `https://cutt.ly/Qjgrko3` illustrate the effect of methylation and acetylation of DNA or of histone tail.

1. The nucleosomes [I13] surround a given gene but nucleosomes can roll along DNA downstream towards the gene to be transcribed and opens the DNA double strand. The modification of the histone tail can prevent or facilitate the opening of the double strand.

2. The portion of DNA between the nucleosome and gene corresponds to the promoter part of DNA initiating the gene expression. Proteins initiating the transcription bind to it or alternatively it can be transcribed to RNA.

The methylation [I13] and acetylation [I1] of the histone tail serves as the first example. The binding of the methyl, acetyl, or some other group to the histone tail has an indirect effect on the gene. Histone is positively charged. Since DNA is negatively charged, DNA and histone bind together.

The addition of a modifier can increase or reduce the charge of the histone and tighten or loosen the binding between histone and DNA. Methyl is positively charged and tightens the binding

and makes the opening of DNA necessary for transcription more difficult. Acetyl is negatively charged and loosens the binding so that the transcription becomes easier.

Consider next the methylation of a promoter region (https://cutt.ly/3jj8ohZ).

1. A promoter is a sequence of DNA to which proteins bind that initiate transcription of a single RNA from the DNA downstream of it. This RNA may encode a protein, or can have a function in and of itself, such as tRNA, mRNA, or rRNA. Promoter region has therefore two - it seems alternative - functions.

2. The methylation of cytosin occurs at CpG islands associated with the promoter region of gene. Promoter region is the region to which proteins initiating the transcription of gene bind. Methylation occurs also for the promoter regions of CpG-islands [I30].

3. How methylation silences the gene transcription? Methylation decreases the charge of DNA locally and loosens the binding to histone. This would favor the transcription of the promoter region instead of the transcription of the gene requriing the binding of RNA polymerase to the promoter region.

4. If methyl is always positively charged, the direct binding to DNA reduces DNA charge locally and reduces the interaction between histone and help opening of DNA in the promoter region: this would not facilitate the transcription of gene but transcription of non-translated RNA or protein. The binding would also prevent the binding of RNA polymerase to the promoter region. The start codon of the non-protein coding gene could be in the promoter region.

More facts about DNA methylation [I14] (https://cutt.ly/pjj3G45) are needed to develop a TGD based view about the situation.

1. DNA methylation reprogramming occurs during gameto-genesis and early embryogenesis. The methylation patterns are erased and regenerated. This requires that the memory about the methylation pattern is stored. In the TGD framework MB could serve as the temporary information storage.

2. DNA methylation occurs also in highly transcribed gene bodies and must be distinguished from the methylation of promoter regions. The methylation of gene bodies seems to relate to splicing and could prevent the transcription of intronic portions of the gene.

3. In general, the level of DNA methylation is very low. The level of methylation is however high in promoter regions. In particular, in CpG islands [I5] (https://cutt.ly/sjj3STW) accompanying the promoter regions of genes, especially those coding for housekeeping proteins.

4. Usually the methylation of C in CpG leads to a mutation replacing C with T. This could have led to CpG loss in DNA except in CpG islands, where some stabilization mechanism should prevent the mutations: presumably an energy barrier somehow caused by CpG is involved.

   Hypermethylation accompanies cancer and also aging [I65, I71] and could be seen in the TGD framework as reflecting the approach to epigenetic chaos basically due to the reduction of the scale of quantum coherence in turn caused by the reduction of the values of h_{eff}.

5. CpG loss is believed to be induced by transposable elements (TEs) attaching to DNA and hopping around it. TEs are methylated and lose CpG as C transforms to T.

6. So called housekeeping proteins [I12] are enzymes crucial for various functions including general gene expression, and the control of various housekeeping functions takes place via the control of the expression of housekeeping genes. Therefore CpG islands, which are stable against mutations and allow both methylation and demethylation are needed. Dynamical and differential methylation is also known to relate to memory recall in the case of hippocampus.

   For CpG islands $C \to T$ the mutations induced by methylation are prevented by some mechanism. The loss of CpG makes sense outside CpG islands since this stabilizes the genes against C $\to$ T mutations.

MB uses enzymes and ribozymes as a tool in the control of the basic biochemical processes. DNA methyltransferases [I15] catalyze methylation and MB would control the process by activation of this enzyme. In the case of demethylation the enzymes used are demethylases [I8].

The mechanism of demethylation can be taken as an example since the failure of demethylation might lead to hypermethylation of CpG islands known to accompany aging [I65, I31] and in TGD framework it could be due to the approach of the dark genome and proteome to thermal equilibrium.

1. Oxidative demethylation [I9] (`https://cutt.ly/Gjj2Ilz`) replaces CH_3 group with hydrogen. This requires the presence of a reactive oxygen species (ROS). ROS include superoxide O_2^-, hydrogen peroxide H_2O_2 and hydroxyl radical OH.(`https://cutt.ly/yjj2Ubv`).

   Superoxide is produced in aerobic metabolism via $O_2 + e^- \to O_2^-$. This in turn leads to reactions $2H^+ + 2O_2^- \to H_2O_2 + O_2$ followed by $H_2O_2 + e^- \to HO^- + OH$ and $2H^+ + 2e^- + H_2O_2 \to H_2O$.

2. Demethylation is catalyzed by demethylases in presence of O_2. N-methyl groups are oxidized with oxygen coming from ROS O_2 and CH_2O splits out so that the net reaction is $R_2N - CH_2 \to R_2N - H + CH_2O$.

   Enzymes known as alpha-ketoglutarate-dependent hydroxylases act as DNA demethylases. Also Cytochrome P450 [I6] (`https://cutt.ly/ujj2OuK`) catalyzes demethylation in histones and some forms of DNA (cytocine associated with CpG). "450" refers to "450 nm"", which is the wavelength at which cytochrome P450 has maximum absorption. The wavelength corresponds to blue light near UV range and the photon energy is 2.76 eV. CYPs is a very large class of enzymes catalyzing metabolic processes.

What TGD view could be?

1. Suppose that MB controls bio-matter by expressing its moods coded by bio-harmonies in terms of dark photons 3N-plets (say) with the frequency patterns correlating with mood and affecting matter in mood dependent manner via a transformation to bio-photons.

2. 60 per cent of promoter regions of human genes contain CpG islands of length about 100-1000 codons and almost all housekeeping genes have CpG islands in their promoter regions. Why?

3. MB would induce both methylation and demethylation and other modification using various enzymes which they could activate by dark 3N-photons using as address the dark proton sequence associated with the enzyme. After activation the reaction would proceed by the proposed general mechanism of biocatalysis.

4. One can imagine several alternative courses of events after the activation. Even the question whether the energy transfer is from short to long length scales associated with MB or vice versa is not fully settled: this depends on the arrow of time assignable to this process.

   In the case of CYP450, one cannot avoid the temptation to ask whether a biophoton with 450 nm wavelength could be formed in a decay of 3N-dark photon to ordinary photon.

Methylation, aging, and memory

According to the abstract of [I31] (`https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3482848/`), the general trends, supported by an increasing body of both in vitro and in vivo work, are the establishment of global hypomethylation (non-CpG islands) and regions of hypermethylation (primarily CpG islands) with age. CpG islands are located in the promoter regions of genes, in particular those of housekeeping genes.

Hypomethylation outside CpG islands could be due to the spontaneous mutation $C \to T$ but also the failure of the control of the methylation by MB could be involved. Hypermetylation

of promoter regions implies that the promoter region transcribing RNA is transcribed instead of gene. This could be due to the failure of demethylation caused by the loss of the control.

In both cases the loss of control could have the same reason. The MBs of the genes coding for housekeeping genes and possibly also the MBs of the housekeeping enzymes approach thermal equilibrium with the ordinary bio-matter.

How methylation could relate to aging in TGD framework?

1. Methylation could become irreversible during aging and lead to hypermethylation if MB loses the control of demethylation. If enzymes are the control tools of MB, the reduced transcription of DNAs coding for demethylases would lead to a failure of the control. The approach of MBs of DNA and enzymes to thermal equilibrium with ordinary biomatter could be the basic reason for the failure.

2. Housekeeping proteins are an especially important class of proteins since they catalyze basic biological functions necessary for the transcription of genes - also the genes coding form them. Their promoter regions are also almost always CpG islands. Therefore one can say that the methylation of their promoter regions would be a natural cause of various problems with housekeeping activities caused by aging.

3. CYP450 catalyzes generation of ROS in turn catalyzing demethylation and a large number of metabolic processes crucial for the functioning of the organism. In particular, demethylation could become less effective with aging due to the reduced level of CYP450. CYP450 is a housekeeping protein and the promoter regions of genes coding for CYP450 would be methylated. Methylation slows down transcription of CYP450 and this in turn slows down demethylation. This positive feedback loop eventually leads to a kind of death spiral.

4. Differential methylation of the hippocampus is known to be crucial for the memory recall (here memories are understood as learned behaviors rather than episodal memories) [J176]. Differential methylation is not possible without demethylation. If methylation becomes irreversible the formation of recallable memories becomes more difficult. Short term memory recall as also memory recall in longer time scales indeed become less effective during aging.

5.10.2 How epigenetic information is inherited?

There is evidence for the inheritance of epigenetic information.

1. Epigenetic inheritance takes place in mitosis and sometimes also in meiosis. The methylation related epigenetic disorder increases with aging.

2. How could the epigenetic information be inherited in this picture? It could be represented by the geometry of MB - flux tube network - and at the genetic level by both control genes. Emotional aspects, something new, would have bio-harmony as a correlate, and bio-harmony is determined by cyclotron frequencies determined by the magnetic field strengths of the flux tubes. Not only cell but also MB replicates and the replication of MB induces replication at cell and DNA level.

   Both genetic and epigenetic information could be inherited in the replication if MB replicates geometrically like a particle in the decay A$\rightarrow$ A+A. Usually particles are regarded as pointlike and Feynman diagram expresses this. The line A decays to two lines A+A. This makes sense also for 3-surfaces, in particular magnetic bodies, replacing the point like particles. That replication occurs at the fundamental physics is a new element in TGD based vision.

   At the level of causal diamonds (CDs) A$\rightarrow$A+A would look like follows. The CD of A in the initial state and the CDS of A+A in the final state would intersect and contain the vertex region. Could the moods of A be inherited by A:s in A+A under some conditions - in other words, are cyclotron frequency spectra of flux tubes of A inherited?: this is true i the flux tubes would replicate as such.

   Some methylation patterns are inherited in meiosis but not all. If these patterns are determined by the bio-harmony, magnetic flux tubes are copied faithfully in some cases even in meiosis but not always.

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Part II

THE NOTION OF SELF

Chapter 6

Self and Binding: Part I

6.1 Introduction

The conflict between the non-determinism of state function reduction and determinism of time evolution of Schrödinger equation is serious enough a problem to motivate the attempt to extend physics to a theory of consciousness by raising the observer from an outsider to a key notion also at the level of physical theory by bringing in the notion of self. Further motivations come from the failure of the materialistic and reductionistic dogmas in attempts to understand consciousness in neuroscience context. There are reasons to doubt that standard quantum physics could be enough to achieve this goal and the new physics predicted by TGD is indeed central in the proposed theory.

6.1.1 Zero Energy Ontology

Zero Energy Ontology (ZEO) was forced by the interpretational problems created by the vacuum extremal property of Robertson-Walker cosmologies imbedded as 4-surfaces in $M^4 \times CP_2$ meaning that the density of inertial mass (but not gravitational mass) for these cosmologies was vanishing meaning a conflict with Equivalence Principle. In ZEO physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds (CDs) defined as intersections of future and past directed light-cones ($\delta M^4_{\pm} \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology.

ZEO combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of universe and about the values of conserved quantum numbers of the Universe can be avoided since everything is in principle creatable from vacuum. Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in ZEO. ZEO leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II_1. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD.

ZEO (ZEO) means that one must distinguish between M-matrix and U-matrix. M-matrix characterizes the time like entanglement between positive and negative energy parts of zero energy state and is measured in particle scattering experiments. M-matrix need not be unitary and can be identified as a "complex" square root of density matrix representable as a product of its real and positive square root and of unitary S-matrix so that thermodynamics becomes part of quantum theory with thermodynamical ensemble being replaced with a zero energy state. The unitary U-matrix describes quantum transitions between zero energy states and is therefore something genuinely new. It is natural to assign the statistical description of intentional action with U-matrix since quantum jump occurs between zero energy states.

Quantum measurement theory based on ZEO can be said to imply the notion of self and to explaining basic aspects of consciousness when one includes also the hierarchy of Planck constants characterizing hierarchy of quantum criticalities. At the embedding space-level CD is the correlate

of self whereas space-time sheets having their ends at the light-like boundaries of CD are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves. Zero energy ontology leads also an argument explaining why the arrow of subjective time induces an apparent arrow of geometric time as a result if intentional action and why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD).

6.1.2 Hierarchy Of Planck Constants

The hierarchy of Planck constants corresponds to a hierarchy $h_{eff} = n \times h$ [K44, **?**, K90]. The original hypothesis was that it corresponds to a hierarchy of singular coverings of embedding space $M^4 \times CP_2$- or rather - given causal diamond (CD).

The recent view is that there is a hierarchy of quantum criticalities such that the sub-algebra of super-symplectic algebra for which conformal weights are n-ples of those for the entire algebra acts as conformal gauge symmetries at given level. Due to the resulting non-determinism the space-time surfaces connecting 3-surfaces at the opposite boundaries of CD are gauge degenerate and there are n conformal equivalence classes analogous to sheets of Riemann surface of $z^{1/n}$. This view has far reaching consequences. The hierarchy of quantum criticalities has an interpretation as that for macroscopic quantum phases and the phase transitions increasing n to its multiple occur spontaneously and generate also negentropy if NMP is assumed. Hence evolution can be seen as a gradual reduction of criticality occurring unavoidably.

An alternative formulation [K112, K87, K90, **?**] emerged in terms of gravitational Planck constant $h_{gr} = GMm/v_0$, where v_0 is characteristic velocity in the system consisting of two masses involved, introduced originally by Nottale [E1] h_{gr} would be associated with the flux tubes connecting the two masses. Later it became clear that the identification $h_{eff} = h_{gr}$ leads to considerable insights in biology: in particular bio-photons can be identified as ordinary photons resulting from dark cyclotron photons with a universal energy spectrum.

The book metaphor inspired by the original view about hierarchy of Planck constants is however very useful. The value of the Planck constant characterizes partially given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory.

6.1.3 P-Adic Physics As Physics Of Cognition

p-Adic mass calculations relying on p-adic length scale hypothesis led to an understanding of elementary particle masses using only super-conformal symmetries and p-adic thermodynamics. The need to fuse real physics and various p-adic physics to single coherent whole led to a generalization of the notion of number obtained by gluing together reals and p-adics together along common rationals and algebraics (see fig. `http://tgdtheory.fi/appfigures/book.jpg`, which is also in the appendix of this `http://tgdtheory.fi/appfigures/book.jpg`). The interpretation of p-adic space-time sheets is as correlates for cognition. p-Adic and real space-time sheets intersect along common rationals and algebraics and the subset of these points could be called intersection of realities.

In fact, the intersection can be interpreted in more abstract sense at the level of WCW as surfaces for which parameters (WCW coordinates) are such that the interpretation both as real and p-adic surface is possible. In this way one avoids discretization at space-time level. It has turned out that string world sheets and partonic 2-surfaces with defining parameters in an extension of

rationals define naturally the intersection and strong form of holography allows the continuation of these 2-surfaces to space-time surfaces.

The outcome is a vision about hierarchy extensions of rational numbers defining an evolutionary hierarchy. So called ramified primes associated with the extension define preferred primes identifiable as p-adic primes and weak form NMP allows to understand p-adic length scale hypothesis and its generalization stating that primes near powers of primes are favored by NMP.

There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement, which need not be bound state entanglement in standard sense. Negentropic entanglement might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. The generation of NE as the outcome of the reduction is not totally random process: the prediction is that second law need not universal truth holding true in all scales. To avoid making wrong conclusions about NMP, one must keep in mind that entanglement entropy is two-particle property whereas thermodynamical entropy is single partcle property.

Quantum measurement theory allows only final states, which have density matrices which are projectors so that the rational entanglement probabilities $p = 1/n$ are identical in this case. If the prime p divides n, one obtains negative entanglement entropy and one can say that entanglement is negentropic. Negentropy is largest for the largest power of prime dividing n and one could define entanglement entropy as that associated with this prime.

6.1.4 NMP

One obtains standard quantum measurement theory by assuming that the density matrix of the sub-system is the universal observable. In state function reduction this observable is measured and the system goes to an eigenstate of it. It can however happen that the eigenvalues are degenerate and in this case one can ask whether the reduction leads only to an eigen space so that entanglement characterized by a n-dimensional projection operator remains.

If p divides n, one obtains negative entanglement entropy and one can say that entanglement is negentropic. Negentropy is largest for the largest power of prime dividing n.

Negentropy Maximization Principle (NMP) [K73] codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to maximal reduction of entanglement entropy - or equivalently - gain of entanglement negentropy- at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

The interpretation is that NMP favors generation of negentropic entanglement (NE). One can of course argue that the generation of this kind of entanglement is extremely improbable. The hierarchy of Planck constants involving quantum criticality could however provide the way to generate it.

TGD inspired theory of consciousness forces to challenge the hypothesis that NMP always forces the state function reduction to the sub-space defined by the projector with maximal dimension appearing in the decomposition of the density matrix. NMP would not allow the self to make choices, which are bad deeds in the sense that they do not increase maximally the negentropic resources of the Universe. We would live in the best possible Universe becoming better all the time. This is obviously too good to be true.

The weak form of NMP allows the choice leading to maximal negentropy gain but allows also those choices for which the reduction occurs to a sub-space of the space defined by projector. When this sub-space is 1-dimensional standard quantum measurement results and the self is isolated from the target of observations. Negentropic entanglement has interpretation as attention with positively colored contents of consciousness. Experience of love would be one attribute of this kind of state. Weak form of NMP would be like God allowing the sinner to choose between Good and Evil.

Weak form of NMP turns out to have surprisingly strong consequences. For instance, by choosing the sub-space to have dimension given by power of prime, the state function reduction can yield a larger negentropy gain than otherwise. Primes near powers of prime as dimensions of final

state projector are optimal from the point of view of evolution since they give a large negentropy gain and generate large p p-adicity, which means higher evolutionary level in number theoretical sense: this result is nothing but a generalization of p-adic length scale hypothesis.

NMP generalizes also so that it applies to hyper-finite factors of type II_1 and also in this case it is possible to define negentropic entanglement. In this case entanglement negentropy is positive because the projector for the sub-space as dimension smaller than one as the inverse of the index of inclusion. The interpretation is that the degrees of freedom below measurement resolution carry NE characterized by the projector to the sub-space.

6.1.5 The Notion Of Self

The quantum notion of self solved several key problems of TGD inspired theory of consciousness but the precise definition of self has remained a long standing problem and I have been even ready to identify self with quantum jump. Zero energy ontology allows what looks a final solution of the problem. Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

p-Adic physics as correlate for cognition leads to the notion of negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness. Consistency with standard quantum measurement theory forces negentropic entanglement to correspond to density matrix proportional to unit matrix. Unitary entanglement typical for quantum computing systems gives rise to unitary entanglement. A natural conjecture is that the integer n in $h_{eff} = n \times h$ corresponds to the dimension of the unit matrix associated with negentropic entanglement. Also a connection with quantum criticality made possible by non-determinism of Kähler action and extended conformal invariance emerges so that there is high conceptual coherence between the new concepts inspired by TGD.

The identification of the imbedding space correlate of self as causal diamond (CD) of the embedding space combined with the identification of space-time correlates as space-time sheets inside CD solved the problems concerning the relationship between geometric and subjective time.

Subjective memory is assumed to correspond to an average of conscious experiences of quantum jumps occurred after the last wake-up of self (the first one in the sequence of state function reduction at same boundary of CD). This leads to the identification of qualia as averages of the increments of quantum numbers and zero modes in the ensemble of quantum jumps defining self. Summation hypothesis states that self X experiences the experiences of its subselves as abstracted experiences, averages X_{ij} about sub-subselves X_{ij}. Subselves of un-entangled selves can entangle (this is due to the many-sheeted sub-system concept) and this allows fusion and sharing of mental images.

Quantum entanglement provides a mechanism leading to the formation of irreducible wholes at the level of mental images. Entanglement can be entropic bound state entanglement or negentropic entanglement, which need not involve binding energy. The latter is possible only in the intersection of real and p-adic worlds where life can be said to reside and quantum criticality of TGD Universe accompanied by the hierarchy of Planck constants is essential for it. Quantum entanglement is possible also in time direction in zero energy ontology. It is tempting to assign negatively colored emotions to the entropic entanglement and positive emotions to the negentropic one. In TGD framework the standard vision about brain based on reductionistic-holistic dichotomy must be replaced with a trinity in which negentropic entanglement corresponds to a mode of cognition, which does not allow linguistic expression and episodal memories, and various mental feats of synesthetes and idiot savants could be seen as a manifestation of negentropic entanglement. Also meditative consciousness would be negentropic.

Selves are called irreducible if they possess no subselves, otherwise reducible. Subselves correspond to mental images so that irreducible subselves possess no mental images and are in a state of pure self-awareness: it is not clear whether this kind of states are possible in practice. When the subselves of self fuse to single negentropic subself, a state of "one-ness" results in somewhat

different sense. This mode of consciousness can be identified as "whole-body" consciousness and differs from ordinary consciousness during which self has large number of mental images. These modes could naturally explain emotional/holistic and rational modes of mind. These two modes could make it possible to understand various dichotomies like brain/left brain, emotional/analytic, religous/rational, Eastern/Western,... One could understand linear cognitive processes like thinking and language as self cascades in which self decomposes into subselves, which in turn decompose into subselves, which ... and self hierarchy implies connection with computationalism.

The possibility of negentropic entanglement (NE) has profound implications. It leads to a vision about learning as a basic quantum process possible in the intersection of real and p-adic worlds and made possible because state function reduction ceases to be a random process for negentropically entangled zero energy states. Quite concrete ideas about the role of synaptic transmission and neural transmitters for consciousness emerge. Music experience provides an especially interesting application for the vision about consciousness and zero energy ontology together with number theoretical vision inspires several concrete interpretations. Synchronous firing of neurons- in particular at 40 Hz frequency- is an attractive correlate for the negentropic entanglement and synesthesia can be interpreted as a particular manifestations of negentropic entanglement.

In TGD framework it is not at all obvious that the highest levels of our personal self hierarchy should correspond to the size of the physical body. Various empirical facts, in particular the observations related to the special effects of excitations of geomagnetic fields and ELF em fields in EEG frequency range on brain, inspire the hypothesis that our selves correspond to topological field quanta of em fields associated with EEG frequencies and thus by Uncertainty Principle have size scale of Earth. This leads to a rather radical modification of the brain centered views about consciousness, and one can quite seriously consider the questions like what physical death means from the point of view of consciousness: it could be that electromagnetic part of self hierarchy could survive after the physical death as a "soul".

This chapter is devoted to the theoretical aspects related to the definition of self. In second chapter applications of the notion of self are discussed. The plan of this chapter is as follows.

1. In the first section the notion of self is defined and various aspects related to it are discussed. This includes discussion about the flow and arrow of time, qualia, quantum model for intelligent systems, emotional representation of Boolean logic, the origins of ethics and moral as NMP allows to understand them, and self referentiality. Also the general structure of conscious experience is considered: self has sub-selves experienced as mental images and sharing and fusion of mental images is possible in many-sheeted space-time. Various aspects of binding are discussed in terms of negentropic entanglement. The basic prediction is entire self hierarchy and also the aspects related to this hierarchy are discussed.

2. Second section is devoted to a critical question: is NE experienced directly or does it only define a model of self and is it necessary to have a mechanism allow to make the information in question conscious. Although the most elegant assumption is that sequence of repeated state function reductions makes NE conscious, the possibility that interaction free measurement might be needed to achieve this, is discussed.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

6.2 Quantum Self

The section introduces the definition of self, discusses the role of entanglement in binding, introduces the basic assumptions about the structure of conscious experience of self and some of their consequences.

The necessary conceptual background includes ZEO, hierarchy of Planck constants, fusion of real physics and p-adic physics to single coherent whole - adelic physics, the notion notion of negentropic entanglement, and weak form of NMP. These building bricks are discussed in the introduction.

6.2.1 Quantum Jump As Moment Of Consciousness

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphorical sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies". Quantum jump would have actually a complex anatomy corresponding to unitary process U, state function reduction and state preparation at least.

Quantum jump has a complex anatomy since it must include state preparation, state function reduction, and also unitary process characterized by U-matrix.

It took quite a long time to realize that state repeated state function reductions which do not change state at all in standard quantum measurement theory are quite essential for the notion of self and that the first state function reduction at the opposite boundary of CD corresponds to the state function reduction assigned with quantum measurement.

In ZEO the repeated state function reduction leave the passive boundary and the parts of the zero energy states at the passive boundary invariant whereas the active boundary and parts of states at it change. In other worlds, one has state function in the moduli space charactering the position of the active boundary (discrete Lorentz boosts leaving passive boundary invariant and discrete translations in the proper time distance between the tips of CD). Each repeated state function reduction corresponds to a unitary process inducing de-localization in these degrees of freedom and localization so that fixed CD results.

6.2.2 Definition Of Self In ZEO

Intuitively self corresponds to a sequence of quantum jumps which somehow integrates to a larger unit much like many-particle bound state is formed from more elementary building blocks. It also seems natural to assume that self stays conscious as long as it can avoid bound state entanglement with the environment in which case the reduction of entanglement is energetically impossible. One could say that everything is conscious and consciousness can be only lost when the system forms bound state entanglement with environment. Second intuitive view is that self is a subsystem able to remain un-entangled with the environment. This view can be subjected to criticism.

The precise definition of self has remained a long standing problem and I have been even ready to identify self with quantum jump. ZEO allows the most feasible candidate for the solution of the problem found hitherto.

In ZEO self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and also to self. One can also identify the age of self as the increase of the distance between the tips of CD. The first quantum jump to the opposite boundary corresponds to the act of free will or death of self and re-incarnation of self at the opposite boundary of CD.

The part of zero energy state at the fixed boundary is stable so that it indeed represents a system able to remain un-entangled. All entanglement associated with the passive boundary is either negentropic or bound state entanglement since state function reduction produced it destroys non-negentropic entanglement unless it is bound state entanglement.

Since number theoretic entropies are natural in the intersection of real and p-adic worlds, this suggests that life resides in this intersection identifiable in terms of string world sheets and partonic 2-surfaces. A natural assumption is that self experiences expansion of consciousness as it entangles negentropically. Quite generally, an infinite self hierarchy with the entire Universe at the top is predicted.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images (sub-sub-selves of self). This implies the notion of aging of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-sub-selves) increases.

The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts

a hierarchy of quantum jumps ad self such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle would correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday.

Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the causal diamond (pair of future and past directed light-cones in $H = M^4 \times CP_2$). For electron this time scale is.1 second, the fundamental biorhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $\hbar/\hbar_0$ multiples of this time scale.

6.2.3 Two Variants For The Notion Of Self

I have considered two basic notions of "self".

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

   Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

   ZEO solves this problem. The sequence of quantum jumps defining self consist of only those for which state function reduction takes place on fixed boundary of CD! In ordinary quantum measurement theory these state function reductions would have no effect on state. Now however the wave function characterizing the position of the second boundary of CD disperses towards "geometric future" of the fixed boundary. Geometric time corresponds to the proper time distance between the tips of CD whose quantum average value increases. Self corresponds to this sequence of quantum jumps and indeed remains unentangled at the fixed boundary and also experiences flow of geometric time with definite arrow.

2. According to the later variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

   It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps but there are some objections against this idea. Quantum jumps as moment of consciousness should indeed be a moment as we understand moment! One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

The first view about self, which I believe is nearer to the correct one, does not exclude the hierarchy of selves, and one should be also in this case able to construct a well-defined mathematical scheme allowing to understand what fractality of quantum jumps and selves at the level of space-time correlates could mean. The following argument represents such a proposal.

Let us start from the CD model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience and allow wave function in the moduli space of CDs essential for the new view about arrow of time and self.

Let us make the following assumptions.

1. Assume the hierarchy of CDs within CDs in a sense to be specified more precisely below. CDs would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the CD. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to average temporal distance T between the tips of the CD in the wave function in space of CDs. The lifetime of self corresponds to the quantum average for the increase ΔT during the sequence of state function reductions to a fixed boundary of CD. A reasonable guess is that ΔT is of same order as T.

4. We know that the contents of sensory experience comes from a rather narrow time interval of duration about.1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the CD to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of CDs generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of CD is chosen in such a way that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious

experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that classically the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive (not however that this boundary disperses to future). Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint CDs is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint CDs (see **Fig.** `http://tgdtheory.fi/appfigures/sharing.jpg` or **Fig. ??** in the appendix of this book).

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can de-localize in the sense that there is a wave function associated with the position of the CD and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several CDs are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different CDs. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from a longer to shorter scale.

6.2.4 Basic Consequences Of The Definition Of Self

Summation hypothesis, when combined with the mechanism for the formation of abstractions and mechanism of subjective memory, has rather nontrivial consequences.

Self, psychological time and its arrow

There are many difficult questions related to the relationship between subjective and geometric time. How the arrow of subjective time is mapped to the arrow of geometric time? How to understand the sharp distinction between geometric future and past at the level of conscious experience? What is the average interval of geometric time assignable to quantum jump and how it depends on the p-adic prime p characterizing system and on the value of Planck constant? Can one assign to quantum jumps space-time region about which the contents of conscious experience are, and how the temporal and spatial scales of this region depend on p and the value of Planck constant?

The emergence of ZEO and hierarchy of Planck constants provides to my opinion the most convincing partial answers to these questions found hitherto. the answers are not final however as the considerations of last section demonstrate.

1. Zero energy state is identifiable in positive energy ontology as a physical event, say elementary particle scattering such that positive and negative energy parts of the state correspond to the initial and final states of the event. The geometric correlate is a CD formed by a pair of future and past directed light-cones of M^4 and corresponds to a region of the embedding space rather than that of space-time.

2. The temporal distance T between the tips of the CD brings to physics a new time scale and simple argument predicts p-adic length scale hypothesis (favored primes p satisfy $p \simeq 2^k$, k prime), and that the minimal value of T for elementary particles corresponds to secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$. For nonstandard values of $\hbar$ T scales like $\hbar/\hbar_0$. In the case of zero energy state describing electron this time scale is.1 seconds and corresponds to the 10 Hz frequency defining the fundamental biorhythm, and the duration of moment of sensory experience.

3. The simplest explanation for the arrow of geometric time relies on the view about self as a sequence of repeated reductions at fixed boundary of CD. The sequence involves unitary evolution in the moduli space of the active boundary and is essentially dispersion. Each reduction means localization in the moduli space of CDs and by purely geometric argument the distance beween the tips of CD tends to increases. This distance defines the age of self and the arrow of phychological times means its average increase. In the first state function reduction to the opposite boundary of CD the arrow of geometric time changes but the distance between the tips increases also in this reduction.

4. There is a strong analogy with cosmic time and a natural proposal is that the quantum counterpart for cosmic time correspond to this kind of parameter for a very large CD. The relative positions of the of tips define part of the moduli space of CD and this space is discrete by number theoretical universality and correspond to a tessellations assignable to cosmic time constant hyperboloid having discrete algebraic subgroup of Lorentz group as isometry group. The hierarchy of tessellations is expected to relate to the hierarchy of algebraic extensions of rationals defining an evolutionary hierarchy. This would predict quantization of redshifts in cosmology.

Qualia

Since physical states are labeled by quantum numbers, various qualia correspond naturally to the increments of quantum numbers in quantum jump which leads to a general classification of qualia in terms of the fundamental symmetries [K50]. One can speak also about geometric qualia assignable to the increments of zero modes which correspond to the classical variables in ordinary quantum measurement theory and non-quantum fluctuating degrees of freedom which do not contribute to the metric of world of classical worlds (WCW) in TGD framework. Dark matter hierarchy suggests that also qualia form a hierarchy with larger values of Planck constant identifiable as more refined qualia. Rather amusingly, visual colors would correspond to increments of color quantum numbers assignable to quarks and gluons in standard model physics. The term "color", originally introduced as an algebraic joke, would directly relate to visual color.

NMP demands that self generates NE. One manner to achieve this is by performing a state function reduction to opposite boundary of CD meaning death and re-incarnation of self. The more pleasant option is to become an NE gatherer so that negentropic mental images are created: selves try to eat other selves to get negentropic sub-selves. This is nothing but metabolism with metabolites identifiable as negentropic carriers of quantum numbers. Fundamental qualia would correspond to quantum numbers for metabolites.

Quantum model for intelligent system

The concept of self provides justification for the assumptions behind the quantum model for intelligent systems [K26]. One can understand at very general level the mechanism for how universe forms abstractions about itself. Even the basic hierarchical structures of language could be identified in terms of Russian doll like structure formed by selves with phonemes possibly representing the lowest level selves in case of language. The possibility of NE possible in the intersection of real and p-adic worlds is perhaps the most important new element and makes possible the identification of quantum correlates of rules and abstractions. The intersection is number theoretically universal so that the number field assigned with it is some extension of rationals depending on the evolutionary level. NE in the intersection defines symbolic (real) and cognitive representations (p-adic) accompanying each other. Time-like negentropic entanglement between boundaries of CD in fermionic degrees of freedom is in principle also possible and would provide a natural representation for a Boolean rule $A \to B$ with paired instances of A and B represented by state pairs.

The close connection with the computationalistic approach to psychology and consciousness is obvious. The hierarchy of selves is analogous to a hierarchy of higher level computer languages. Note also the analogy with the hierarchy of the modules of a computer program. Selves could be interpreted as symbolic representations for the objects of external (and internal) world and cascades of selves generating selves inside selves provide a model for sensory experience and cognition. This model provides also a possible representation for logical implication sequences as temporally

ordered sequences generating sub-selves. NE between selves is a good candidate for representing how wholes are formed from parts consciously as also for the formation of associations. Abstraction process emerges naturally as a formation of quantum average selves about the sub-sub-selves of self. Zero energy ontology is ideal for construction of hierarchies as negentropically entangled states formed from zero energy states formed from....

NE and also quantum statistical determinism makes possible reliable thinking and sensory experiencing at the level of self and one could in principle model brain and sensory organs as ensembles of sub-sub-systems for which quantum measurement of certain observables occurs in quantum jump leading to the thought or sensory experience [K26]. For negentropic entanglement the outcome of the state function reduction is rather deterministic but U process can generate ensemble since one can obtain from a given negentropically entangled state new ones by permuting the entangled state pairs. This kind of transformation makes possible to realize quantum computations using negentropic qubits formed by entangled positive and negative energy parts of the state [K73]. Biological quantum computation could be rely on this kind of fuzzy qubits and the model of DNA as a topological quantum computer [K3] can be formulated in terms of negentropic qubits. What is especially nice is that temporal statistical averages become possible since mind-like space-time sheets can have also time-like distance: thus individual can learn form experience if temporal ensemble of cognitive space-time sheets is available.

Do positively colored emotions allow a representation of Boolean logic?

Weak form of NMP allows the state function reduction to occur in $2^n - 1$ ways corresponding to subspaces of the sub-space defined by n-dimensional projector if the density matrix is n-dimensional projector (the outcome corresponding to 0-dimensional subspace and is excluded). If the probability for the outcome of state function reduction is same for all values of the dimension $1 \leq m \leq n$, the probability distribution for outcome is given by binomial distribution $B(n,p)$ for $p = 1/2$ (head and tail are equally probable) and given by $p(m) = b(n,m) \times 2^{-n} = (n!/m!(n-m)!) \times 2^{-n}$. This gives for the average dimesion $E(m) = n/2$ so that the negentropy would increase on the average. The world would become gradually better. Note that one assumes that there is some preferred basis for the states and these numbers apply when this basis is given.

One cannot avoid the idea that these different degrees of negentropic entanglement could actually give a realization of Boolean algebra in terms of conscious experiences.

1. There should be a mapping of k-dimensional subspaces of n-dimensional space to the fermionic representation of Boolean algebra

2. Could one speak about a hierarchies of codes of cognition based on the assignment of different degrees of "feeling good" to the Boolean statements? If one assumes that the n:th bit is always 1, all independent statements except one correspond at least two non-vanishing bits and corresponds to negentropic entanglement. Only of statement (only last bit equal to 1) would correspond 1 bit and to state function reduction reducing the entanglement completely (brings in mind the fruit in the tree of Good and Bad Knowlege!).

3. A given hierarchy of breakings of super-symplectic symmetry corresponds to a hierarchy of integers $n_{i+1} = \prod_{k \leq i} m_k$. The codons of the first code would consist of sequences of m_1 bits. The codons of the second code consists of m_2 codons of the first code and so on. One would have a hierarchy in which codons of previous level become the letters of the code words at the next level of the hierarchy.

In fact, I ended up with almost Boolean algebra for decades ago when considering the hierarchy of genetic codes suggested by the hierarchy of Mersenne primes $M(n+1) = M_{M(n)}$, $M_n = 2^n - 1$.

1. The hierarchy starting from $M_2 = 3$ contains the Mersenne primes $3, 7, 127, 2^{127} - 1$ and Hilbert conjectured that all these integers are primes. These numbers are almost dimensions of Boolean algebras with $n = 2, 3, 7, 127$ bits. The maximal Boolean sub-algebras have $m = n - 1 = 1, 2, 6, 126$ bits.

2. The observation that $m = 6$ gives 64 elements led to the proposal that it corresponds to a Boolean algebraic assignable to genetic code and that the sub-algebra represents maximal number of independent statements defining analogs of axioms. The remaining elements would correspond to negations of these statements. I also proposed that the Boolean algebra with $m = 126 = 6 \times 21$ bits (21 pieces consisting of 6 bits) corresponds to what I called memetic code obviously realizable as sequences of 21 DNA codons with stop codons included. Emotions and information are closely related and peptides are regarded as both information molecules and molecules of emotion.

3. This hierarchy of codes would have the additional property that the Boolean algebra at $n + 1$:th level can be regarded as the set of statements about statements of the previous level. One would have a hierarchy representing thoughts about thoughts about.... It should be emphasized that there is no need to assume that the Hilbert's conjecture is true.

   One can obtain this kind of hierarchies as hierarchies with dimensions $m, 2^m, 2^{2^m}, ...$ that is $n(i+1) = 2^{n(i)}$. The conditions that $n(i)$ divides $n(i+1)$ is non-trivial only for at the lowest step and implies that m is power of 2 so that the hierarchies starting from $m = 2^k$. This is natural since Boolean algebras are involved. If n corresponds to the size scale of CD, it would come as a power of 2.

   p-Adic length scale hypothesis has also led to this conjecture. A related conjecture is that the sizes of CDs correspond to secondary p-adic length scales which indeed come as powers of two. In case of electron this predicts that the minimal size of CD associated with electron corresponds to time scale $T = .1$ seconds, the fundamental time scale in living matter (10 Hz is the fundamental biorhythm). It seems that the basic hypothesis of TGD inspired partly by the study of elementary particle mass spectrum and basic bio-scales (there are 4 p-adic length scales defined by Gaussian Mersenne primes in the range between cell membrane thickness 10 nmandsize 2.5 μm of cell nucleus!) follow from the proposed connection between emotions and Boolean cognition.

Hilbert's conjecture relates in interesting manner to space-time dimension. Suppose that Hilbert's conjecture fails and only the four lowest Mersenne integers in the hierarchy are Mersenne primes that is $3, 7, 127, 2^{127} - 1$. In TGD one has hierarchy of dimensions associated with space-time surface coming as 0, 1, 2, 4 plus embedding space dimension 8. The abstraction hierarchy associated with space-time dimensions would correspond discretization of partonic 2-surfaces as point set, discretization of 3-surfaces as a set of strings connecting partonic 2-surfaces characterized by discrete parameters, discretization of space-time surfaces as a collection of string world sheet with discretized parameters, and maybe - discretization of embedding space by a collection of space-time surfaces. Discretization means that the parameters in question are algebraic numbers in an extension of rationals associated with p-adic numbers.

In TGD framework it is clear why embedding space cannot be higher-dimensional and why the hierarchy does not continue. Could there be a deeper connection between these two hierarchies. For instance, could it be that higher dimensional manifolds of dimension $2 \times n$ can be represented physically only as unions of say n 2-D partonic 2-surfaces (just like $3 \times N$ dimensional space can be represented as configuration space of N point-like particles)? Also infinite primes define a hierarchy of abstractions. Could it be that one has also now similar restriction so that the hierarchy would have only finite number of levels, say four. Note that the notion of n-group and n-algebra involves an analogous abstraction hierarchy.

How memories are represented and recalled?

Formation of memories and memory recall are key elements in the vision proposed by Hawkins [J109]. The question is what memories and memory recall are. If quantum jump is the fundamental process, it should automatically give rise to memories and memory recall.

1. Memories in given scale would naturally correspond to sequences of mental images defined by negentropically entangled sub-CDs of CD in given scale. According to earlier view the sequences of moments of consciousness bind to form higher level moments of consciousness, selves. Somewhat different view is that formation of selves means formation of sequence of

negentropically entangled sub-CDs stable against NMP and preserved in quantum jump and even increasing in size. Thus self would correspond to a property of state and consciousness would be associated with the replacement of state with a new one.

2. The hierarchical structure of memories would emerge naturally. Conscious memory recall would correspond to a generation of negentropic entanglement between the new mental images emerging in the state function reduction (recall that the sizes of CDs increase and new sub-CDs emerge) and already existing negentropically entangled mental images. Generation of negentropic entanglement would give rise to the experience of recognition of the new mental images.

3. The natural guess is that negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is generated if the new sensory input is "consistent" with older mental images. The addition of new tensor factor would mean a more abstract representation so that the sequence of quantum jumps would mean accumulation of experience. Consistency with older mental images could mean that the mental images have same "name". The name could correspond to p-adic cognitive representation. The physical correlate could be a collection of resonance frequencies. The names would be same if the frequencies for older mental images and new one are same, so that resonant interactions becomes possible. The generation of negentropic entanglement would be like finding a radio station.

For this proposal memory recall and memory formation are actually more or less the same thing. Only the completely new memories claimed to be formed in hippocampus would not involve memory recall. The new memory would correspond to a new sub-CD or ensemble of sub-CDs representing the associated negentropically entangled mental images. Neuronal loop could make possible to build copies about the new memory and thinking about it would create copies of corresponding p-adic cognitive representations which in turn could be transformed via state function reduction to an opposite boundary of CD to actions. In TGD framework the 4-D hierarchy of memories could continue from hippocampus to the magnetic body: this would explain the correlation of EEG with memory and also with various other brain functions.

Self as a moral agent

There are many ways to interpret evolution in TGD Universe.

1. p-Adic evolution would mean a gradual increase of the infinite p-adic prime characterizing the entire universe implying the gradual increase of p-adic primes characterizing individual partonic 2-surfaces and therefore their size. Infinite primes at the n:th level of hierarchy defining the analogs of bound states of multiply second quantized arithmetic quantum field theory can be mapped to irreducible polynomials of n variables and for $n = 1$ they define irreducible extensions of rationals. Infinite integers in turn define polynomials giving rise to reducible extensions of rationals. Hence infinite primes having interpretation in terms of bound states define levels of the hierarchy of algebraic extensions defining evolutionary hierarchy.

2. The hierarchy of Planck constants suggests evolution as the gradual increase of the Planck constant characterizing p-adic space-time sheet (or partonic 2-surface for the minimal option). This evolution could be seen as a migration to the pages of the book like structure defined by the generalized embedding space and has therefore quite concrete geometric meaning. It implies longer time scales of long term memory and planned action and macroscopic quantum coherence in longer scales.

3. The vision about life as something in the intersection of real and p-adic words allows to see evolution information theoretically as the increase of number entanglement negentropy implying entanglement in increasing length scales. This option is consistent with the first one if the effective p-adic topology characterizes the real partonic 2-surfaces in the intersection of p-adic and real worlds. The singular coverings of CD s and CP_2 are characterized by an Abelian group Z_n permuting the sheets of the covering and corresponds naturally to powers

of the (quantum) phase $q = exp(i2\pi/n)$ allowing to define the notion of angle in p-adic context but only with a finite resolution since only finite number of angles are represented as phases for a given value of n. The increase of the integers n could be interpreted as the emergence of higher algebraic extensions of p-adic numbers in the intersection of the real and p-adic worlds. These observations suggest that all three views about evolution are closely related.

The third kind of evolution would mean also the evolution of spiritual consciousness if the proposed interpretation is correct. In each quantum jump U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function redution process involves also the choice of the type of entanglement it could be interpreted as a choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The selfish option has the risk of leading to non-algebraic bound state entanglement implying a loss of consciousness: death as the prize of sin. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices.

In this framework one could therefore understand the physics correlates of ethics and moral. The ethics is simple: evolution of consciousness to higher levels is a good thing. Anything which tends to reduce consciousness represents violence and is a bad thing. Moral rules are related to the relationship between individual and society and presumably develop via self-organization process and are by no means unique. Moral rules however tend to optimize evolution. As blind normative rules they can however become a source of violence identified as any action which reduces the level of consciousness.

Weak form of NMP indeed allows the self to choose between good and evil since the reduction need not take place to the maximal dimension n_{max} defined by the projector in question but also to sub-spaces. This in fact allows to have larger negentropy gains as strong form of NMP: when n_{max} is product of primes it can happen that some smaller integer has larger power of prime as a factor so that negentropy gain is larger. The choice $n = 1$ means vanishing negentropy gain and implies isolation of self. Weak form of NMP makes also possible realization of Boolean algebra in terms of the lattice of sub-spaces of the n_{max}-dimensional space: only that $n = 0$ case is excluded so that one has $2^{n_{max}} - 1$ choices. In set theoretic representation of Boolean algebra this option corresponds to empty set.

There is an entire hierarchy of selves and every self has the selfish desire to survive and moral rules develop as a kind of compromise and evolve all the time. The need to satisfy the needs of NMP without dying (this in general means increase of negentropy) has led to the discovery of metabolism as the fundamental form of crime! Self can eat other selves and in this manner gain the NE of sub-selves and live longer. This has the positive outcome that self makes possible for its sub-selves (mental images) to evolve via repeated death and re-incarnations. Replication of magnetic bodies having concrete counterpart as splitting of 3-surfaces analogous to 3-particle vertex of Feynman diagram is another discovery making it possible for selves to replicate.

The newest progress in this evolution is brought by the cosmology of consciousness, which forces to extend the concept of society to four-dimensional society! The decisions of "me now" affect both my past and future and time like quantum entanglement makes possible conscious communication in time direction by sharing conscious experiences. One can therefore speak of genuinely four-dimensional society. Besides my next-door neighbors I had better to take into account also my nearest neighbors in past and future (the nearest ones being perhaps copies of me!). If I make wrong decisions those copies of me in future and past will suffer the most. Perhaps my personal hell and paradise are here and are created mostly by me.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* space-time region, rather than only time=constant snapshot, and gives rise to a "prophecy", a prediction for the future and past, which would be reliable if the world were completely classical). As a matter fact, it is p-adic space-time sheets which correspond to intentions and plans and act of volition transforms p-adic space-time sheet to a real one. Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps. Thus selves are genuine moral agents.

Self-referentiality of consciousness and evolution

Quantum classical correspondence is the basic guiding principle of quantum TGD. Thanks to the failure of a complete determinism of classical dynamics, space-time surface can provide symbolic representations not only for quantum states (as maximal deterministic regions) but also for quantum jump sequences (sequences of quantum states) and thus for the contents of consciousness. These representations are regenerated in each quantum jump, and make possible the self referentiality of consciousness: self can be conscious of what it *was* conscious of. This allows to avoid infinite regress and replaced it with endless evolution.

Evolution in turn involves several aspects. The increase of the complexity of the algebraic extension of rationals in the intersection of reality and p-adicities and by strong form of holography identifiables as string world sheets and partonic 2-surfaces whose parameters (WCW coordinates essentially) are in the extension. The ramified primes in the extension define the preferred primes.

In strong form of holography p-adic continuations of 2-surfaces to preferred extrmals identifiable as imaginations would be easy due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K81]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes.

NMP leads to a generalizations of p-adic length scale hypothesis stating that primes near powers of prime are favoured. Generation of NE defining Akashic records is a one aspect of evolution. Increase of Planck constant $h_{eff} = n \times h$ and thus size scale of macroscopic quantum systems and CDs serving as correlates of selves is second aspect of evolution.

6.2.5 General Structure Of Conscious Experience

Combining summation hypothesis and the hypothesis about subjective memory one can understand quite a lot about the phenomenology of consciousness.

Summation hypothesis

Binding of selves by entanglement and summation hypothesis are the basic assumptions about the structure of contents of consciousness of self. Unentangled sub-system X possessing self behaves essentially as a separate sub-Universe with respect to NMP. This means that unentangled subsystems X_i of X, in particular sub-selves, participate in each quantum jump. If one postulates that the conscious experiences of sub-systems X_i of unentangled sub-system X integrate with the self experience of X to form single experience, one obtains a filtered hierarchy of conscious experiences with increasingly richer contents. The integrated experience cannot a simple sum of individual experiences of sub-selves (we do not experience the conscious experiences of neurons separately). Rather, the experience of X is most naturally sum of abstractions about experiences of X_i. A natural hypothesis is that X forms kind of abstraction or average $\langle X_{ij} \rangle$ about the experiences of sub-selves X_{ij} of X_i representing what it is to be average X_{ij}, that is average over the mental images of X_i.

This kind of mechanism would explain why we do not experience the experiences of individual neurons, microtubules, DNA: s, etc... as a huge multitude of separate experiences and do note get drowned to useless information. Combining summation hypothesis with the hypothesis about subjective memory (described in previous section), one can understand self as an object having genuine extension in subjective time. In particular, it is possible to identify short term memory as a subjective memory. Also temporal average in geometric sense is possible since mind-like space-time sheets can have also time-like separation.

A challenge for the hypothesis of self and summation hypothesis is provided by split brain patients [J26]. It seems that in most serious cases either right or left half dominates the behavior of the split brain patient and communication between brain hemispheres is lacking. It is known that brain hemispheres learn to communicate indirectly. Is the hypothesis about summation of the right and left selves to form mental images of a higher self ireally consistent with the behaviour of split brain patients?

1. The dominance of either hemisphere is highly analogous to the dominance of a person over another one. The sudden changes of personality can be understood as result of different cognitive specializations of the two hemispheres. The lacking information transfer between hemispheres explains why right and left brain behave so differently (to the extend that they can have different future plans!). It is well known that in early childhood hemispheres behave as separate personalities and certain period in the learning of language seems to involve communication between brain hemispheres: left hemisphere comments what right hemisphere is doing. This kind of direct communication usually ceases, when the direct physical connection between brain hemispheres has developed.

2. One must of course ask what "dominance" really means. A possible definition is based on the notion of self hierarchy and magnetic body as intentional agent. Magnetic body could direct its attention in normal circumstances to either left hemisphere or right hemisphere or both if they are entangled (entropically or negentropically). The unattended hemisphere could be conscious but would not contribute to the conscious experience of the magnetic body representing us. Corpus callosum- the axon bundle connecting right and left hemisphere- would serve as a natural correlate for their entanglement, which should be negentropic in the normal situation. Quite generally, axons would serve as correlates for the entanglement so that also sensory receptors would be in this sense part of the brain. Note that this would make possible macroscopic quantum coherence between distance parts of body and brain and the regions of quantum coherence would be highly irregular.

3. The alternating hemisphere dominance characterizes also healthy persons and could provide magnetic body with three different views about world corresponding to hawks and doves and those between. Problems begin when either hemisphere dominates for too long time. For instance, for schizophrenics the time of dominance is longer than normally. For split brain patients the absence of physical connection between hemispheres makes impossible quantum entanglement binding the hemispheres together to form single coherent whole and the body of the patient is inhabited by two persons. The length of time-interval during which given hemisphere contributes to our conscious experience could be rather short. Interestingly, in the case of dolphins and some birds the second hemisphere sleeps. Is this for metabolic reasons or is the second hemisphere entangled with the collective consciousness of the dolphin horde? The theory of bicameral mind assumes that human consciousness before the evolution of language was dominated by another hemisphere entangled with collective level of consciousness. I have discussed a model of bicamerality in the earlier formulation of TGD inspired theory of consciousness in [K107, K108]. One can of course whether that dolphins could represent a modern example about bi-cameral consciousness.

Sharing and fusion of mental images

The standard dogma about consciousness is that it is completely private. It seems that this cannot be the case in TGD Universe. Von Neumann algebras known as hyper-finite factors of type II_1 (HFF) [K138, K44] provide the basic mathematical framework for quantum TGD and this suggests important modifications of the standard measurement theory besides those implied by the zero energy ontology predicting that all physical states have vanishing net quantum numbers and are creatable from vacuum. The notion of measurement resolution characterized in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of HFFs implies that entanglement is defined always modulo some resolution characterized by infinite-dimensional sub-Clifford algebra $\mathcal{N}$ playing a role analogous to that of gauge algebra.

This modification has also important implications for consciousness. For ordinary quantum measurement theory separate selves are by definition unentangled and the same applies to their sub-selves so that they cannot entangle and thus fuse and shared mental images are impossible: consciousness would be completely private.

Space-time sheets as correlates for selves however suggests that space-time sheets topologically condensed at larger space-time sheets and serving as space-time correlates for mental images can be connected by flux tubes so that mental images could fuse and be shared.

HFFs allow to realize mathematically this intuitive picture. The entanglement in $\mathcal{N}$ degrees of freedom between selves corresponding to $\mathcal{M}$ is below the measurement resolution so that these

selves can be regarded as separate conscious entities. These selves can be said to be unentangled although their sub-selves corresponding to $\mathcal{N}$ (mental images at upper level) can entangle. Fusion and sharing of mental images becomes possible. For instance, in stereo vision right and left visual fields would fuse together. More generally, a pool of shared stereo mental images might be fundamental for evolution of social structures and development of social and moral rules and language (shared mental images make possible common meaning for symbols of language). A concrete realization for this would be in terms of hyper-genome making possible collective gene expression [K52, K65].

Self as a statistical ensemble, emotions, and qualia

The sequence of quantum jumps defining self defines also a sequence of completely unentangled quantum states resulting in the state reduction process governed by NMP. This set of states, which grows in size quantum jump by quantum jump, defines in a natural manner a statistical ensemble identifiable as the fundamental realization of the otherwise fictive notion of statistical ensemble fundamental in the formulation of statistical physics. As far as conscious experience is involved, it seems that it is the increments of quantum numbers and zero modes which are the relevant statistical variables.

This observation anchors the theory of conscious experience to statistical physics [K50]. For instance, the increments of zero modes resp. quantum numbers are responsible for geometric resp. non-geometric qualia. More precisely, the gradients with respect to subjective time for the zero modes and for the net quantum numbers associated with selves correspond to qualia. One can classify non-geometric qualia to kinesthetic qualia (sense of pressure and force and, more generally, gradient of any conserved (with respect to geometric time) quantity associated with self with respect to subjective time); and generalized chemical qualia (rates for the changes of numbers of particles with various quantum numbers). Various entropies associated with self and sub-selves in turn characterize the sharpness of the mental images, and one can relate concepts like attentiveness, alertness and the level of arousal to these variables.

Statistical aspect could be involved with sensory experiences also in the sense of ensemble averaging. For instance, various cones of retina are sensitive to different wavelength regions (red, green, blue) and their experiences must correspond to different colors. Therefore our color experience, which corresponds to average color, should be abstraction about experiences of a small group of retinal cells. Ensemble averaging could be present in case of sense such as temperature and pressure sense. Also temporal averaging with respect to *geometric* time would be made possible by mind-like space-time sheets and could be present.

The original proposal was that emotions some kind of qualia since also ordinary qualia have the characteristic black-white dichotomies. What is clear that emotions relate very closely to information. For instance, peptides are both informational molecules and molecules of emotion [J55]. This suggests that positive-negative dichotomy for emotions correlates directly with negentropic-entropic dichotomy for entanglement. For instance, the neurotransmitters producing positive (negative) emotions would generate negentropic (entropic) entanglement. The fate of the right amygdala would be a specialization to experience negative emotions by entangling mostly by bound state entanglement whereas left amygdala specialized to positive emotions would enjoy the negentropic entanglement.

In positive energy ontology it seems impossible to have quantum coherence in human time scales. The occurrence of 10^{39} quantum jumps per second probably means that at the lowest level of self hierarchy corresponding to time scale which is 10^4 Planck times statistical averaging thermalizes sub-selves completely so that mental images would contain no information. Decoherence is the physical counterpart of this process. In zero energy ontology the situation changes. The time scale assignable to CDassumed to be an octave of CP_2 time represents a completely new time scale which is macroscopic even for elementary particles. This time scale provides a simple estimate for the average increment of psychological time per quantum jump. For electron and quarks the time scales are.1 seconds and 1 millisecond and correspond to basic time scales of nervous system. The hierarchy of Planck constants allows to scale up these time scales and makes possible communication using photons with arbitrarily low wave lengths since large enough Planck constant implies that the energy of photon is above the thermal threshold. Negentropic entanglement makes possible the formation of completely new kind of macroscopic quantum systems. Time-

like entanglement makes possible fusion of quantum jumps to longer quantum jumps and thus macrotemporal quantum coherence.

The feed of metabolic energy could destroy entropic entanglement and feed negentropic entanglement as such: for a simple model see [K45, K46]. Interestingly, there is a well-documented disease in which the patient can live for decades in single frozen moment of consciousness. Is negentropic entanglement with abnormally large value of Planck constant in question? Or is entropic entanglement with abnormally large binding energy and therefore not possible to destroy by the feed of standard metabolic energy quanta in question?

Reducible and irreducible selves

Sub-selves correspond to mental images of self. Irreducible selves do not posses sub-selves and have thus no mental images. The interpretation of this kind of experience -if possible in practice- would be as a pure awareness without content. Whether this kind of states are really possible is not obvious since any space-time sheet contains smaller space-time sheets. When all sub-selves of self fuse (negentropically) together to yield a kind of stereo-consciousness (fusion of left and right visual fields gives rise to 3-D stereo vision), something exceptional results also. One might interpret this kind of state as whole-body consciousness, a state of oneness in very literal sense. Synchronous neuronal firing could be a signature of this kind of states at neuronal level. Reducible selves have several sub-selves experienced as mental images. One can model conscious processing as cascades leading to creation of sub-selves of sub-selves of...: selves are interpretable as symbolic representations of objects of sensory experience and a close parallelism with computationalism and connectivism emerges. In zero energy ontology negentropically entangled zero energy states form this kind of hierarchy.

6.2.6 Binding And Quantum Entanglement

How different components of conscious experiences, such as various sensory qualia and the active components of conscious experience involving thoughts, conscious selections and volition, integrate to single experience, is known as binding problem. In the original approach I distinguished between binding of conscious experiences and binding of conscious experiencers. Since mental images define experiences and are itself experiencers at a lower level of hierarchy, there seems however to be no need for this kind of distinction.

Negentropic entanglement as a mechanism of binding

Quantum entanglement provides a mechanism of binding of selves to larger selves. If the entanglement is negentropic, selves would experience an expansion of consciousness in the fusion. I have considered also the possibility of bound states entanglement and suggested that this leads to a loss of consciousness. Certainly bound state entanglement in the generic case cannot correspond to NE for which density matrix is projector. Whether conscious is lost in the formation of bound state entanglement and whether the higher level system is conscious remain open questions.

At the level of mental images (sub-selves) NE corresponds to the integration of parts to wholes. NE could create mental images representing rules as a collection of instances of rule as pairs of quantum states. Negentropically entangled Schrödinger cat would know that it is better to not open the bottle.

The successes of p-adic physics suggest that it should be possible to label also real selves/space-time sheets by p-adic primes. NMP and adelic view give strong support for this view. Algebraic extensions of rationals define a hierarchy and the parameters characterizing string world sheets and partonic 2-surfaces in the intersection of real and p-adic worlds belong to these algebraic extensions. By strong form of holography these surfaces carry the information about both space-time surfaces and quantum states and define cognitive representations. Boolean cognition (fermions) and cognitive representations reside in the intersection.

p-Adic primes would naturally correspond to so called ramified primes of extension. In strong form of holography p-adic continuations of 2-surfaces to preferred extrmals identifiable as imaginations would be easy due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector:

the interpretation would be that some space-time surfaces can be imagined but not realized [K81]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes.

NMP leads to a generalization of p-adic length scale hypothesis so that also primes powers of general prime rather than only $p = 2$ are allowe. Hence also real selves would form a p-adic hierarchy. Sensory experience corresponds to the space-time surfaces and to the classical correlates of quantum states. Both p-adic length scale hierarchy and its generalizations and the hierarchy of Planck constants reduce to the hierarchy of algebraic extensions of rationals.

The fusion of selves to a larger self by bound state entanglement means a formation of a bound state and the binding energy could be liberated as a usable energy. Thus quantum metabolism could accompany the negentropic binding of the mental images. In the case of NE the possibility that the binding energy is effectively negative would also make possible liberation of energy, and I have proposed that this might take place in $ATP \to ADP + P_i$ defining the fundamental step of metabolism in which the high energy phosphate bond is believed to liberate metabolic energy quantum [K45, K46]. High energy phosphate bond could correspond to a magnetic flux tube carrying NE. Jail and love are good metaphors for the two kinds of correlations represented by bound state entanglement and NE. The recent view is that metabolites are NE carriers and that NE is transferred to the used in metabolism. This applies to all forms of metabolism, not only energy metabolism.

Different components of sensory experience, even sensory qualia, naturally correspond to separate sub-selves, whose individual experiences are separate but combine to form various qualia in our experience. In TGD framework they could correspond to sensory pathways or parts of them and perhaps containing also primary sensory organs: this option looks at this moment the most convincing one. Quite generally, it seems that the reliability of the sensory experiences and the absence of experienced volition is guaranteed by the hypothesis about subjective memory.

In accordance with this, the experienced volition is most naturally related to the first state function at the opposite boundary of CD and means death and re-incarnation of corresponding self producing in typical case negentropy by NMP. Sensory perception in turn can be assigned to the sequence of state function reductions at fixed boundary of CD defining sensory mental images as sub-self.

For instance, synchronous neuronal firing could be understood as a consequence of almost simultaneous wake-up of neuronal sub-selves near criticality for phase transition changing the local topology of the space-time sheets associated with sub-self. 40 Hz neural synchrony to be discussed later has a nice interpretation in terms of the generation of NE.

If neurons have sub-selves, also subneuronal quantum jumps are possible and this could eventually make synchronous assembly and de-assembly of microtubules and even synchronously occurring biochemical reactions possible. Primary sensory experiences could occur in part of the sensory pathway containing also primary sensory organ and nerve pulse activity could be regarded as resulting from the creation or wake-up of sensory sub-self by quantum jump leading to state able to remain unentangled. It came as a surprise that in TGD universe our sensory representations (an entire hierarchy is involved) could be realized at the magnetic sensory canvas associated with the electromagnetic body accompanying the physical body and having size much larger than the physical body [K62].

A possible example of the bound state entanglement of sub-selves could be the binding of right and left visual fields to single visual field. The visual fields can sometimes fail to bind: this should result from the failure of the corresponding sub-selves to generate mutual entanglement with sufficient rate or at all (the connection between brain hemispheres is lacking).

Bio-feedback is a well-established phenomenon in which person receives feedback from the behaviour of, say, single neuron and learns to control voluntarily its behaviour. A possible mechanism of bio-feedback is based on quantum entanglement generated between the (sub)self of the person and the self of neuron. Socio-feedback at the level of entire society could be important mechanism making possible to establish moral and behavioural rules of the society: this socio-feedback is perhaps the basic function of sleep.

Binding geometrically

Quantum-classical correspondence suggests that the concept of binding should have a counterpart at the level of space-time geometry. The gluing of the space-time sheets by topological sum to larger space-time sheets creates nested hierarchical structures. This suggests that the summation of mental images to a collection of mental images experienced by a given self corresponds geometrically to the gluing of the material space-time sheets of sub-selves to the material space-time sheet of self by topological sum operation involving the formation of "wormhole contacts" (having physical identification as bosons and their super partners).

The binding of experiences (or experiencers) in turn would naturally correspond to the glueing of 3-surfaces together along their boundaries by join along boundaries bonds (topological sum for boundaries). Magnetic flux tubes is the more recent term meaning essentially same as join along boundaries bond. Magnetic flux tubes define a correlate for both kinds of entanglement.

The geometric counterpart of self defines a geometric representation for the subjective history of the self. For instance, larger mind-like space-time sheets at the higher level of the hierarchy could contain or generate holes making possible for smaller mind-like space-time sheets to form magnetic flux tubes. This mechanism would provide a concrete geometric realization for the communication between different levels of the hierarchy of selves. For instance, long term memories could become conscious through this kind of mechanism.

There are several arguments supporting the importance of flux tubes.

1. The dynamical realization of the self hierarchy as a master-slave hierarchy of various kinds of super conductors [K89, K88] relies on the identification of the magnetic flux tubes between the space-time sheets belonging to various levels of hierarchy as Josephson junctions. The "biofeedback" made possible by the magnetic flux tube makes it possible for the selves at higher levels of the hierarchy to experience what it is to be lower level self. In particular, our immediate sub-selves are represented by topological field quanta of ELF em fields associated with EEG frequencies and thus have size of order Earth's circumference by Uncertainty Principle, whereas sensory experiences involve in essential manner entanglement with sub..sub-selves with size scale of neuronal circuits.

2. Magnetic flux tubes are perhaps the most interesting magnetic flux tubes in the TGD based quantum model of biology. Wormhole magnetic flux tubes consisting of a pair of space-time sheets with opposite time orientations, carrying magnetic fluxes with opposite directions, and containing also dark matter with large value of Planck constant are especially interesting. They play a key role in TGD inspired view about bio-chemistry and in the model of DNA as topological quantum computer [K3].

Cognitive entanglement between real and p-adic variants of the partonic 2-surface should be probable only for preferred primes. The successful applications of p-adic physics give good reasons to believe that real partonic 2-surfaces and also space-time regions can be a labelled by p-adic primes characterizing their effective p-adic topology. This should make sense at least in the intersection of real and p-adic worlds. The most natural entanglement is between partonic 2-surface and its p-adic counterpart and has maximum for a unique prime. One expects that this negentropy is expressible solely in terms of rational and common algebraic points of real and p-adic surfaces and thus using only the data about real partonic surface. If this entanglement negentropy has a space-time correlate, one could expect that it is maximum for the same prime and that the geometry of the partonic 2-surface and perhaps also of corresponding light-like 3-surface and even of a 4-D space-time region reflects this p-adic topology. This prime could characterize the local p-adic topology to which the real region can be transformed easily (, that is criticality against this kind of transition). This easiness could be measured by the total number of rational and common algebraic points of the partonic 2-surface if the transition amplitude is expressible in terms of the information coming from the common points.

It has become clear that the effective p-adic topology most naturally manifests itself rather abstractly at the level of WCW and by strong form of holography for the parameters of string world sheets and partonic 2-surfaces belonging to an algebraic extension of rationals defining also the extension of p-adic numbers. It is of course quite possible that these parameters have interpretation in terms of space-time geometry and topology. Good example is provide by the

conformal moduli characterizing the conformal equivalence classes of partonic 2-surfaces and string world sheets. They have rather concrete geometric interpretation (say as positions for punctures). p-Adic variants of Teichmueller parameters indeed emerged first in p-adic mass calculations [K27]. What is nice is that these parameters are general coordinate invariants so that one avoids the problems with General Goordinate Invariance resulting if space-time coordinates are p-adicized and one wants to map real and p-adic space-time surfaces to each other.

Wholes and parts

The basic feature of higher level cognition is the formation of wholes from parts. NE between selves representing parts provides an attractive model for this process. NE is indeed highly suggestive in the case of cognition. One can wonder whether positive-negative dichotomy for emotions could reflect the negentropic-entropic dichotomy for entanglements. This would conform with the idea that the transformation of NE to bound state entanglement liberates metabolic energy and information and transforms nutrient to entropic waste. Therefore emotions would not reduce to special kind of qualia. The association of negatively colored emotions with bound state entanglement need not be the correct thing to do. Rather, the color of emotion tells how large negentropy gain is in state function reduction for sub-self. It it vanishes, the emotion is maximally negative.

Sub-selves represent symbolically the components of conscious experience, say letters of the word: in absence of NE between these "letter" selves the sum experience is set of letters whereas higher level experiences is about average letter. If sub-selves get entangled, there are no sub-self-experiences and sum-experience is about the word as is also the higher level experience. Understood word or written language could correspond to NE between the mental images representing letters. This entanglement could be also time like and by light-like 3-surfaces connecting a temporal sequence of CDs.

Entanglement might be also time-like in zero energy ontology and this could relate closely to the differences between right and left hemispheres. For right brain hemisphere time-like (and also space-like) NE could occur in longer time scales than for the left one as the saying right brain sings-left brain talks and the fact that spatial thinking is associated with the right hemisphere suggests.

This overall picture will be applied to the modelling of music experience later. The hypothesis will be also applied to explain paradoxical result of certain experiment testing right-left brain differences.

Entanglement and directed attention

Directed attention is one of the basic processes of consciousness occurring continually. Directed attention seems to involve free choice but focusing of attention could also occur spontaneously. One can approach the problem of identifying the physical correlates of directed attention from several angles.

1. The possibility to interpret self as a statistical ensemble suggests that the entropy of the mental image regarded as ensemble of sub-sub-selves of self measures its fuzziness. The negentropy of the mental image is maximal if sub-sub-selves are negentropically entangled to form a single coherent whole. Both attentiveness, alertness and level of arousal should relate very closely to the negentropy and thermal entropy of the mental image.

   Attention entangles it with the self attending it and creates negentropic system and in this manner prevents NMP to force the death of the mental image. Attention should bring in NE and this requires the feed of metabolites carrying NE.

   7 ± 2 rule of cognitive science suggests that the maximum number of our cognitive subselves, which can be awake simultaneously, is rather limited. The rule might be based on the metabolic limitations: sub-selves can have high energy NE content only in the presence of an external negentropy feed and metabolism must provide the needed negentropy feed. Note however that the needed metabolic energy might be extremely low. One could interpret the focused of attention as a wake-up of sub-self and keeping it in wake-up state and hence in short term memory. This could occur at the expense of the other sub-selves, which would be in wake-up state for only short times.

Negentropic fusion of mental images would be alternative strategy to keep them alive: note however that this requires state function reduction at opposite boundary of the CD involve with them so that the re-incarnated mental images would be fused.

2. One can imagine that sub-sub-self inside sub-self representing mental image (say "monitor screen" as average over subs-ub-selves representing the visual objects) somehow pops up one level higher in the self hierarchy so that it becomes mental image. Geometrically this could correspond to the re-gluing of the corresponding space-time sheet to the space-time sheet of self instead of that of sub-self. Negentropic entanglement could be in question.

3. Self is assumed to experience the sub-systems immediately below it in the hierarchy or perhaps to the entire collection of mental images. This might however not be what attention is basically. Rather, attention seems to select one particular mental image and put other mental images to background and feed NE to this mental image as its mental images. It seems possible to direct attention to lower levels of the self hierarchy than the one immediately below. For instance, I can direct my attention to the entire sentence, which I am writing here or to some word of this sentence or to individual letters of this word. The phenomenon of bio-feedback demonstrates that it is possible to learn to direct the attention to even single neuron. This suggests that selves are able to modify the hierarchy of selves by raising some sub...sub-self to the role of sub-self temporarily and thus experience the former sub...sub-self as a direct mental image.

4. The formation of the flux tubes between mind-like space-time sheets belonging to different levels of the self hierarchy provides a candidate for the geometric correlate of directed attention. A formation of flux tube connecting partonic 2-surface assignable to self with a partonic 2-surface assignable to sub-self would be in question. Both the directed character of attention and the selection of a particular mental image would have clear geometric correlates. The attention to an object of perceptive field would separate the corresponding mental image from the fusion of mental images. In the case of bound state entanglement this would require the feed of metabolic energy. In the case of negentropic fusion carrying energy it could liberate metabolic energy.

Anyone can do a simple but thought provoking experiment suggesting the presence of the macroscopic quantum entanglement at the level of brain and a change of the level of sub-self in the self hierarchy. Look at a mirror, direct your attention at your left eye, and redirect the gaze to the right eye. What you find that it is impossible to perceive the change in the direction of the eye gaze.

1. Consider first what probably happens when we perceive a moving object. A negentropic binding of the mental images of the visual field to single mental image implies that both the parts and the whole can be experienced so that the motion is perceived. If the direction of the gaze is stationary, the object moves relative to the background, and if the direction of the gaze follows the object the background moves with respect to the direction of gaze. In both cases the motion can be perceived.

2. If the eye follows its own rotating mirror image, neither of these options is realized if the environment to which the attention is directed is restricted to be the eye itself. The direction of the gaze should remain the same in order to perceive the change of the direction of the gaze but this is impossible.

3. The perceptive field however contains also other objects and one could argue that if the attention is directed also to these simultaneneously, it should be possible to perceive the changing direction of gaze as they move relative to the changing direction of gaze. Does the very act of directing attention to the mirror image of eye separate it from the NE with the other mental images so that the conscious comparison with them is not possible anymore? Or is the visual mental image representing eye at a different level of hierarchy from the very beginning and cannot negentropically entangle with the other visual mental images? Eye cannot perceive itself! Not even in mirror.

4. This argument raises the question whether it is possible to perceive the the motion of object if the attention is permanently directed to it? Is it necessarily to direct the attention only temporarily to the object and whether the saccadic motion of eyes could relate to this? There are almost incredible sounding experiments demonstrating that the attention directed intensely to a fixed object makes it impossible to become aware what happens in environment.

Entanglement and altered states of consciousness

NE might provide the Royal Road to the understanding of altered states of consciousness. Entanglement can take place both at the level of self and sub-selves, In the latter case one can consider the possibility that self can choose in state function reduction whether the mental images are entangled entropically or negentropically. Weak form of NMP indeed predicts this.

For self the NE would be kind of moment of mercy by higher level self. Both space-like and time-like entanglement are possible and this can lead to transpersonal experiences and memories extending past the own life time. Also the increases of p-adic prime or Planck constant could be be involved with these experiences. Clearly, a wide repertoire of expanded states of consciousness is predicted. This picture conforms with the view that a certain kind of personal moral and intellectual evolution is a prerequisite for enlightenment experiences.

Examples of altered states of consciousness are transpersonal experiences and enlightenment experiences in which one identifies with some larger consciousness. For instance, prenatal experiences could result from a time-like NE of a sub-self with self having a temporal extension of order lifetime or longer and having kind of abstracted experience about the period of life before birth. Experiences like "sharing the sorrow of all mothers of dead soldiers" could involve the entanglement of sub-self with a collective mental image resulting in the entanglement with a collective mental images having quite concretely as mental images of mothers. If the notion of field body having size at least of order Earth size makes sense, this idea does not look so implausible anymore.

Direct eye contact as an example of quantum entanglement between experiencers?

Direct eye contact is fundamental in the communication between living creatures. The naïve intuitive picture of cartoon drawings about direct eye contact is is as rays connecting the eyes of persons involved. TGD suggests that this naïve picture actually represents fundamental mechanism for the temporal fusion of selves to form larger selves. What could happen is that magnetic flux tubes are formed between eyes, and, if the neural window hypothesis holds true, also between brains and eventually between sensory canvases.

MEs are optimal for this purpose. The coherent photons associated with them would be the required macroscopic quantum phase associated with the entire higher level self. Thus it is perhaps not accident that extended states of consciousness are so often described as experiences about radiance of light. A weaker hypothesis is that eye contact involves only the formation of magnetic flux tubes along which classical communication based on propagation of classical signals occurs. Also for this option MEs are optimal candidates for magnetic flux tubes.

The reader has possibly noticed that these arguments open up the possibility that our visual field in some sense corresponds to the actual visual field rather than only its cognitive representation provide by the visual pathways. The photons arriving along MEs connecting our brain with the objects of the perceptive field could provide the join along boundaries bonds extending our sensory self to contain part of the external world. Our visual field would still be determined by the light entering to our eyes so that no contradictions with well established empirical facts about vision are encountered. This kind of extension of visual self could however provide completely new ways for brain to compute the distances to the objects of the perceptive field since the basic information would not be mere two-dimensional picture in retina. The most plausible option seems to be however the one in which ultimate sensory representations are realized outside brain at the sensory canvas provided by the magnetic flux tube structures which can be even of the order of Earth size. This option is discussed in [K99].

Semitrance mechanism

The notion of semitrance allows to understand how higher level selves can communicate to and control and coordinate the behaviour of lower levels selves. If individual contains at least part

of time at least single sub-self, this sub-self can entangle with higher level self and in this trance state can communicate with the self and possible sub-selves and transmit commands, advices or messages. Communication is here quite generally understood as a generation of mental images, waking-up of sub-selves, these sub-selves could be p-adic sub-selves of real selves in accordance with the idea that communication is part of cognition. The wake-up process initiates self-organization leading to a final state pattern representing the message. Final state pattern depends only weakly on the stimulus serving as message: this is as it should be.

The NE of the right or left brain hemisphere (or some part of it, perhaps the linguistic regions with respect to which human brain has highest asymmetry) with a collective self could be the basic mechanism making it possible to communicate the commands of the collective self to left and/or right hemisphere as "hallucinations". This leads to a TGD variant of the vision of Jaynes about bicamerals and schizophrenics as persons who differ from the average modern man in that they are able to receive commands and advice from collective levels of consciousness as hallucinations [J111]. The notion of semitrance leads to very general views about how various societies (cells as societies of proteins, organisms as societies of cells, societies of various animals) develop and allows also to understand various altered states of consciousness [K107, K108].

The semitrance mechanism involves the generation of NE and liberation of metabolic energy if the liberation of metabolic energy always accompanies transfer of NE to the receiver. This non-metabolic energy might have something to do with the miraculous architectural feats of the ancient bicameral cultures (consider only pyramides) and the unusual physical strength of schizophrenics discussed in [J111].

Entanglement and sleep

What happens for our self during sleep? One can imagine several alternative answers to the question.

1. We really lose consciousness during sleep. This means that our self entangles negentropically with some other self. One can however ask why NE should not be possible and whether it could be the reason for healing effects of sleep. ZEO implies that the self representing our wake-up consciousness dies and re-incarnates at opposite boundary of CD. An interesting question is whether we can remember anything about this period of consciousness and whether memories about dreams are this kind of memories.

2. Long term memory representations are not constructed during sleep so that we do not remember anything about sleep time consciousness except when we wake up from REM sleep: note that in this case the memories fade rapidly in accordance with the idea that long term memories are not constructed. Synchronous hippocampal theta is indeed absent during sleep and synchronous firing would be a natural candidate for both the communications of mental images to magnetic body and for the generation of memory representations as negentropic fusions of mental images. If these memory representations are nor formed there is nothing to remember.

3. We are able to remember what happened during sleep only if we are asleep. Perhaps synchronous theta and delta oscillations are involved with the construction of negentropic memory representations experienced only during sleep just as theta synchrony is essential for memories about daytime experiences. The mirror mechanism of long term memories might allow this kind of possibility. These memory representations would be incomprehensible from the point of day-time consciousness. The strange mental images experienced just at the verge of falling asleep or waking up, which have meaning before transition but lose it during the transition, might reflect this.

Irrespective of whether the entanglement is bound state entanglement or NE, an important function of sleep could be the formation of larger collective selves. During sleep our selves could entangle to form a kind of a stereo consciousness representing human condition. This process could involve either phase transition changing local topology or a formation of magnetic flux tubes with much larger space-time sheets characterized by the same local topology. This mechanism could make possible subconscious communication between the members of society and also establish

conscience and moral. The topological field quanta associated with photons generated by EEG during sleep have frequency smaller than 7 Hz [K52]. This suggests that the higher level selves in question correspond to these topological field quanta and thus have a wake-up time of order .5 seconds during delta wave sleep. Mental images would not disappear but would become more abstract during sleep.

6.2.7 Self Hierarchy

The basic outcome of the definition of self is the prediction that infinite hierarchy of selves exists. This prediction clearly distinguishes TGD from brain centered theories of consciousness.

Infinite hierarchy of selves with God at the top

A rather dramatic prediction is a Russian doll like hierarchy of conscious experiencers having the entire Universe, God, at the top. The necessary localization in zero modes making the Universe of conscious experience classical together with the proposed concept of self allows to understand both active and passive aspects of consciousness and a general classification of various types of conscious experiences becomes possible. Summation hypothesis, sharing of mental images and "enlightenment" by the generation of negentropic entanglement hypothesis provide a general framework for interpreting various transpersonal experiences and altered states of consciousness as resulting from entanglement with larger units of consciousness.

Self, evolution and, self-organization

Quantum jumps between quantum histories make also possible genuine quantum self-organization. The concept of self-organization gets quite new additional meaning in TGD framework. Self-organization means also evolution of self-hierarchies. Self-organization by quantum jumps can be regarded as a hopping in the zero modes characterizing the macroscopic aspects of the space-time surface. Each self is a dissipative system which ends up to some asymptotic self-organization pattern in the presence of the external energy feed (and even without it). Dissipation is the ultimate Darwinian selector picking up the winning selves as favored self organization patterns. Since sub-selves correspond to mental images, the immediate implication is that also memes are subject to similar selection. For instance, the formation of long term memories and habits could be understood as a formation of surviving sub-selves.

The time evolution by quantum jumps has many facets. One of them relates to effective p-adic topology and is expected to be of speciall importance if live resides in the intersection of real and p-adic worlds. Simple arguments leads to the conclusion that evolution for a given space-time sheet must correspond to a sequence of p-adic primes increasing in a statistical sense. This means that the concept of nearness defining the effective topology becomes gradually more refined, the complexity of the universe increases, and the maximal information contents of the conscious experience increase in the long run (like $p \times log(p)$ or at least as $log(p)$ as a function of p-adic prime characterizing the system). This is nothing but evolution. NMP, which states that entanglement negentropy gain maximal for allowed quantum jumps, enhances this tendency.

The TGD based realization of the quantum criticality, besides making macroscopic quantum systems possible, in a well-defined sense maximizes the intelligence and complexity of the universe [K26]. In biosystems a concrete realization of quantum criticality is in terms of magnetic flux tube structures and electret type space-time sheets representing solutions of field equations dual to each other and having opposite signs of Kähler action density.

TGD universe is quantum spin glass and this adds additional aspect to the self-organization process. For instance, the energy landscape of the spin glass is fractal like structure containing valleys inside valleys and provides an ideal dynamical memory mechanism. Spin glass degeneracy also provides a mechanism increasing the lifetimes of the bound states formed by join along boundaries/flux tube condensates and thus could allow macrotemporally quantum coherent states able to perform quantum computation like activities. The impossibility of macrotemporal quantum coherence is indeed the main objection against quantum theories of consciousness.

This looks nice but one can ask whether the framework of standard quantum theory is all that is needed to formulate quantum TGD and the notion of quantum criticality. The original motivations for introducing the hierarchy of Planck constants and the generalization of the embedding

space to a book like structure having as pages the almost copies of the embedding space were purely physical. Now it seems that this generalization is required by a need to have a proper formulation of quantum criticality of TGD Universe. The hierarchy of Planck constants leads to a whole bundle of ideas about quantum biology and evolution of consciousness and also to a detailed model for how living matter can perform topological quantum computation like activities [K12, K3, **?**, K8].

State function reduction reducing entanglement is a random process unlike that producing negentropic entanglement and implies quantum de-coherence. Therefore the unentangled sub-selves of self define a statistical ensemble in a natural manner and dissipation is naturally related to the aging of self since the statistical ensemble in question grows quantum jump by quantum jump. The averaging over quantum jumps means that the contents of consciousness of self thermalize with mental images becoming more and more fuzzy.

Haken's classical theory of self-organization applies almost as such if only entropic entanglement is considered since time development by quantum jumps means hopping around the space of zero modes characterizing the size and shape and induced Kähler fields associated with the space-time surface $X^4(X^3)$. Negentropic entanglement of mental images changes however the situation in time scale which could be the time scale assignable to the CDs associated with the entangled selves.

Self-organization involves Darwinian selection performed by dissipation inside each self. Dissipation selects also surviving sub-selves having interpretation as mental images. Hence the selection of memes is also in question.

Subjective aging results from dissipation and is the price paid for having autonomous self separated from environment. Very concretely, the mental image of self represented by sub-self gets more and more entropic during aging. One can also formulate questions about what happens in death in terms of physical concepts. Does only the bodily sub-self (mental image about body) cease to exist in the physical death so that only the field body consisting of magnetic flux tube structures and massless extremals (MEs, topological counterparts of light rays) remains? Can one identify the field body as the counterpart of what is called soul? Could the field body get interested of some new biological body and use it as sensory and motor organ (re-incarnation)? Is entanglement with some larger self generated after death (and during sleep)?

Space-time as a 4-dimensional living being

The new concept of the psychological time means a dramatic generalization of the standard view about subjective existence. mind-like space-time sheets are distributed everywhere around material space-time sheets of infinite time duration and all of them can participate in a given quantum jump. Therefore one can say that the entire space-time is a conscious, living being. Civilizations of the geometric past and future exist simultaneously with us. We are members of a four-dimensional society in the sense that our actions affect the life of selves of both geometric past and future since each quantum jump performed by us changes the macroscopic space-time in both past and future.

Everyday experience suggest that the geometric past is relatively rigid. Although changes in a given time scale can occur below some length scale, changes in larger scales are probably rare. Sensory representations could however change and this could explain the instability of long term memories. Turning point decisions are probably not possible for the me of my geometric past: otherwise dramatic quantum jump changing completely my personal identity would occur.

The notion of the four-dimensional body (both material and field bodies) becomes natural and only the concentration of consciousness to the psychological now during the physical life creates the illusion that the reality corresponds to the time=constant snapshot of the time evolution. Near death experiences indeed support the view that life is experienced as a temporal whole when the dominating contribution from the sensory input and motor actions is absent. 4-dimensional body is not static but changes quantum jump by quantum jump which suggests that life is like a four-dimensional sculpture which is gradually refined. We in our youth now experience in slightly more deeper manner and live in a society having slightly higher level of moral. Note that the newest view about arrow of time means that the creation of this 4-D sculpture can be also seen as classical time evolution in the first approximation.

6.3 Self And Model Of Self

The concept of self seems to be absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness and would be counterpart for observer in quantum measurement theory.

The original proposal was that self is conscious entity.

1. Self corresponds to a subsystem able to remain un-entangled under the sequential informational "time evolutions" U. Exactly vanishing entanglement is practically impossible in ordinary quantum mechanics and it might be that "vanishing entanglement" in the condition for self-property should be replaced with "subcritical entanglement". If space-time decomposes into p-adic and real regions, and if entanglement between regions representing physics in different number fields vanishes, space-time indeed decomposes into selves in a natural manner. Causal diamonds would form natural embedding space correlates for selves and their hierarchy would correspond to self hierarchy.

2. The intuitive idea inspired by the formation of bound states of particles from particles was that self corresponds somehow to an integration of quantum jumps to single coherent whole. Later I gave up this idea since it was difficult to understand how the integration could take place.

3. The next suggestion was that quantum jumps as such correspond to selves. It was however difficult to assign to selves identified in this manner a definite geometric time duration. It is an empirical fact that this kind duration can be assigned to mental images (identified as subselves).

4. Concerning the notion of self the notion of negentropic entanglement (NE) (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is central. NMP implies that Universe is like a library with new books emerging continually at its shelves. It turned out that NE - "Akashic records" must be experienced directly and defines what might be called permanent self - self as understood in the framework of meditation practices.

   The original wrong idea was that so called interaction free measurement could give information about NE at the same time leaving it invariant. It turned out that interaction free measurement does not allow to read the "Akashic records" but makes possible to read memories relying on bit representations (not qubits). These representations could give rise to self model and often referred to as ego in meditative practices.

5. The approach which seems the most convincing relies on the following observation. In ordinary positive energy ontology repeated state function reductions leave the state invariant. In ZEO this is not the case. There is wave function in moduli space of causal diamonds (CDs) and all sizes of CD characterized by the proper time distance between the tips of CD and all Lorentz boosts of CD are allowed. State function reduction localizes this wave function so that the other boundary of CD is at fixed light-cone boundary but other remains delocalized.

   The sequences of ordinary state function reductions leaving state unchanged are replaced with sequences for which the part of the zero energy state associated with a fixed boundary of CD remains unchanged in state function reduction whereas the state at the other end of CD changes. This is something new and explains the arrow of time and its flow and self could be understood as a sequence of quantum jumps at fixed boundary of CD (with the average location of second boundary shifted towards geometric future like in dispersion). Amusingly, this is in accordance with the original proposal except that state function reductions take place on same boundary of CD as long as self exists. For this option NE is directly experienced and at the passive boundary of CD gives rise to the unchanging part of self. There is no need to read the Akashic records by any mechanism.

   This view is extremely attractive since it implies that the act of free will interpreted as genuine state function reduction must mean reversal for the direction of geometric time at some level of hierarchy of selves. The proposal has indeed been that sensory perception and motor action are time reversals of each other and that motor action involves sending of negative energy signals to the geometric past.

6.3.1 NE And Self

NE provides a model for associations as rules in which superposition of tensor product states defines rule with entanglement pairs defining its various instances. This generalizes to N-fold tensor products. Associations would be realized as N-neuron NE stable against NMP. One could also think of realizing associative areas in terms of neurons, whose inputs form entangled tensor product and when sensory inputs are received they form analogous tensor product in representative degrees of freedom.

Thus NE is necessary for mental images (having sub-CDs as correlates) to mental images representing spatial patterns. NE in time direction for these patterns (zero energy states) is in turn necessary to bind them to sequences of mental images representing abstract memories as sequences of mental images. Negentropically entangled sequence would be a quantal counterpart for the original association sequence introduced as purely geometric concept.

If one accepts the identification of self as a sequence of state function reductions to a fixed boundary of CD then the identification of NE at the passive boundary of CD as a building brick of self is natural. One must distinguish from self the self model (one might speak of ego) which would rely on memory representations at the active boundary of CD.

By definition NE tends to be preserved in quantum jumps also at the active boundary of CD so that it represents information as approximate invariant: this conforms with the idea of invariant representation and quite generally with the idea that invariants represent the useful information. Self as opposed to self model be determined by NE at the passive boundary of CD.

Self model would be based on the properties of state at the active boundary of CD: also here NE is possible but is not absolutely stable. If the notion of interaction free measurement makes sense also in TGD based quantum measurement theory, the models of self and external world can be defined in terms of representations (sensory -, memory -, cognitive -) and their time reversals and correspond to the reflective level of consciousness as opposed to the phenomenal consciousness to which sensory qualia contribute mostly. Self representations are not exact invariants although there seems to be no end for experience of consciousness: sleep in this framework can be interpreted as a period about which there are no memories accessible in wake-up state. If the contribution of the magnetic body dominates during sleep, this can be understood.

The picture about repeated state function reductions suggest the following view about self. The passive part of zero energy state is not changed during its life cycle and negentropic entanglement associated with it is preserved. Self at given level of hierarchy is in wake up state during period of fixed direction of geometric time. When the reductions begin to occur at the opposite boundary of CD self "falls asleep": symmetry suggests that new self living in opposite direction of geometric time is generated. Also in biological the change of time direction at some level of hierarchy might take place.

6.3.2 Is Interaction Free Measurement Needed To Deduce Information About Self Model?

The assumption that self model is a negentropically entangled system which does not change in state function reduction, leads to a problem. If the conscious information about this kind of sub-self corresponds to change of negentropy in quantum jump, it seems impossible to get this information. Quite generally, if moment of consciousness corresponds to quantum jump and thus change, how it is possible to carry conscious information about quantum state? The following proposal for non-destructive reading of memories and future plans allows to resolve this problem.

The objection is that the repeated state function reductions make the NE at the passive boundary of CD a part of the conscious experience defining the static background representing the experiencer as the background whereas the contribution to the experience from the changing active boundary of CD would define the figure.

This interpretation seems reasonable and actually the only possible one in the recent formulation of the theory. One can however consider the possibility that interaction free quantum measurement could allow to "read" memory representations realized in terms of bits. These representations would define self model localizable to the changing boundary of CD as opposed to the permanent self.

Bomb testing problem as a model for interaction free measurement

One can consider a generalization of so called interaction free measurement as a way to deduce information about self model. This information would be obtained as sequences of bits and might be correspond to declarative, verbal memories rather than direct sensory experiences.

1. The bomb testing problem of Elitzur and Vaidman gives a nice concrete description of what happens in interaction free measurement [B1] for an illustration of the system considered (see `http://tinyurl.com/kx2jsyu`).

   The challenge is to find whether the bomb is dud or not. Bomb explodes if it receives photon with given energy. The simplest test would explode all bombs. Interaction free measurement allows to make test by destroying only small number of bombs and at idealized limit no bombs are destroyed.

   The system involves four lenses arranged in square and two detectors C and D at the upper right corner of the square. In the first lense at the lower left corner the incoming photon beam splits to reflected and transmitted beams: the path travelled by transmitted beam contains the bomb.

   (a) The bomb absorbs photon with a probability which tells the fraction of photon beam going to the path at which bomb is (is transmitted through the lense). The other possibility is that this measurement process creates a state in which photon travels along the other path (is reflected). This photon goes through a lense and ends up to detector C or D through lense.

   (b) If the bomb is dud, the photon travels through both paths and interference at the lense leads the photon to detector D. If C detects photon we know that the bomb was not a dud without exploding it. If D detects the photon, it was either dud or not and we can repeat the experiment as long as bomb explodes, or C detects photon and stop if the detector continues to be D (dud). This arrangement can be refined so that at the ideal limit no explosions take place and all.

2. The measurement of bomb property is interaction free experiment in the sense that state function reduction performed by absorber/bomb can eliminate the interaction in the sense that photon travels along the path not containing the bomb. One might say that state function reduction is an interaction which can eliminates the usual interaction with photon beam. State function reduction performed by bomb can change the history of photon so it travels along the path not containing the bomb.

   This picture is only metaphorical representation of something much more general.

1. Bomb could be of course replaced with any two-state system absorbing photons in one state but not in the other state, say atom. Now one would test in which state the atom is gaining one bit of information in the optimal situation. Two-state atom could thus represent bit and one could in principle read the bit sequence formed by atoms (say in row) by this method without any photon absorption so that the row of atoms would remain in the original state.

2. Two-state system could be replaced with N-state system. In this case the testing selects at first step one state as analogs of bomb intact and the remaining states as analogs of dud. If the answer was "dud" in the first step, the next step selects one preferred state from $N-1$ states and regards the remaining states as "dud". The process continues until the state of the system is measured.

3. In TGD framework the photon paths branching at lenses correspond to branching 3-surfaces analogous to branching strings in string model and photon wave splits to sum of waves travelling along the two paths.

Memory recall as an interaction free measurement

One can imagine several applications if the information to be read in interaction free manner can be interpreted as bit sequences represented as states of two-state system. Lasers in ground states and its excited state would be analogous many particle quantum system. In TGD framework the analog of laser consisting of two space-time sheets with different sizes and different zero point kinetic energies would be the analogous system.

For instance, a model of memory recall with memories realized as negentropically entangled states such that each state represents a bit can be considered. The model applies also to the reading of future plans (memories on reversed time direction).

1. Reading of a particular bit of memory means sending of negative energy photon signal to the past, which can be absorbed in the reading process. The problem is however that the memory representation is changed in this process since two state system returns to the ground state. This could be seen as analog of no-cloning theorem (the read thoughts define the clone). Interaction free measurement could help to overcome the problem partially. Memory would not be affected at all at the limit so that no-cloning theorem would be circumvented at this limit. Memory bit to be read would be mathematically analogous to bomb in the Elizur-Weizman bomb tester thought experiment in which one tries to determine whether bomb is active (bit 1) and can therefore explode or passive (bit 0) and cannot explode.

2. A possible problem is that the analogs of detectors C and D for a given qubit are in geometric past and one must be able to decide whether it was C or D that absorbed the negative energy photon! Direct conscious experience should tell whether the detector C or D fired: could this experience correspond to visual quale black/white and more generally to a pair of complementary colors?

3. ZEO means that zero energy states appear have both embedding space arrows of time and these arrows appear alternately during periods of repeated state functions having no effect at the other boundary of CD. This dichotomy would correspond to sensory representation-motor action dichotomy and would suggest that there is no fundamental difference between memory recall and future prediction by self model and they different only the direction of the signal.

4. Since photon absorption is the basic process, the conscious experience about the bit pattern could be visual sensation or even some other kind of sensory qualia induced by the absorption of photons. The model for the lipids of cell membrane as pixels of a sensory screen suggests that neuronal/cell membranes could serve defined digital self model at the length scale of neurons.

Some comments are in order.

1. To avoid misunderstandings it should be emphasized that TGD based view about memory is not the same as the standard view. In ZEO brain is four-dimensional and in principle memories can be negentropically entanglement memories in geometric past. It is possible to build copies of memories by memory recall, and learning would correspond to a generation of large enough number of copies of the memory mental image. Memory recall could be seen as a negative energy signal inducing the interaction free measurement of memory qubits. Dark photons with EEG frequencies (say in theta band characterizing hippocompus) but having energies of visible photons could be involved with the memory recall. Correlation between EEG and bio-photons supports this view.

2. If the systems taking the role of the detectors C and D in interaction free measurement are analogous to population reversed lasers, their return to the ground state could automatically generate virtual sensory input propagating to the sensory organs and allowing to check whether it is consistent with the actual sensory input. The generation of the feedback signal takes some time expected however to be much shorter than that for a typical neuronal activity.

   Since the signals would propagate with light velocity, the virtual sensory input could travel practically instantaneously from the brain to sensory organs and possibly also vice versa.

Libet's experiments on passive aspects of consciousness [J87] in fact demonstrate a time delay which is fraction of second having interpretation in terms of time to propagate to a layer of magnetic body of size scale of Earth and back: these delays are consistent with the fact that the chronon of sensory experience is about.1 seconds. The propagation of photon signals in both directions would make possible construction of sensory representation in time scale much shorter than that of neural activity. This mechanism could also explain generation of after images.

3. Photons can be replaced with phonons or quanta of any other wave motion with constant propagation velocity (no dispersion of signal) in a given reference frame. This suggests that imagination and internal speech correspond to the two reading mechanisms of memories.

One could also introduce self as a subsystem, which is only potentially conscious and here the notion of NE (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) suggests an approach based on interaction free measurement. NMP implies that Universe is like a library with new books emerging continually at its shelves. It turned out that negentropic entanglement - "Akashic records" must be experienced directly and would define what might be called permanent self. Interaction free measurement does not allow to read the "Akashic records" but makes possible to read memories relying on bit representations (not qubits). These representations could give rise to self model.

Chapter 7

Self and Binding: Part II

7.1 Introduction

The conflict between the non-determinism of state function reduction and determinism of time evolution of Schrödinger equation is serious enough a problem to motivate the attempt to extend physics to a theory of consciousness by raising the observer from an outsider to a key notion also at the level of physical theory by bringing in the notion of self. Further motivations come from the failure of the materialistic and reductionistic dogmas in attempts to understand consciousness in neuroscience context. There are reasons to doubt that standard quantum physics could be enough to achieve this goal and the new physics predicted by TGD is indeed central in the proposed theory.

7.1.1 Zero Energy Ontology

Zero Energy Ontology (ZEO) was forced by the interpretational problems created by the vacuum extremal property of Robertson-Walker cosmologies imbedded as 4-surfaces in $M^4 \times CP_2$ meaning that the density of inertial mass (but not gravitational mass) for these cosmologies was vanishing meaning a conflict with Equivalence Principle. In ZEO physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds (CDs) defined as intersections of future and past directed light-cones ($\delta M^4_{\pm} \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology.

ZEO combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of universe and about the values of conserved quantum numbers of the Universe can be avoided since everything is in principle creatable from vacuum. Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in ZEO. ZEO leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II_1. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD.

ZEO (ZEO) means that one must distinguish between M-matrix and U-matrix. M-matrix characterizes the time like entanglement between positive and negative energy parts of zero energy state and is measured in particle scattering experiments. M-matrix need not be unitary and can be identified as a "complex" square root of density matrix representable as a product of its real and positive square root and of unitary S-matrix so that thermodynamics becomes part of quantum theory with thermodynamical ensemble being replaced with a zero energy state. The unitary U-matrix describes quantum transitions between zero energy states and is therefore something genuinely new. It is natural to assign the statistical description of intentional action with U-matrix since quantum jump occurs between zero energy states.

Quantum measurement theory based on ZEO can be said to imply the notion of self and to explaining basic aspects of consciousness when one includes also the hierarchy of Planck constants characterizing hierarchy of quantum criticalities. At the embedding space-level CD is the correlate

of self whereas space-time sheets having their ends at the light-like boundaries of CD are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves. Zero energy ontology leads also an argument explaining why the arrow of subjective time induces an apparent arrow of geometric time as a result if intentional action and why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD).

7.1.2 Hierarchy Of Planck Constants

The hierarchy of Planck constants corresponds to a hierarchy $h_{eff} = n \times h$ [K44, **?**, K90]. The original hypothesis was that it corresponds to a hierarchy of singular coverings of embedding space $M^4 \times CP_2$- or rather - given causal diamond (CD).

The recent view is that there is a hierarchy of quantum criticalities such that the sub-algebra of super-symplectic algebra for which conformal weights are n-ples of those for the entire algebra acts as conformal gauge symmetries at given level. Due to the resulting non-determinism the space-time surfaces connecting 3-surfaces at the opposite boundaries of CD are gauge degenerate and there are n conformal equivalence classes analogous to sheets of Riemann surface of $z^{1/n}$. This view has far reaching consequences. The hierarchy of quantum criticalities has an interpretation as that for macroscopic quantum phases and the phase transitions increasing n to its multiple occur spontaneously and generate also negentropy if NMP is assumed. Hence evolution can be seen as a gradual reduction of criticality occurring unavoidably.

An alternative formulation [K112, K87, K90, **?**] emerged in terms of gravitational Planck constant $h_{gr} = GMm/v_0$, where v_0 is characteristic velocity in the system consisting of two masses involved, introduced originally by Nottale [E1] h_{gr} would be associated with the flux tubes connecting the two masses. Later it became clear that the identification $h_{eff} = h_{gr}$ leads to considerable insights in biology: in particular bio-photons can be identified as ordinary photons resulting from dark cyclotron photons with a universal energy spectrum.

The book metaphor inspired by the original view about hierarchy of Planck constants is however very useful. The value of the Planck constant characterizes partially given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory.

7.1.3 P-Adic Physics As Physics Of Cognition

p-Adic mass calculations relying on p-adic length scale hypothesis led to an understanding of elementary particle masses using only super-conformal symmetries and p-adic thermodynamics. The need to fuse real physics and various p-adic physics to single coherent whole led to a generalization of the notion of number obtained by gluing together reals and p-adics together along common rationals and algebraics (see fig. `http://tgdtheory.fi/appfigures/book.jpg`, which is also in the appendix of this `http://tgdtheory.fi/appfigures/book.jpg`). The interpretation of p-adic space-time sheets is as correlates for cognition. p-Adic and real space-time sheets intersect along common rationals and algebraics and the subset of these points could be called intersection of realities.

In fact, the intersection can be interpreted in more abstract sense at the level of WCW as surfaces for which parameters (WCW coordinates) are such that the interpretation both as real and p-adic surface is possible. In this way one avoids discretization at space-time level. It has turned out that string world sheets and partonic 2-surfaces with defining parameters in an extension of

rationals define naturally the intersection and strong form of holography allows the continuation of these 2-surfaces to space-time surfaces.

The outcome is a vision about hierarchy extensions of rational numbers defining an evolutionary hierarchy. So called ramified primes associated with the extension define preferred primes identifiable as p-adic primes and weak form NMP allows to understand p-adic length scale hypothesis and its generalization stating that primes near powers of primes are favored by NMP.

There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement, which need not be bound state entanglement in standard sense. Negentropic entanglement might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. The generation of NE as the outcome of the reduction is not totally random process: the prediction is that second law need not universal truth holding true in all scales. To avoid making wrong conclusions about NMP, one must keep in mind that entanglement entropy is two-particle property whereas thermodynamical entropy is single partcle property.

Quantum measurement theory allows only final states, which have density matrices which are projectors so that the rational entanglement probabilities $p = 1/n$ are identical in this case. If the prime p divides n, one obtains negative entanglement entropy and one can say that entanglement is negentropic. Negentropy is largest for the largest power of prime dividing n and one could define entanglement entropy as that associated with this prime.

7.1.4 NMP

One obtains standard quantum measurement theory by assuming that the density matrix of the sub-system is the universal observable. In state function reduction this observable is measured and the system goes to an eigenstate of it. It can however happen that the eigenvalues are degenerate and in this case one can ask whether the reduction leads only to an eigen space so that entanglement characterized by a n-dimensional projection operator remains.

If p divides n, one obtains negative entanglement entropy and one can say that entanglement is negentropic. Negentropy is largest for the largest power of prime dividing n.

Negentropy Maximization Principle (NMP) [K73] codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to maximal reduction of entanglement entropy - or equivalently - gain of entanglement negentropy- at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

The interpretation is that NMP favors generation of negentropic entanglement (NE). One can of course argue that the generation of this kind of entanglement is extremely improbable. The hierarchy of Planck constants involving quantum criticality could however provide the way to generate it.

TGD inspired theory of consciousness forces to challenge the hypothesis that NMP always forces the state function reduction to the sub-space defined by the projector with maximal dimension appearing in the decomposition of the density matrix. NMP would not allow the self to make choices, which are bad deeds in the sense that they do not increase maximally the negentropic resources of the Universe. We would live in the best possible Universe becoming better all the time. This is obviously too good to be true.

The weak form of NMP allows the choice leading to maximal negentropy gain but allows also those choices for which the reduction occurs to a sub-space of the space defined by projector. When this sub-space is 1-dimensional standard quantum measurement results and the self is isolated from the target of observations. Negentropic entanglement has interpretation as attention with positively colored contents of consciousness. Experience of love would be one attribute of this kind of state. Weak form of NMP would be like God allowing the sinner to choose between Good and Evil.

Weak form of NMP turns out to have surprisingly strong consequences. For instance, by choosing the sub-space to have dimension given by power of prime, the state function reduction can yield a larger negentropy gain than otherwise. Primes near powers of prime as dimensions of final

state projector are optimal from the point of view of evolution since they give a large negentropy gain and generate large p p-adicity, which means higher evolutionary level in number theoretical sense: this result is nothing but a generalization of p-adic length scale hypothesis.

NMP generalizes also so that it applies to hyper-finite factors of type II_1 and also in this case it is possible to define negentropic entanglement. In this case entanglement negentropy is positive because the projector for the sub-space as dimension smaller than one as the inverse of the index of inclusion. The interpretation is that the degrees of freedom below measurement resolution carry NE characterized by the projector to the sub-space.

7.1.5 The Notion Of Self

The quantum notion of self solved several key problems of TGD inspired theory of consciousness but the precise definition of self has remained a long standing problem and I have been even ready to identify self with quantum jump. Zero energy ontology allows what looks a final solution of the problem. Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

p-Adic physics as correlate for cognition leads to the notion of negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness. Consistency with standard quantum measurement theory forces negentropic entanglement to correspond to density matrix proportional to unit matrix. Unitary entanglement typical for quantum computing systems gives rise to unitary entanglement. A natural conjecture is that the integer n in $h_{eff} = n \times h$ corresponds to the dimension of the unit matrix associated with negentropic entanglement. Also a connection with quantum criticality made possible by non-determinism of Kähler action and extended conformal invariance emerges so that there is high conceptual coherence between the new concepts inspired by TGD.

The identification of the imbedding space correlate of self as causal diamond (CD) of the embedding space combined with the identification of space-time correlates as space-time sheets inside CD solved the problems concerning the relationship between geometric and subjective time.

Subjective memory is assumed to correspond to an average of conscious experiences of quantum jumps occurred after the last wake-up of self (the first one in the sequence of state function reduction at same boundary of CD). This leads to the identification of qualia as averages of the increments of quantum numbers and zero modes in the ensemble of quantum jumps defining self. Summation hypothesis states that self X experiences the experiences of its subselves as abstracted experiences, averages X_{ij} about sub-subselves X_{ij}. Subselves of un-entangled selves can entangle (this is due to the many-sheeted sub-system concept) and this allows fusion and sharing of mental images.

Quantum entanglement provides a mechanism leading to the formation of irreducible wholes at the level of mental images. Entanglement can be entropic bound state entanglement or negentropic entanglement, which need not involve binding energy. The latter is possible only in the intersection of real and p-adic worlds where life can be said to reside. Quantum entanglement is possible also in time direction in zero energy ontology. It is tempting to assign negatively colored emotions to the entropic entanglement and positive emotions to the negentropic one. In TGD framework the standard vision about brain based on reductionistic-holistic dichotomy must be replaced with a trinity in which negentropic entanglement corresponds to a mode of cognition, which does not allow linguistic expression and episodal memories, and various mental feats of synesthetes and idiot savants could be seen as a manifestation of negentropic entanglement. Also meditative consciousness would be negentropic.

Selves are called irreducible if they possess no subselves, otherwise reducible. Subselves correspond to mental images so that irreducible subselves possess no mental images and are in a state of pure self-awareness: it is not clear whether this kind of states are possible in practice. When the subselves of self fuse to single negentropic subself, a state of "one-ness" results in somewhat different sense. This mode of consciousness can be identified as "whole-body" consciousness and

differs from ordinary consciousness during which self has large number of mental images. These modes could naturally explain emotional/holistic and rational modes of mind. These two modes could make it possible to understand various dichotomies like brain/left brain, emotional/analytic, religous/rational, Eastern/Western,... One could understand linear cognitive processes like thinking and language as self cascades in which self decomposes into subselves, which in turn decompose into subselves, which ... and self hierarchy implies connection with computationalism.

The possibility of negentropic entanglement has profound implications. It leads to a vision about learning as a basic quantum process possible in the intersection of real and p-adic worlds and made possible because state function reduction ceases to be a random process for negentropically entangled zero energy states. Quite concrete ideas about the role of synaptic transmission and neural transmitters for consciousness emerge. Music experience provides an especially interesting application for the vision about consciousness and zero energy ontology together with number theoretical vision inspires several concrete interpretations. Synchronous firing of neurons- in particular at 40 Hz frequency- is an attractive correlate for the negentropic entanglement and synesthesia can be interpreted as a particular manifestations of negentropic entanglement.

In TGD framework it is not at all obvious that the highest levels of our personal self hierarchy should correspond to the size of the physical body. Various empirical facts, in particular the observations related to the special effects of excitations of geomagnetic fields and ELF em fields in EEG frequency range on brain, inspire the hypothesis that our selves correspond to topological field quanta of em fields associated with EEG frequencies and thus by Uncertainty Principle have size scale of Earth. This leads to a rather radical modification of the brain centered views about consciousness, and one can quite seriously consider the questions like what physical death means from the point of view of consciousness: it could be that electromagnetic part of self hierarchy could survive after the physical death as a "soul".

This chapter is devoted to the theoretical aspects related to the definition of self. In second chapter applications of the notion of self are discussed. The plan of this chapter is as follows.

1. In the first section the notion of self is defined and various aspects related to it are discussed. This includes discussion about the flow and arrow of time, qualia, quantum model for intelligent systems, emotional representation of Boolean logic, the origins of ethics and moral as NMP allows to understand them, and self referentiality. Also the general structure of conscious experience is considered: self has sub-selves experienced as mental images and sharing and fusion of mental images is possible in many-sheeted space-time. Various aspects of binding are discussed in terms of negentropic entanglement. The basic prediction is entire self hierarchy and also the aspects related to this hierarchy are discussed.

2. Second section is devoted to a critical question: is NE experienced directly or does it only define a model of self and is it necessary to have a mechanism allow to make the information in question conscious. Although the most elegant assumption is that sequence of repeated state function reductions makes NE conscious, the possibility that interaction free measurement might be needed to achieve this, is discussed.

This is the second part of the chapter devoted to the notion of self and discusses various applications of TGD inspired notion of self.

1. Some applications at brain level are considered including the differences between left and right brain hemispheres and music experience.

2. Negentropic entanglement seems to be the key to the understanding of altered states of consciousness. What I call whole-body consciousness is discussed in this framework. Also EEG synchrony and synesthesia are analyzed in terms of negentropic entanglement.

3. Higher levels of biological self hierarchy are discussed. Here the notion of magnetic body is central.

4. An attempt to understand what happens in ageing and death is made.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

7.2 Some Applications At Brain Level

In this section the notion of self and related notions are applied to brain at general level. Due to the introduction of the notion of negentropic entanglement (NE) the representation differs from the earlier one decisively. The most recent progress (2015) in understanding of ZEO, NMP, the role of NE, hierarchy of Planck constants and its its correlation with hierarchy of quantum criticalities, and number theoretic universality realized in terms of adelic physics have not however been taken into account properly although I have made some comments here and there.

7.2.1 A Simple Model For Cognition

The hierarchy of selves and summation hypothesis allows to construct a very general model for cognitive processes including as a special case thinking, analysis of visual experience, and language. In nutshell: cognitive process could be regarded as cascade like process leading to a generation of selves followed by generation of sub-selves for these leading to.... Quantum jump becomes the building block of cognition and thought but is not sufficient alone. p-Adic space-time sheets as correlates of cognition provide geometric correlates for thoughts, intentions, plans, etc.. are a fundamental element of cognition. The longheld idea that the transformation of intention to action corresponds to p-adic-to-real transition has been given up: it is mathematically awkward and is not needed.

The intersection of real and p-adic worlds understood as partonic 2-surfaces and string world sheets allowing an interpretation in both real and p-adic sense and the intersections of real and p-adic partonic 2-surfaces consisting of rational and common algebraic points define the lowest level cognitive representations. NE is possible only in the intersection in accordance with with the vision that cognitive representations carry the information.

Quantum criticality of TGD and existence of selves

The model of cognition provides a new view to the role of quantum criticality of TGD. TGD Universe is like a system at a top of hill at a top of hill at.... More concretely, there is an infinite fractal hierarchy of sub-algebras of super-symplectic algebra isomorphic to the full algebra with conformal weights coming as n-ples of those for the full algebra [K44, K31, K32, K33, K34, K90]. This kind of sub-algebra acts as conformal gauge symmetries at the level of criticality labelled by n. The phase transitions replacing n with its multiple occur spontaneously and one obtains infinite inclusion hierarchies with $n(i)$ dividing $n(i+1)$. These hierarchy would naturally have interpretation as inclusion hierarchies for hyper-finite factors of type II_1 [K138].

The value of Planck constant $h_{eff}/h = n$ would label these hierarchies and for large values of n one would have macroscopic quantum coherence. By NMP the first state function reduction to the opposite boundary of CD would in ZEO give rise to a phase transition increasing h_{eff} but meaning death of corresponding self and re-incarnation at opposite boundary. Selves would fight to get NE to satisfy the needs of NMP and in this manner to avoid this fatal first state function reduction. The fight for survival would allow sub-selves representing to die and born again generate NE and evolution would be the outcome. Weak form of NMP allows also reductions for which the NE is not maximal. This option is actually better concerning generation of NE.

TGD universe would be in a state of maximal alertness ready to generate cascades of selves representing cognitive acts. Our sensory and cognitive acts would be only part of those of the entire Universe proceeding from top to bottom as infinite trees with branches representing new selves and nodes representing moments of wake-ups for the selves. Or expressing it in the terminology of AI: we would be like subprograms of infinite program represented by entire universe. The presence of higher level selves means that cognitive acts can proceed from the level of even entire biosystem to the level of DNA. This encourages to interesting speculations: for instance, the ideas of Sheldrake about learning at the level of species and even biosphere might find justification [K103].

Number theoretical criticality is an important aspect of quantum criticality and is taken to mean that life and conscious intelligence reside in the intersection of real and p-adic worlds, where discrete cognitive representations. By strong form of holography the intersection would consist of string world sheets and partonic 2-surfaces characterized by parameters in some algebraic

extension of rationals defining a hierarchy. By conformal invariance the moduli spaces of conformal equivalence classes restricted to algebraic extension would define the intersections.

Quantum jump as cognitive process

The following scenario is a vision about what happens in cognition much before the recent progress in understanding ZEO, NMP, the notion of negentropic entanglement, and hierarchy of Planck constants labelling that of quantum criticalities and dark matter, and is therefore out-of-date at the level of details.

U process followed by a cascade of state function reductions will be identified as the basic cognitive act.

1. State function reduction can be characterized as a binary tree. At each step of the state function reduction cascade some sub-selves manage to remain unentangled, some sub-selves lose their consciousness by developing entropic bound state entanglement, or experience expansion of consciousness by entangling negentropically. A particular branch of the process stops if sub-self allows no decomposition to entropically entangled but otherwise free pieces. What is new is that the entanglement is also time-like and time-like entanglement turns out to be central for understanding of what happens in learning.

2. The binary tree of state function reduction has a natural ordering. This ordering need not have any correlate at the level of geometric time. At the level of subjective time and conscious experience the correlate for ordering could exist but if self experiences its sub-selves as averages of sub-sub-selves this cascade is experienced only partially by given sub-self. One can of course argue that self wakes up in each quantum jump separately and quantum jump sequence should be seen as a sequence of "awakenings" (I used this term earlier): this awakening is however something different from the emergence of mental image. Maybe time-like NE is which binds this sequence of "awakenings" to a continuous stream of consciousness that we experience.

3. The outcome of the state function reduction is random when it leads to un-entangled sub-self but statistical determinism implies reliability at the level of ensemble. For NE state function reduction is nearly deterministic process and in this case one can speak in reasonable approximation about an iteration of a unitary processes defined by the powers of U. This iterative process defines a self-organization process expected to be also behind learning.

4. One possible interpretation of the self cascade is as a representation for an abstraction process representing thoughts about thoughts about... Our poor ability to form statements about statements about... would correspond to the fact that self experiences only its sub-selves directly. Another interpretation is as analysis, in which initial experience gradually sharpens and gets more and more structured during the decomposition into sub-selves. Sub-selves could be thought as symbols of language or as logical statements or objects in picture: interpretation depends on what kind of cognitive process is in question. This process occurs in several time scales- even in the time scale defined by human life cycle. The modular structure of cognitive acts is also analogous to the modular structure of a computer program: starting of subprogram means the reduction of entanglement for the corresponding subsystem.

One can see this process also at the level of embedding space correlates.

1. Selves wake up and begin to perform quantum jumps. The embedding space counterpart for self is CD (causal diamond) characterized by time scale coming as powers of two and is scaling like the value of Planck constant. Subselves correspond to sub-CDs. Wake-up requires a feed of metabolic energy to destroy the bound state entanglement. Self could be also created from vacuum or disappear to it in a quantum jump generating a completely new CD or annihilating it.

2. Cognitive process proceeds in a cascade like manner starting from the root of tree formed by CDs and going downwards along the tree choosing at each node some branches. For instance, understanding of a sentence would correspond to waking up of large self A representing

sentence in its entirety, words its sub-selves B_i, phonemes to sub-selves C_{ij} of B_i, etc... waking-up in this order. Similarly, the act of decomposing the figure to objects and of objects to sub-objects would correspond to a temporal sequence generating selves within selves. NE would be crucial for experiencing both the whole and the parts simultaneously. Background would be the largest conscious self and objects would correspond to a sequence of selves. Selves C_{ij} and further sub-selves can be generated before generation of next C_{i+1}: this should occur in case linguistic mental image: generation of word self would be followed by the generation of syllables and phonemes and only after this would next word be generated. Time non-locality of self experience with respect to geometric and subjective time would be essential.

7.2.2 Cognition, Learning, And Ne At The Level Of Brain

NE is information carrier and learning is gaining information. Does this mean that learning takes place automatically in the intersection of real and p-adic worlds? Unitary U-matrix between zero energy states characterizes single step of quantum jump sequences and for negentropic states the state function reduction is not random process and in the first approximation U^N characterizes the outcome of N subsequent quantum jump so that learning process should be characterized by the iteration defined by the powers of U.

In neuroscience synaptic contacts are believed to be crucial for cognition, learning, and memory and it is interesting to try to relate this picture to the TGD based vision about conscious information and learning. How NE could be realized at the level of brain? Is it time-like, space-like, or both? Can one assign the generation of NE between neurons to the attachement of neurotransmitter to receptor? Can one relate the general quantum model of learning to the neuroscience based model of learning relying on the growth of brain cells, synaptic contacts, and synaptic plasticity?

The picture of the standard neuroscience about learning

It is good to summarize first the vision of standard neuroscience about the neural correlates of learning.

1. Basic notions

Synaptic transmission [J10, J29] is believed to be a key element of brain consciousness. Synaptic transmission takes place as synaptic vesicles carrying neural transmitter. Given neuron can release several transmitters. The transmitter molecules bind to the receptors at the postsynaptic cell membrane. Depending on whether this process leads to a de-polarization or hyper-polarization one speaks of excitatory or inhibitory receptors (activation potentials). Since most transmitters attach mostly to either kind of receptor, one speaks about excitatory and inhibitory transmitters although this terminology is misleading. Receptors can be classified to relatively simple ion channel receptors and more complex receptors involving second messenger proteins.

The belief is that the primary process does not involve communications with genome but if one accepts the DNA as topological quantum computer picture-in particular, on the existence of magnetic flux tubes connecting cell membrane and DNA nucleotides- the possibility that these communications are an essential element of process and that a new kind of gene expression at cell membrane level is involved. The communication to the DNA could take with light velocity if massless extremals are involved.

The synaptic strength characterizes the sensitivity of the postsynaptic neuron to the firing of the presynaptic neuron. It depends on the density of receptors and their activity as well as the total amount of neural transmitter transferred between neurons determined by the number of synaptic vesicles transmitted. This in turn depends on the size of the synaptic button. All these parameters are affected in learning understood as a change of synaptic strengths. It must be emphasized that learning in this sense should be seen as a neural correlate for conscious (or unconscious-to-us) learning and possibly of memory. What is essential that the response of the postsynaptic neuron changes. This picture relies on the technical assumption that learning reduces to the changes of synaptic strengths. This assumption is probably an over-idealization: much more probably happens.

2. Learning at brain level

Learning in the sense as it is defined above can take place at the level of both anatomy and physiology. Learning at the level of anatomy can mean growth of new synaptic connections and of even new neurons. For instance, the growth of new neurons in hippocampus is now understood to be essential prerequisite for learning. It is believed that the information from the connections of old neurons is transferred to those of cortical neurons. This can of course happen but in TGD framework this is not necessary since the new view about time allows to interpret memory as communications with the brain of the geometric past.

Learning at the level of physiology is known as synaptic plasticity [J27] and involves several mechanisms. Synaptic plasticity means that the sensitivity of the postsynaptic neuron to the signals from presynaptic neuron can change.

1. Sensitivity means essentially the probability for the firing as a response to the firing of presynaptic neuron and this is controlled by the sign and magnitude of the activation potential and the increase of the sensitivity means a generation of stronger de-polarization or weaker hyper-polarization. Postsynaptic neuron can become more or less sensitive to the presynaptic neuron whereas presynaptic neuron can send stronger signal by increasing the number of synaptic vesicles.

2. The change of the sensitivity of the postsynaptic neuron can take place several mechanisms [J27].

   (a) The first mechanism involves the modification of protein kinases whose function is to phosphorylate the receptor which means essentially providing it with metabolic energy. The effectiveness of the protein kinases is regulated. Second mechanism depends on second messenger neurotransmitters regulating gene transcription and regulates the levels of key proteins at synapses. Gene expression is affected in this mechanism and the effect is long-lasting.

   (b) Third mechanism affects the number of ion channels (ion transfer between cell interior and exterior is basically responsible for the activation potential) and is involved with long term potentiation (LTP [J19]) and - depression (LTD [J18]) believed to be central mechanisms of learning memory. LTP is believed to be of central importance in hippocampus. The change of the density of receptors is one manner to achieve LPT or LTD. For so so called AMPA receptors [J5] to which glutamate binds this mechanism is well-established. Also phosphorylation and de-phosphorylation of AMPA receptors and change in the probability of glutamate release is a decisive factor.

3. The notion of Hebbian learning [J13] applies to LTP. Hebbian rules summarizes the above picture as simple mathematical rules allowing computer modelling. When pre-synaptic and postsynaptic neurons fire simultaneously, synaptic connections are affected. Weak stimulations of several pathways add up. Also temporal summation takes place if the frequency of firing is high enough. Strong stimulation of one pathway affects also other pathways. More general formulation of the rules does not require the firing of the postsynaptic neuron. For anti-Hebbian learning de-sensitization takes place. Also non-Hebbian learning is believed to take place.

4. The change of the postsynaptic action potential need not be the only outcome of learning. If this were the case, the huge number of neural transmitters and receptors inducing different responses would not be needed. The change of the sensitivity is only one aspect of learning and as its relationship to conscious learning is unclear.

TGD based vision about cognition and learning

In the following a brief summary about TGD inspired view concerning cognition and learning in general and at brain level is given.

1. Basic ideas

The general ideas about cognition have been also discussed but is useful to summarize them again.

1. Sub-self interpreted as a mental image is key notion. Sub-selves wake-up, fall asleep, and fuse together losing consciousness or experiencing expansion of consciousness.

2. The cascade of state function reductions can be regarded as an analysis leading to a final state in which sub-selves are either entropically or negentropically entangled systems. The latter systems can be seen as negentropic mental images resulting as sub-selves fuse together. In the case that two sub-selves are involved, the resulting mental image can be regarded as an abstraction or rule such that the state pairs appearing in the superposition correspond to the instances of the rule. If one state pair dominates then association in classical sense is in question in good approximation.

3. NE can take place between systems which belong to same or different number fields and gives rise to various kinds of conscious experiences. At least in the case that the other system is p-adic, NE should be a correlate for the conscious experience of understanding.

4. Zero energy states for brain represent rules as pairs of positive energy (initial) and negative energy (final) states. M-matrix characterizes zero energy state and defines a rule representing "laws of physics" at the level of conscious experience. Different M-matrices are orthonormal with respect to each other and in ensemble all of them appear and each of them can be also regarded as representing one particular instance of a rule.

A new element is that unitary time evolution characterized by U-matrix forces the learning to occur in the sector of state space containing zero energy states for which positive and negative energy parts of the states are negentropically entangled. U-matrix and its powers characterize the learning process. When the states are negentropically entangled, state function reduction for M-matrix is not a random process but leads to a unique state maximizing negentropy and in a good approximation the restriction of U matrix to these states codes for the evolution of M-matrix. U^N restricted in this manner characterizes the M-matrix after N quantum jumps. Therefore learning is unavoidable in the case of negentropic states and U^N at the limit of large number of quantum jumps characterizes the learning. The value of N is of course limited by the size of CD assigned to the learning system. One can of course wonder whether the unitary period is following by a return to unentangled state via the liberation of metabolic energy associated with the NE.

The powers of U define an iterative map and iterative maps are the key element of self organization and also one of the main tools of generating fractals [K103]. Quantum classical correspondence therefore suggests that 4-D fractal self-organization patterns define the space-time correlates for learning.

2. General view about learning at the level of brain

M-matrix for brain codes its view about laws of physics. In diagonal form represents pairing of initial and final states as rules $A \to B$. For instance, in fermionic degrees of freedom these rules can be interpreted as Boolean rules. More generally, the interaction as quantum associations containing superposition of instances of the associations are in question. Huge quantum superposition of rules is possible since the number of neurons large and the information storage capacity of entanglement increases exponentially with the number of neurons.

U-matrix approximated as a matrix restricted to represent unitary evolution of negentropic zero energy states assignable to brain provides the first principle description for learning as the sequence of powers U^N. In the models of associative learning learning is reduced to a local process expressible in terms of changes of the synaptic contacts. This suggests that the basic building block of U matrix is synaptic transmission. This means an analogy with the basic braiding operation of the neighboring strands represented as R-matrix defining the unitry matrix for topological quantum computation [K3]. There is also an analogy with generalized Feynman diagrams. The incoming particles would be neurons. Synaptic transmission analogous to particle exchange between two neurons. U matrix can be regarded as a quantum superposition over all possible diagrams containing arbitrary number of synaptic transfers. Multiverse picture at neural level thus results as one might expect since macrotemporal and macroscopic quantum coherence is involved. If the

situation reduces in a reasonable approximation to a description in terms of synaptic transfers one can in principle describe synaptic plasticity, LTP, and LTD and other mechanisms to in terms of the basic building block of U associated with the synaptic transmission and mathematically analogous to Feynman propagator. The binding to the receptor could induce communications with genome and also the U-matrix assignable to topological quantum computations at the DNA level might be involved.

As such this picture provides only a first principle formulation for what conscious learning is and it requires a work to deduce predictions testing this vision or at least to gain understanding using this vision. A key aspect of NE is that it carries metabolic energy. This has been already proposed to provide a first principle explanation for the notion of the high energy phosphate bond crucial for the understanding of $ATP \to ADP + P_i$ process defining the key stop of metabolism [K45, K46].

Also space-like NE is possible for positive (negative) energy parts of the states. In particular, negentropic entanglement between presynaptic neuron and postsynaptic genome generated by the attachment of the transmitter to the receptor might make sense. There is temptation to assign to this connection a magnetic flux tube identified as a carrier of metabolic energy released in the process and inducing ionic currents leading to the processes affecting the synaptic strength as well as the states of neurons involved. The larger the metabolic energy release is, the more intense are the ionic currents involved and the stronger the modification is. This would provide a first principle explanation for why more effective phosphorylazation of the receptor as a correlate for learning. Of course, the explanation works even without the heavy conceptual machinery if one is ready to accept the somewhat nebulous notion of high energy phosphate bond.

7.2.3 Ne And The Role Of Neurotransmitters

Soon after starting to develop TGD inspired theory of consciousness, I somehow ended up to an email correspondence with Gene Johnson who insistently emailed me links to abstracts about neuroscience. I read the classic Bible about brain by Kandel *et al* [J119] and tried to make sense of it in my own conceptual framework. This was of course hopeless task since I had only the notions of quantum jump and self. The feeling that something very simple -about which I do not and perhaps cannot ever have a slightest clue- must be behind this incredible complexity made the situation really frustrating. The deeper meaning of EEG, nerve pulse neurotransmitters, hormones- actually of entire brain chemistry and also biochemistry- remained a total mystery.

Development of ideas

After the required number of years however some concrete ideas began to emerge.

1. The notion of magnetic body with fractal onion-like structure meant a decisive step of progress. Also the hierarchy of Planck constants and dark matter as controller of visible matter in living systems emerged. The function of EEG as communication and control tool of magnetic body using biological body as a motor instrument and sensory receptor looked very natural. This led also to a proposal that there is an entire hierarchy of EEGs and their variants. After several trials a vision about nerve pulses as concomitants of quantum level communications emerged as also a vision about DNA as topological quantum computer based on the flux tubes connecting DNA nucleotides with the lipid layers of cell membrane emerged and providing a function for the intronic portions of genome as carriers of quantum computer programs [K3].

2. Also a vision about the biochemical role of dark matter evolved. In particular, phase transitions reducing Planck constant for a magnetic flux tube would induce its contraction and force biomolecules near to each other. This would explain the miracles of DNA replication, translation, and transcription and quite generally the processes known as aggregation of proteins. The reconnection of magnetic flux tubes changing the topology of the biological Indra's net would be also a central mechanism.

3. The model of nerve pulse and the vision about living matter as a kind of dynamical Indra's net led to a first clear idea about the role of neural transmitters. Transmitters are classified

to inhibitory or excitatory depending on whether they increase or reduce the magnitude of the membrane potential. This property is however a property of the receptor rather than that of the transmitter. The same transmitter can have both excitatory and inhibitory receptors although often either receptor type dominates. The proposal was that neural transmitters are associated with the ends of the links of the 4-dimensional web connecting neurons to each other. Neurotransmitter attaches to the plug defined by the receptor connecting the communication wire from presynaptic neuron to the flux tube leading to the passive portion of postsynaptic DNA strand acting as sensory receptor. This would make possible rapid communications to DNA. The corresponding active portion of DNA strand could then respond by generating an activity at the level of cell membrane. This conforms with the general idea that proteins represent only one particular outcome of the gene expression. This left open the question whether the excitatory-inhibitory dichotomy could have some deeper meaning.

4. Also it became clear the emotions and information are closely related and that peptides acting both as neurotransmitters and hormones are crucial for emotions [J55]. I proposed that emotions are "entropic" qualia. Although I realized the importance of negentropic entanglement I did not have time or I was not able to realize how far reaching this notion actually is.

Is genome a fractal counterpart of brain?

Fractality replaces standard reductionism in TGD Universe. An old idea inspired by p-adic length scale hypothesis is that the binary structures associated with p-adic scales $L(k) \propto 2^{k/2}$ and $L(k+2)$ define a fractal hierarchy. Brain hemispheres would represent one example of this kind of pair, lipid layers of cell membrane second one, and DNA double strand third one. Just for fun one could assume that the structure and functions of brain hemispheres have fractal analogs at the level of DNA double strand and vice versa and look what kind of questions this inspires.

1. Could the identical structures of DNA strands correspond to the anatomical similarity of right and left brain and could the functional asymmetry of the strands correspond to the laterizalization of brain function? Could the genome act as the brain of cell? Could various brain areas have counterparts at the level of DNA? Could the hydrogen bonds between nucleotides serve as the counterpart of corpus callosum? Could the splitting of these bonds during transcription and replication correspond to what happens to a split brain patient?

2. Before continuing it must be made clear that the global identification of right-left dichotomy with holistic-reductionistic dichotomy is wrong. One can however consider its local variant with holism and reductionism assigned do the pairs of right and left brain areas. For instance, in contrast to the naïve rule the emotional right (left) brain (amygdala) would be reductionistic (holistic, negentropic) whereas the intellectual right (left) would be holistic (reductionistic, entropic). The practical reason to the division to the entropic and negentropic pieces could relate to the metabolism. The entropic regions could provide the binding energy as a usable energy to the positive energy NE. Good is not possible without Evil! There are no winners without losers!

   Right brain is specialized in spatial thinking and left brain to verbal thinking and arithmetics: the geometry-algebra division of mathematics! Right brain is not so good in motor actions as left brain as any right-handed person knows. Right brain is however better in tactile sensing: right handed persons tend to use left hand for touching objects to get an idea about their shape. Also this can be understood in holistic-reductionistic picture.

3. Apart from reflex actions almost all activities of the body seem to be controlled to a high degree by brain. Could also the activities of cell be regarded as motor actions of the genome acting as the brain of cell receiving sensory input from the cell membrane? Could one identify the analogs of sensory areas receiving information from cell membrane, processing, and sending it to the association areas? Could the analogs associative areas be identified as intronic portions of DNA performing topological quantum computations and communicating the outcome to the higher motor areas at the intronic portions of the of the complementary strand, wherefrom they would be communicated to the primary motor areas identifiable as

the regions of DNA expressing themselves either chemically (RNA and proteins), as activities generated directly at the level of cell membrane, or electromagnetically? For instance, could neurotransmitter in the receptor generate the feed of sensory input to the genome inducing the change of the membrane potential as the counterpart of motor action. Could prokaryotes without introns be analogous to brain with only primary sensory and motor areas or to mere ladder-like nervous system?

One could argue that the analogy between DNA are brain fails because second DNA strand is completely passive whereas both brain hemispheres express themselves via motor actions. This is not the case! Both DNA strand has regions expressing themselves but the transcription takes place in opposite directions. Hence DNA strands have motor and sensory areas as also brain does, and the natural guess is that primary motor areas correspond to the areas expressing themselves in terms of RNA, proteins, and possibly also as actions at the level of cell membrane. Primary sensory areas would correspond to to regions complementary to the primary motor regions.

4. What right brain sings-left brain talks metaphor could mean in this picture? Pitch-rhythm dichotomy is more technical expression for this dichotomy. Function providing local data and its Fourier transform providing global data is more abstract representation for this dichotomy and Uncertainty Principle for momentum and position relates closely to these two representations of information. This dichotomy could reflect the presence of two different natural time scales and millisecond time scale for nerve pulses and.1 second time scale for moments of sensory experience are the natural candidates.

   If so, this dichotomy could directly reflect the different time scales assignable to u and d type quarks (1 millisecond) and to electron (100 ms) and reduce to the level of elementary particle physics. This dichotomy would also have fractally scaled up variants made possible by the hierarchy of Planck constants. The analog of Fourier transform would be the NE of sub-CDs (assignable to quarks) to single mental image inside electron's CD. The analog of function itself would be a collection of sub-CDs representing separate unentangled mental images assignable to individual nerve pulses in millisecond time scale. Also the topological quantum computations assigned to the intronic portions correspond to different time scales due and reflect quark-lepton dichotomy. The quarks in question could be the quarks assigned to the ends of flux tubes in the model of DNA as topological quantum computer.

5. This raises some questions. Could the gene expressions of the two strands somehow reflect this dichotomy? For instance, could the flux tube structures assignable to the amino-acid sequences correspond to the millisecond and 100 ms scales assignable to quarks and electron have the property that also the functioning of these proteins is characterized by these typical time scales? According to [I68] the time scales of protein folding vary from.1 s to 10^3s. According to Wikipedia [I17] the typical time scale is 1 millisecond which suggests that the time scales correspond to two ranges beginning from ms and 100 ms respectively. There are also short proteins for which the folding takes place in microsecond time scales which might relate to the CD of proton.

What can one say about the function of neurotransmitters?

Can one say anything interesting about the function of neurotransmitters if one combines this highly speculative picture- which can be defended only by the belief on fractality as universal principle- with the idea that bound state and NE make possible the fusion of mental images.

1. Suppose that the fusion of neuronal mental images is required to build higher level mental images that we experience. Suppose that neuronal mental images involve DNA in an essential manner. Suppose that magnetic flux tubes serve as correlates for the entanglement so that the transmission of nerve pulse from pre-synaptic neuron to post-synaptic one creates a flux tube connection between neurons possibly extending to the genome of the post-synaptic neuron. The transmitter at the end of flux tube attached to the receptor acting as a plug would build this connection to some part of DNA specialized to receive particular kind of sensory data from a particular region of cell membrane with complementary strand activating as a

response a motor function inducing gene expression at cell membrane level. Gene expression as build-up of proteins would not be necessary and is also too slow for neural activities.

2. Suppose that the entanglement between neurons generated in this process is always negentropic as the interpretation as the idea about neural correlate for a conscious association suggests. One could also ask whether the neurons could entangled entropically and whether the entropic-inhibitory association could make sense. This does not lead to anything interesting and entropic entanglement between neurons should be regarded as a pathological condition. Note that neuron-neuron entanglement would be naturally time-like and in this case only NE might be meaningful.

   (a) To gain some perspective consider the activation of cell in general by some external perturbation from the resting state to the active state (here I have learned a lot from email correspondence with Vladimir Mateev) In the resting state the proteins inside cell are passive -or rather, forced to be passive- as one might expect on basis of the general vision about homeostasis. The unfolded proteins and unfolded portions of the folded proteins are connected by hydrogen bonds to ordered water so that the folding occurring otherwise spontaneously is prevented. One can say that the cellular winter prevails. The situation is however nearly critical and if external perturbation occurs cell liberates metabolic energy melting the ice and spring comes. Also the outer surfaces of globular proteins are hydrogen bonded and when the ordered water melts, spontaneous melting of the protein takes place leading to a partial unfolding.

   The resulting folded proteins and partially unfolded globular proteins interact by forming aggregates and this activity would naturally involve $\hbar$ reducing phase transitions and flux tube reconnections. In TGD based model the mechanism of both folding and melting would be the liberation of metabolic energy destroying the hydrogen bonds and the energy for this comes from the ATP containing positive energy negentropic bond between O=s of phosphates.

   (b) Similar situation could prevail at the cell membrane. One can imagine that cell membrane is like a particle at the bottom of a small potential well. At the other side there is a deep well representing the generation of nerve pulse and at the other side a high wall corresponding to hyper-polarization requiring energy. Both polarization and hyper-polarization are prevented by the freezing of protein activities needed to induce them. The flux tubes connecting the presynaptic neuron and receptor and possibly genome are always negentropic and their formation can as such serve as the signal leading to the partial melting of the ordered water making possible to generate action leading to either de-polarization or hyper-polarization. The signal could be just the additional metabolic energy making it possible for these transitions to occur.

   (c) This picture does not require any communications from the receptor to the genome and in the simplest situation the resulting action could be seen as the analog of reflex action. These communications could of course be present and the negentropic entanglement could make it easier to induce de-polarization also now. Also the question whether excitatory-inhibitory dichotomy for the receptors has some deeper meaning apart from taking the neuron nearer to or farther from criticality for firing remains unanswered.

7.2.4 Differences Between Left And Right Brain Hemisphere

The differences between left and right brain hemisphere or lateralization of brain functions -as the more technical term states it - represent a challenge for any theory of consciousness. This difference is often stated by saying that right brain is holistic and left brain reductionistic - or more concretely - that left brain talks and right brain sings, left brain is linear and right brain parallel, or that left brain is algebraist while right brain is geometer. The assignment of the holism-reductionism to the hemispheres as whole is probably an exaggeration. For instance, right limbic brain is specialized to negative emotions and left limbic brain to positive emotions and it is not clear whether this has anything to do with holism or reductionism. It could however be that pairs of various left and right brain regions could be characterized in terms of this dichotomy or perhaps trinity in which

reductionism, holism, and their fusion are possible but that a given region of given hemisphere can favor any of these options.

Holism, reductionism and their fusion, entanglement, and zero energy ontology

In TGD framework the basic mechanism responsible for reductionism-holism dichotomy would be the possibility of the mental images to fuse to larger mental images. Depending on the nature of entanglement the resulting mental images are either negentropic or entropic. Entropic entanglement represents a holism as the antipode of reductionism whereas NE seems to represent a fusion of holism and reductionism. It would be tempting to assign positive emotions to the NE and negative emotions to the entropic entanglement. Both limbic hemispheres could be holistic but negentropic-entropic dichotomy would distinguish between them.

For the purposes of survival it is good to have both all these three views about reality. In politics hawks, doves and compromize makers would be a counterpart for this phenomenon. This would favor lateralization in a more general sense that a brain region in given hemisphere favours unentangled emotionally neutral mental images, negentropically fused mental images with positive emotional coloring, or entropically fused mental images with negative emotional coloring. Also metabolism could favor formation of the unpleasant entropic mental images since this liberates energy which could be stored in metabolic entanglement as a metabolic energy. Interestingly, it has been proposed that the simultaneous presence of holism and reductionism could explain the amazing mental feats of idiot savants. The irony is that these persons are usually unable to describe their experiences using language, which brings in mind the reports of meditators telling that it is impossible to tell anything about englightment experience using language. Maybe language relates crucially both to the ability to decompose the mental images to smaller pieces and to form entropically entangled wholes of them.

I might be self-contradictory here. On one hand, I have proposed that the feats of idiot savants are possible because they do not conceptualize and in this manner replace reality with the names of the objects of the reality: something extremely economical if one counts bits. On the other hand, I am proposing that the formation of concepts corresponds to the NE. It seems that I should distinguish between two kinds of conceptualizations: the NE without language on one hand achieved in meditative practices and the combination of both entropically entangled and non-entangled representations making possible language but losing the insight of genius.

Zero energy ontology suggests a quantitative formulation of this vision based on the observation that the time scale of electron's CD corresponds to the.1 second time scale defining fundamental biorhythm whereas millisecond time scale defining the fundamental time scale of nerve pulse activity could relate closely to the time scale of CDs assignable to u and d quarks predicted to play a key role in quantum information processing in the model of DNA ast topological quantum computer. There are also shorter times scales, in particular the time scales assignable to proton which can be estimated to be of order 10^{-7} seconds. Also p-adically scaled up variants of these time scales are possible as well as zooming of these time scales at the pages of the Big Book defining generalized embedding space and partially labeled by the values of Planck constant. The first guess is that quark and lepton time scales are behind the reductionism-holism division. Holism would mean temporal binding of the mental images assignable to nerve pulse patterns and characterized by millisecond time scale to negentropic (or possibly entropic) sub-selves characterized by.1 second time scales. Quark like sub-CDs of electronic CDs would serve as embedding space correlates for these mental images.

Objection against simplistic view about lateralization

The hypothesis that right brain is more holistic than left brain can be tested and a considerable support for the hypothesis have been found. There is however a rather paradoxical experimental result challenging the hypothesis in its simplest form and suggesting that the roles of various processing levels of brain hemispheres in the specialization to geometric shapes and linguistic symbols can vary. In [J112] there is report about two experimental situations testing right-left differences.

1. Subject persons saw figure S consisting of smaller figure F: s. On basis of neural firing left brain seemed to recognize smaller F: s whereas right brain seemed to recognize the entire

figure S: just as expected.

2. For control purposes figure S consisting of small F: s was replaced with a figure of anchor consisting of small cups. What happened was that left brain recognized the anchor and right brain recognized the cups! Also firing patterns were essentially the same! It was conjectured that the smallness of cups -smaller than letter F: s- might have something to do with the unexpected result.

Apparently the replacement of letters with geometric shapes means that the roles of brain hemispheres changed. This suggests that the naïve vision about roles of hemispheres must be replaced with something more complex in which one has scale hierarchy of levels such that each level has its own specialization.

1. Suppose first that at the lowest level of the hierarchy the left hemisphere is better in recognizing letters than familiar shapes and right hemisphere better in recognizing familiar geometric shapes than letters.

2. The subject persons are asked to concentrate on either the entire figure or details which repeat themselves. This raises the question whether a single detail becomes actually the whole since the attention is directed to details. If this is the case, the first assumption would explain why right brain hemisphere fires as cup is recognized. Same applies to the left hemisphere in the case of letter F.

3. When the figure as a whole must be recognized, the recognizing hemisphere seems to be the one for which the recognition should be more difficult! The hierarchy of CDs allows to consider the possibility that there is a fractal hierarchy of levels corresponding to different size scales for the structures appearing in the figure. The very fact that subject person is conscious about the existence of smaller details means that smallest structures are mapped to the first level of the hierarchy so that in both cases the figure as a whole would be mapped to the second level of the hierarchy. If one takes the experimental result at a face value, letters should be more familiar to the right hemisphere and geometric shapes of everyday objects to the left hemisphere at the second level of the hierarchy.

4. That the roles of brain hemispheres in lateralization depend on the level of the hierarchy might have an explanation in terms of basic information processing involving communications between hemispheres. Maybe there is a mapping from the first level of hierarchy of a given hemisphere to the second level of hierarchy at the opposite hemisphere and so on. At higher levels of the hierarchy the hemispheres would perceive each others visual percepts. Right hemisphere at the n: th level would receive sensory signals from $n-1$: th level of left brain and vice versa. In this kind of situation the maximal effectiveness of the information processing would be achieved if these two ladders rather than hemispheres have similar specializations.

Some examples

This framework explains various aspects of holism-reductionism dichotomy when given pair of brain regions is considered but it is not meant to apply to brain hemispheres as a single pair.

1. Linear-parallel dichotomy suggests that in a given time scale left hemisphere corresponds to large number of un-entangled sub-selves whereas right hemisphere would correspond to a larger number of entangled sub-selves with entropic (at least in case of limbic brain) or NE. For instance, the unentangled sub-selves can correspond to letters of written text at left hemisphere. At right hemisphere they could correspond to objects of everyday life or even understood words of written text with mental images representing letters entangling negentropically in time direction to form a single mental image. Also much smaller details such as edges an lines of figure having no direct meaning are certainly involved.

   Left brain seems to be skilled in forming mental images about structures consisting of well defined components whereas right brain can grasp the general shape and size of the structure (note however the previous example in conflict with this belief). This could be understood if left brain represents structures linguistically as associative linear structures consisting of

parts represented as sub-selves. Thus a structure could be realized as a reverberating neural circuit in which sub-selves representing parts of the structure keep each other awake.

2. Right hemisphere is also claimed to be less analytic. It might be that also this might hold true only for the right-left-right-.. information processing hierarchy when compared with left-right-left... hierarchy beginning from left brain hemisphere. Certainly the entanglement of mental images would explain this.

3. That left brain talks whereas right brain (almost) sings is more than a loose metaphor. It is known that people who have left brain injury and cannot talk can sometimes express themselves by singing. Linear-parallel dichotomy would suggest that left brain is specialized to subjecto-temporal sequences of parallel small-sized mental images of short duration (say words of speech): this would correspond rhythm and other temporally local aspects of music which dominate in speech. Right brain is specialized to large selves formed by the fusion of parallel sub-selves formed by, say, separate notes of music which can last long time and have no linguistic content. These mental images should carry conscious information about non-local aspect such as pitch of the sound. Although the notes of song are heard one in time, they would continue to live in right brain as parallel mental images and make possible to experience the melody as sad or joyful or to remember the key of the music piece.

4. The poor temporal and spatial resolution assigned to the right hemisphere can be seen as a price paid for the holism of entanglement. Again one must however remember that a scale hierarchy might be involved.

5. The claim that right brain is more emotional should be taken with a caution. It seems better to say that the right limbic brain is dominated by negative emotions and left limbic brain by positive ones. The interpretation would be in terms of entropic *resp.* negentropic entanglement: in this sense left brain would have higher emotional intelligence. On the other hand, right brain is claimed to have better skills in recognizing and expressing emotions. This is not in conflict with the fact that left brain hemisphere is the happier hemisphere. These skills could be understood as a more holistic expression of emotions and their perception, and might also relate to the ability of the right hemisphere to generate negentropic entanglement with other brains.

Dr. P. and twins who saw primeness

Oliver Sack's book "The man who mistook his wife for a hat" [J141] contains fascinating stories about those aspects of brain and consciousness which are more or less mysterious from the view point of neuroscience. There are two stories which relate very closely to reductionism-holism tension of conscious experiencing.

The first story is about Dr. P. who suffered visual agnosia and could not recognize concrete objects, say faces unless some nonvisual association was involved. He could however recognize abstract symbols or objects containing some symbolic details making possible the recognition (he recognized Einstein's face, which has indeed become a symbol of wisdom!). Sacks tells about how his patient tried to recognize glove. "A curved shaped containing five small bags" was his abstract analysis: he could not identify the glove as a glove unless he got it in his hand! He could however define glove as an abstract geometric shape allowing simple linguistic description. Dr. P. could identify abstract shapes and symbols like letters and geometric objects but could not recognize real world objects. Amazingly, Dr. P. used musical associations as a way to cope with the complexities of everyday life. He singed through all his everyday activities and lost control totally if this was for some reason not possible. He could also continue teaching of this music class. For instance, he could recognize his music students only when they moved by recognizing their "body music".

As discussed, reductionism-holism duality provides the deep reason for why we have two brain lobes. This allows to understand what might be possibly involved with Dr. P: s case. Dr. P: s right visual areas had been damaged and he could not recognize faces and concrete objects of the visual field. Left visual areas were in good condition and he could identify abstract objects. Other than visual areas were still in good condition in both hemispheres and he could perform recognition using musical associations, associations created by smells, etc... Sacks notices also a

deep analogy with Dr. P.: s case and neuroscience. Expressing rather freely what Luria said, entire neuroscience up to seventies provided analytic description of left brain about left brain. It had indeed turned out very difficult to assign any easily identifiable cognitive dysfunctions with localized right brain injuries and Luria's opinion was that this necessitated completely different approach which he called "romantic" (stories of right brain about both right and left brain!).

In fact, one can formulate new kind of Uncertainty Principle, perhaps it might be called Uncertainty Principle of cognition. Same mental image cannot be both holistic and reductionistic simultaneously. The combination of reductionistic and holistic descriptions (and all possible intermediate descriptions combining parts to "sub-wholes" in various ways) to single description is impossible even in principle! Science and Art as descriptions of the world are very much like mutually incompatible observables of Uncertainty Principle! The obvious reaction of the alert reader is that NE might allow to achieve both reductionism and holism simultaneously. Maybe this is the case but in this case there is no manner to communicate the mental using language if the proposed interpretation is correct.

Sacks tells also about twins, John and Michael, who had mysterious ability to "see" large numbers. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately "111!". Then John mumbled "37", Michael repeated it and John said "37" third time. Obviously this was their cognitive representation for the decomposition 111=3x37 of number 111 to a product of primes!

How John and Michael did these numerical feats? The first thing to notice is that twins had intelligence quotient of about 60 and could not perform even simplest arithmetical operations. They did not even understand what the concepts of prime and decomposition into prime factors mean conceptually. They however experienced primes as especially interesting numbers and even played a game in which they invented new primes. One can safely assume that they did not consciously calculate the decomposition of number 111 to a product of primes. When asked how they were able to tell the number of matches, they told that they "saw" it. In fact, their eyes moved in strange manner always when they were performing numerical tasks and stopped when the solution was found. Also the decomposition of 111 to a product of 3 primes "37" seemed to occur completely spontaneously "in front of their eyes".

The mysterious ability of twins is not a mere curiosity but could provide a crucial clue to the problem of understanding of how numbers are realized as mental images. Indeed, also ordinary human beings are able to experience directly "N-ness", when the size of N is small. A sensory memory associating the visual mental image with the verbal representations of "N" could be in question. This association resembles synesthetic associations, which are also completely automatic.

Thus the problem transforms to a more general question "How integers are experienced directly?".

1. In TGD framework the answer to the question is obvious. Experiencing of "N-ness" means experiencing "N" separate objects as a single whole and corresponds quantum physically to the generation of NE between the cognitive representatives of individual objects. If the resulting mental image associates automatically with a linguistic expression for "N-ness", say $N = 5 \leftrightarrow five$, reportable recognition of "N-ness" occurs. 7 ± 2 law suggests that this entanglement and association usually occurs only for maximal number of objects not larger than $N = 7 \pm 2$. In case of a numerical genius this number seems to be drastically higher. The generation of this entanglement should be spontaneous self-organization process in either brain hemisphere and entangled objects could correspond to separate neuron groups or neurons.

2. The decomposition of integer $N = N_1 \times N_2$ to a product of integers must in this picture correspond to the spontaneous formation of identical "sub-wholes". This process must be a quantum self-organization process. It could favour the decomposition of $N = N_1 \times N_2$ objects to N_1 "sub-wholes" consisting of N_2 entangled basic objects or decomposition of N_2 sub-wholes consisting of N_1 basic objects or something else depending on factors of N. This kind of final states of self-organization are natural since they are very symmetrical consisting of a repetition of an identical basic unit. This kind of self-organization patterns are analogous to the lattice-like self-organization patterns of Benard flow.

3. NMP [K73] could be involved in the following manner. Suppose that the perception of the

number of N objects generates in brain an ensemble consisting of N mental images, which entangle negentropically. If so, then the simplest expectation is that entanglement probabilities are proportional to $1/N$ and the number theoretical entanglement entropy is large only for p-adic primes dividing N. The prime divisor of N giving rise to the largest number theoretic negentropy would determine the p-adicity involved and this could correspond to a perception about the decomposition of the visual representation of N to N/p pieces.

The model also explains the ability of twins to see whether a given number is prime or not. Primes are stable against decomposition into sub-wholes and are therefore "elementary particles of cognition". Hence primeness is a "visible" property: primes are numerical mental images stable against decay to a set of identical numerical mental images. Note that this dynamical process breaks the symmetry between the factors of integer. This clearly occurred in $111 = 3 \times 37$ example. Twins did not "see" "3": they saw only some 37's and did not explicitly tell that there were precisely three 37: s!

In [K19] a more concrete model for how real space-time sheets could represent integers and their prime factorization by their effectively p-adic topology, is discussed.

7.2.5 Music And Consciousness

Music experience provides an interesting testing ground for several assumptions of quantum TGD and TGD inspired theory of consciousness. The notion of self is especially interesting in this respect.

Some aspects of music experience

It is good to list first some elementary characteristics of music experience that the model should be able to explain. Both rhythmic aspects and pitch of the sound are important. Rhythmic aspects correspond to time domain representation for the intensity of sound carrying local information about sound wave whereas pitch carries global information. The relationship between these two elements of music is like that of function and its Fourier transform. Harmony enters the game when several frequencies are present.

1. Rhythm

There are two basic types of views about rhythm, additive and divisive, and they correspond to the multiplication and sum as basic arithmetic operations.

1. In western music rhythm corresponds to a division of longer periods of time divided into smaller rhythmic units. Rhythm is basically a clock and rhythm is essentially a decomposition of integer to a product of integers defining the rhythmic unit and their number. Classical western music is relatively simple rhythmically (consider only the music of Bach). In the music of Chopin tempo rubato makes the duration of the basic rhythmic unit and of its basic structural elements dynamical but rhythms are still relatively simple although simultaneous 3/4 and 3/8+3/8 appears often. In jazz and various forms of popular music rhythms tend to be highly clocklike but are very complex.

2. In Indian music for instance, rhythms are additive and larger periods of time are constructed from smaller rhythmic unis added to the end of the previous unit. This division corresponds to addition rather than multiplication algebraically. Also intermediate forms can appear and do so often in folk music (say folk music of Greece, Balkan, and Spain). For instance, one can have the sum of 3/4+3/8+3/8 as a repeating rhythmic unit. In flamenco form known as Bulerias [J8] the basic rhythmic unit consists of 12 beats and the collective performance creates a very complex and emotionally catching rhythm, which is almost impossible to analyze to pieces. It is easy to believe the claim that artists often fall in trance during the flamenco sessions.

2. Pitch

Pitch can be identified as the fundamental frequency of note. Pure sine wave is aesthetically unpleasing and harmonics are always present and characterize the music instrument. Not only

frequencies but also phase relationships between them are important. For instance, they distinguish between the phonemes of spoken language and in the case of singing this brings in an important additional element not so important for non-electronic instrumental music. Furthermore, melody is never a mere sequence of precisely defined frequencies. For instance, slow modulations of the pitch reducing mathematically to a superposition of closely separated frequencies and glissandos have emotional affect.

The model of music experience should explain also the following aspects related to pitch understand as fundamental frequency.

1. Octaves of the fundamental are experienced as equivalent. The presence of higher harmonics is needed to make pure sinus wave a musical note. Higher harmonics determine the character of the pitch chracterizing the music instrument.

2. There exists a large number of different scales to which one assigns attributes like diatonic, minor, chromatic, whole tone, pentatonic, diminished... All these scales have quite specific emotional coloring and they characterize different music styles. The minimum frequency interval corresponds to a minimal scaling of the frequency and depends on music style. Western classical music uses semitone as the basic unit corresponding to the scaling $2^{1/12}$ in equally tempered scale but also microintervals are used and the only limitation comes the from ability to discriminate between different frequencies. The scales have special notes such as tonic, supertonic, mediant, subdominant, dominant, submediant, subtonic with special roles in harmony. For instance, listener is often able to remember the basic scales even if the tonic of the scale has suffered several modulations during the music piece. Deviations from basic scale have important emotional effects (say in the case of minor scale).

3. Ancient mathematicians believed that the presence of rational multiples of fundamental frequencies are essential for harmony. It is possible to construct the basic scales involving only rational multiples of the fundamental in terms of selected harmonics. For instance, Pythagorean construction uses only powers of 3/2 and octaves to construct the basic scale (C, G, D, A, E, H, ...). Although the pitch is distinguished only within a finite resolution and equally tempered 12-note scale uses only powers of $2^{1/12}$ of the fundamental, rational multiples of the fundamental might relate deeply to the basic physics of cognition and to the frequencies generated in brain as opposed to those used to produce the music.

4. The expectation of an engineer is that the transposition of the scale should not effect on the music experience and one could think that it could be done in a continuous manner. Many composers, for instances Sibelius, experienced different modes differently and as synesthetes assigned to them different visual associations. Many people are able to recognize the ratios of notes but there is also the much rare phenomenon of absolute ear meaning that subject person is able to tell the pitch of the note directly. A synesthesia like phenomenon is probably in question.

5. An interesting question the notion of absolute scale could make sense to some degree? The fundamental frequency of sound producing organs is 10 Hz and the region of audible frequencies begins at 20 Hz and consists of approximately 10 octaves. kHz frequency is the resonance frequency of head sized object and at this frequency the mechanism allowing to deduce the direction of sound source changes. The biological basis for this would be that 10 Hz and 1 kHz define fundamental biorhythms. The quantum physical basis for this could relate to the p-adic length scale hypothesis predicting that 10 Hz and 1280 Hz could correspond CDs of electron and quarks. To get a contact with concretia note that soprano C corresponds to 1046.50 Hz. Also the cyclotron frequencies assignable to various biologically important ions in endogenic magnetic fields could defined preferred scales. The A above middle C corresponds by convention to 440 Hz, which is integer multiple of 10 Hz but by pure convention and fifth octave of 8.175 Hz which is not too far from the lowest Schumann resonance. An interesting question is whether the transposition to a scale for which the fundamental is simple rational multiple of 10 Hz or lowest Schumann resonance might have some specific emotional effect.

3. Harmony and other collective aspects of music

Harmony relates closely to the interaction of different frequencies and is therefore one particular collective aspect of music experience.

In the terminology of physicists, harmony is a phenomenon of many particle physics with particles replaced notes of the scale and many-particle states with chords. Depending on the ratios of the frequencies certain chords are aesthetically pleasing and emotionally significant and there are also principles governing aesthetically pleasing chord progressions. Harmony might be seen as the vertical aspect of the music whereas melody would correspond to horizontal one. Dissonance is the opposite of harmony and tritonus was forbidden in the early western music but is nowadays used to create tension. Polyphony -say in Bach's music- and simple chords used to accompany singing represent two opposite views about harmony. Chopin's music has especially rich harmonies and emotional expressive power.

While listening music one typically selects some instrument as figure and the rest as a background. In romantic piano concertos the competition between the solist and orchestra about the attention of the listener creates the basic tension. In polyphonic music one must also select the tone progression to which attention is directed and it is difficult -perhaps even impossible- to simultaneously grasp the separte tone progressions. Same applies to other elements of music.

Zero energy ontology, hierarchy of Planck constants, and number theoretic physics

The number theoretic vision brings interesting new physics elements which might help to understand music experience.

1. The hierarchy of selves has as an embedding space correlate the hierarchy of CD is basic prediction. p-Adic length scale hypothesis suggests that quantization of size scales of CDs as octaves and the question is whether this relates directly to the preferred role of octaves in music experience. The time scales of CDs define preferred fundamental frequencies coming as octaves and the hierarchy of Planck constants defines scaled variants of these as rational or integer multiples (depending on generalization of the embedding space).

2. The question is whether these fundamental frequencies also define fundamental keys so that music experience would depend on absolute frequency scale. Even if CDs define fundamental keys, the frequency scale associated with sub-CD as experienced in the rest system of CD can be scaled continuously by performing a Lorentz boost for CD. Even glissando could be achieved for CD by performing to the sub-CD a Lorentz boost continuously and leaving the other tip of CD invariant. The boost would be the hyperbolic analog of an ordinary rotation and act like acceleration from rest to constant velocity inside sub-CD. If one takes this picture seriously also Lorentz boosts would be important part of the representation of music at the level of magnetic body (presumably using MEs). Quantum TGD proper suggests the quantization of these boosts.

3. Number theoretic vision predicts an infinite number of algebraic extensions of rationals inducing those of p-adic numbers -in particular those corresponding to roots of unity. In the p-adic context the proper representation of sine waves requires the introduction of these algebraic extensions and the prediction is that rational multiples of the fundamental frequencies assignable to p-adic length scales should have a special role from the point of view of cognition. In fact, the algebraic extensions are now the correlate for the evolution and define a hierarchy of adelic physics predicting the existence of preferred p-adic primes and when combined with NMP also a generalization of p-adic length scale hypothesis [K137].

   This might justify the belief that the notes of the scale should be expressible in the optimal situation as rational multiples of the fundamental note. The cognitive representation of the music in the intersection of real and p-adic worlds should map the physical frequencies or rather the sine waves at a discrete set of time values to their p-adic counterparts. One has to deal with phase factors defined by plane waves $exp(ift_n)$ at discrete set of points t_n such that the exponent equals to $exp(i2\pi m/N)$ and belongs to the algebraic extension. The harmonics of f obviously satisfy the same condition. The representation of pitch in terms of algebraic extensions of rationals requires that the corresponding partonic 2-surfaces correspond to complex enough algebraic extensions of rationals containing high enough roots

of unity. The modulation of the pitch as superposition of two nearby rational frequencies could is possible without leaving this framework.

4. One can consider also different but not exclusive explanation for why scales define preferred collections of frequencies. Pythagorean scale involves rational multiples of fundamental obtained as powers of 3/2 and 2 so that the frequencies involved correspond to rationals of form $3^m 2^n$ for which only 3-adic and 2-adic norms differ from one. Small-p p-adicity associated with $p = 2$ and $p = 3$ could select the preferred frequencies.

Why octaves are experienced similarly?

The model should explain the basic features of music experience. There are many interesting questions related to this. One of the most important is why frequencies which are 2^k- multiples of the fundamental frequency, notes differing by octaves, are experienced as identical notes.

1. p-Adic length scale hypothesis, zero energy ontology, and octaves

Thus the phenomenon of octaves could relate to the p-adic length scale hypothesis, which implies that physically preferred p-adic primes correspond to primes near prime power powers of two. For instance, this implies that the massless extremals (MEs) associated with physically important p-adic primes have fundamental frequencies which are octaves of each other. Therefore a classical resonance via the formation of join along boundaries bonds/flux tubes becomes possible and real space-time sheets corresponding to preferred p-adic primes can form larger resonant structures. This universal resonance could explain why octaves are experienced similarly. The problem of this argument was that primary p-adic time scales would come as half octaves instead of octaves.

Octaves seem to have much deeper significance than I thought originally and seem to emerge at the level of fundamental formulation of quantum TGD rather than characterizing only a very special kind of sensory experience. In the recent formulation of quantum TGD using zero energy ontology [K29, K28] one uses zero energy states which have their positive and negative energy parts at the light-like boundaries of causal diamonds consisting of future and past directed light-cones.

Physics as a generalized number theory vision, in particular the assumption that real physics and various p-adic physics result as algebraic completions of rational physics, motivates the hypothesis that the temporal distance T between the tips of the causal diamond is quantized and corresponds to powers of 2 using time scale defined by CP_2 size as a basic unit. This assumption allows to deduce p-adic length scale hypothesis ($p \simeq 2^k$, k integer), and to identify T as a secondary p-adic time scale. For electron this time scale is .1 seconds and corresponds to the fundamental 10 Hz biorhythm. For non-standard values of Planck constant T is scaled by a factor $\hbar/\hbar_0$. Thus octaves become a key element of fundamental physics. One can say that causal diamonds as space-time correlates of self appear naturally as octaves. Also rational multiples of fundamental frequency emerge via the hierarchy of Planck constants: in principle all rational scalings of the basic hierarchy are allowed.

2. Is sensory experience 2-adic in some sense?

A stronger hypothesis for the phenomenon of octaves is that cognitive music selves are 2-adic or that real music selves can transform easily to 2-adic selves. One might even consider the possibility that the phenomenon is much more general. Music metaphor has indeed turned out to be of crucial importance for the theory of qualia. Thus music metaphor could reflect the underlying 2-adicity of the sensory experience (at some level of self hierarchy). Perhaps at least some aspects of our experience result from a mimicry of the lowest level of the p-adic self-hierarchy. Taking 2-adicity seriously, one is forced to ask for the possible consequences of 2-adicity. For instance, could it be that at the level of primary qualia the intensity of sensation as function of stimulus depends on the 2-adic norm of the 2-adic counterpart of the stimulus and is thus a piecewise constant function if sensory input?

An observation supporting this speculation is following. When over-learning occurs in tasks involving temporal discrimination, the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [J104] such that the plateaus, where response remains constant are octaves of each other.

This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has a multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jump-wise replacement of the n: th harmonic by $n+1$: th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of over-learning or neurons involved act unisono and the underlying 2-adicity is not masked anymore.

At the level of MEs this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier. This certainly would mean that cognition is an important part of music experience. The strongest assumption is that the real note selves are able to transform to 2-adic selves by a phase transition changing local topology from real to 2-adic. Note however that p-adic length scale hypothesis might be enough.

Does harmonic complexity reduce to 3-adicity?

An interesting question relates to the conditions guaranteeing that a chord is experienced as harmonious in the Pythagorean sense [J23]. Pythagorean tuning is based on the notion of perfect fifths identified as scalings by 3/2 producing the sequence C, G, D, A, E, .. In this tuning major-C scale corresponds to ratios $C = 1/1, D = 9/8, E = 81/64, F = 4/3$, $G = 3/2, A = 27/16, B = 243/128, C = 2/1$. E_b and $F_\#$ correspond to ratios $2^5/3^3$ and $3^6/2^9$. All notes are expressible as powers of two and three. Since the multiplication of any note by a power of two does not affect the harmony it should be to drop the powers of two from the integers characterizing the notes in the ratio of three notes. For instance, C-E-G reduces $3 : 3^4 : 1$, $C - E_b - G$ to $3^4 : 1 : 3^3$, and tritonus $C - E_b - F_\#$ to $3^9 : 1 : 3^3$. The problem of Pythagorean tuning is that one cannot represent 2 as an exact integer power of 3/2 and the scalings give infinite number of tones. If the construction starts from G_b then $F_\#$ and G_b correspond to frequencies, which are not quite identical in Pythagorean tuning. One could make compromize by introducing the geometric mean of $F_\#$ and G_b but this would bring in $\sqrt{3}$ and would force to leave the world of pure rationals. For string instruments and electronic instruments the Pythagorean tuning is practical but for instruments like piano the transposition of the scale is impossible.

One should be able to characterize a given chord harmonically by a function $F(a, b, c)$, which is symmetric under the permutations of the reduced pitches a, b and c obtained by dropping powers of two and is invariant under over all scaling of the reduce frequencies. The elementary symmetric functions $F(a, b, c) = [a^2(b + c) + b^2(a + c) + c^2(a + b)]/abc$ and $G(a, b, c) = [a^3 + b^3 + c^3]/abc$ are the simplest functions of this kind. Either of these functions or their product or ratio could be considered as a measure for the harmonic complexity. The value of the denominator abc equals to 3^n, $n = 3, 7, 12$ in the cases considered. The numerator has in all cases 3-adic norm equal to one for both F and G. This suggests that the 3-based logarithm of the 3-adic norm $1/|abc|_3 = |F|_3 = |G|_3$ having the values 3, 7, and 12 for C-major, C-minor, and tritonus could serve as the measure for the complexity. It is indeed smallest for major and largest for tritonus. 3-adic norm for the product $1/a_1a_2...a_n$ of n notes of the chord defines a measure of complexity in more general case. A good guess is that the 3-adic norms of the elementary symmetric functions give rise to the same measure.

For the chords C-E-G, F-A-C, and G-H-D appearing as basic chords in C- major scale the values of the harmonic measure are 3, 2, and 8. This means that the basic chords are not harmonically equivalent in Pythagorean system whereas in equally tempered system they would be. One might think that this explains why the tonic is remembered. The anomalously low value for F-A-C relates to the fact that it is only tone for which the power of 3 is negative. Situation changes of F is identified as a minimal power of 3 giving F equivalent with Pythagorean F within the resolution of ear to pitch which is about $|\Delta f/f| = 4.3$ per cent. $F = 3^5/2^8$ gives $|\Delta f/f| = 4.8$ per cent. This F would give for F-A-C the harmonic measure 8 which equals to that for G. This looks more reasonable than the purely Pythagorean value. This definition would also allow to find a unique choice of powers of three for 12-chord system. For instance, $F_\#$ is favored over G_b since it corresponds to a positive power of 3.

The ability to express the notes of scale as powers of 3/2 by projecting the outcome to

the basic octave suggests strongly that 3-adicity is an key element of music experience. Years after writing the first version of this text, I received an interesting email from Jose Diez Faixat giving a link to his blog (`http://tinyurl.com/ycesc5mq`). The title of the article in the blog is "Bye-bye Darwin" and tells something about his proposal. The sub-title "The Hidden rhythm of evolution" tells more. Darwinian view is that evolution is random and evolutionary pressures select the randomly produced mutations. Rhythm does not fit with this picture. Faixat published 1993 the first article about his observations in the journal World Futures Vol. 36, pp. 31-56, edited by Ervin Lazlo with the title "A hypothesis on the rhythm of becoming" [I48, I49].

Thus it seems that 3-adicity might be fundamental not only for music experience but for biology. This conforms also with the generalization of p-adic length scale hypothesis implied by the weak form of NMP [K137] that primes near powers of primes are favoured by NMP. p-Adic length scale hypothesis corresponds to $p = 2$ and Faixat's findings and music experience support $p = 3$.

The notion of self and music

The music experience allows also to test the ideas related to the notion of self.

1. Summation hypothesis states that self is a sum of abstracted experiences of sub-selves and thus representing kind of averages about the experiences of sub-sub-selves.

   (a) The conscious experience induced by music decomposes in a clear manner to basic elements identifiable as sub-selves. For instance, melody and more generally various tone progressions could define such sub-selves and the experiences of these sub-selves would sum up to music experience. In the same manner rhythmic patterns define their own sub-selves. Therefore it might make sense to speak about "frequency sub-selves" and "rhythm sub-selves".

   (b) At space-time level the magnetic body and massless extremals (MEs) are the natural candidate for the representation of "frequency sub-selves". One can say that MEs provide a universal music instrument at the level of magnetic body since they allow arbitrary superposition of collinear waves proceeding in the same direction which is non-dispersive (shape of the pulse is preserved) so that arbitrary harmonics are possible for a ME with fixed length. Maybe the temporal duration of sub-selves assignable to MEs is what distinguishes between these representations.

   (c) A collection of sub-selves associated with ME at precisely defined periodically appearing positions could define rhythm whereas frequency selves would correspond to MEs with relatively long temporal duration. Interpreting MEs in terms of communications to the magnetic body, one expects that the rhythm automatically generates short-lasting MEs communication the pulses defining the rhythm to the magnetic body whereas pitch corresponds to long lasting MEs.

   (d) This picture challenges the assumption that the mental images created during music experience are localized to brain. Rather, MEs and magnetic body would be the carriers of the mental images. Maybe one could say that nerve pulse patterns induce these MEs. In left hemisphere nerve pulse patterns induced by the beats of rhythm and having a total duration considerably below.1 second would send single ME to the magnetic body. In right hemisphere the pulse patterns would integrate to single ME having duration of the note.

2. The hypothesis that entanglement creates wholes from parts and that there are three cognitive modes corresponding to reductionistic and holistic cognition and their hybrid based on negentropic entanglement is of special interest in the context of music experience.

   (a) Even admitting the dangers of naïve right-left thinking it would seem natural to assign the rhythmic aspects of the music to the reductionistic regions of brain and various aspects related to pitch to the right brain hemisphere. At least in the latter case MEs

are highly suggestive as a fundamental representation of music at the level of magnetic body. Perhaps music experience actually involves in a very essential manner also magnetic body. That "eastern" music favors additive instead of divisive rhythm could be understood as higher right brain dominance. The extremely mechanical rhythms characterizing the popular music today, the lack of melodic aspects, and the use of the volume of music as the basic means to induce emotional effect, could in turn interpreted in terms of extreme left brain dominance.

(b) Music can have a strong emotional effects and this allows to test the hypothesis that the character of entanglement correlates with the emotional color. Maybe just the fact that these emotions are enjoyable irrespective of whether they are sad or joyful and have an undeniable healing effect can be interpreted in terms of the presence of the NE. For instance, the ability of good music to generate vibrations in spine could relate to this negentropic aspects. Music as purely intellectual experience could induce essentially an analysis of what was heard based on the use of holistic-reductionistic dichotomy. Chopin's music has especially strong healing effect. Tempo rubato might reflect the profound integration of rhythmic aspects, melodic, and harmonic to single organic whole both at the level of representation and music experience.

3. The model of subjective memory and the new view about time might be relevant for the understanding of how the basic key of the music piece can be remembered. If conscious experience for a given self is about the space-time region defined by corresponding CD, one could understand how Mozart was able to experience the entire composition as a single whole. If the music piece defines in the ideal case the fundamental CD inside which the sub-selves representing the elements of the music oiece reside, this CD could also define the fundamental "key" and would be more or less sensorily experienced and need not even to be remembered. This would explain why the return to the original key in classical is so important to relieve the tension created by modulations.

Harmony and self-organization

The phenomenon of harmony should be somehow related to quantum self-organization: perhaps the often used metaphor of harmonious co-existence could be turned around. Various notes correspond to sub-selves in the population of sub-selves and it might be that self-organization favours simultaneous conscious existence of sub-selves corresponding to subsets of frequencies defining basic chords. One could even consider some kind of co-operation between the frequency selves belonging to same basic chord.

The simplest model for the phenomenon of harmony relies on the identification of the chords as "chord selves" formed by entangled "note selves" consisting of negentropically entangled "frequency selves". The listener is self having as sub-selves (mental images) note selves and chord selves which correspond to the same level of the self hierarchy. The entanglement between note selves could occur even at the level of ear between the mind-like space-time sheets sensitive to various frequencies. Topologically it would correspond to the formation of magnetic flux tubes between corresponding partonic 2-surfaces. The ability of the "note selves" of the chord to have stable flux tube bonds between themselves should depend crucially on the fact that the frequencies of the notes of the basic chords have simple rational ratios so that the oscillations involved are commensurate and match together. Hence a resonance phenomenon ins spirit of classical physics involving rational ratios of frequencies would be in question. During listening the chord self continually decomposes into sub-selves when listener consciously concentrates attention to some notes in the chord.

The ability of the music to occasionally create thrills in spine could correspond to whole-body consciousness in unusually large length scale. Note the this scale could correspond also to the secondary time length scale assignable to CD. It presumably involves a resonant fusion of also other than note sub-selves to larger negentropic sub-selves by the formation of stable flux tubes identifiable as magnetic flux tubes. The ability of certain sounds ("Om") to promote the emergence of whole-body consciousness could be due to the ability to very effectively generate negentropic entanglement direction. Perhaps the frequency spectrum of "Om" contains resonant

frequencies of several sub-selves and induces large sub-selves. Also the healing effect of music and sounds could rely on this mechanism.

Focusing attention to some instrument producing melody creates kind of figure-background relationship. This requires that entire instrument playing the melody is represented by "instrument self". An interesting possibility is that various instruments give rise to their own ensembles of frequency-selves. Note that the model makes it easy to understand why experienced performance is not simply the sum of individual performances. Music experience is a complicated self-organization process in which parts compose to wholes by quantum entanglement and vice versa according to how the listener directs his/her attention.

A model for harmony and genetic code

I have constructed a model of music harmony predicting also genetic code correctly and actually even the fact that there is variant of code involving two additional amino-acids [K96]. The model relies on two observations. Icosahedron has 12 vertices - the number of notes in 12-note scale - and 20 faces (triangles), which is the number of amino-acids.

The obvious idea is that amino-acid sequences define sequences of 3-chords defined by the notes at the vertices of the face representing amino-acid. DNA would represent the notes as a sequence of chords and amino-acid would play these notes. As a matter of fact, it turns out that DNA can be seen as a representation of music wit a harmony defined by 64 3-chords corresponding to the DNA codons.

One ends up to the proposal that music harmonies are induced by non-self-intersecting embeddings of 12-note scale as a quint cycle at icosahedron with the edges of the curve connecting neighboring vertices. This kind of cycles are known as Hamiltonian cycles. The 3-chords defined by the triangular faces of the icosahedron assign a notion of harmony to a given Hamiltonian cycle.

The surprising finding is that the symmetries of the resulting Hamiltonian cycles correlate strongly with the structure of genetic code. The numbers of faces at orbits of given face correspond to the numbers of DNAs coding for corresponding amino-acid. One can identify 60 DNAs in terms of 3 Hamiltonian cycles with different symmetry (Z_n for $n = 2, 4, 6$).

60 DNAs are not quite enough, and one has also the problem that already Pythagoras encountered: the 12 quints give slightly more than 7 octaves. One can add an additional tetrahedron to get 64 DNAs. One can glue it to a preferred face of icosahedron to get 13^{th} note differing slightly from one of the notes of the scale. One can also add the tetrahedron without gluing. This gives two genetic codes and 2 additional amino-acids.

The outcome is a geometric representation of both music and genetic code. There are actually 256 different harmonic representations of codes with 64 basic chords defining the particular harmony. The proposal is that DNA and amino-acid sequences correspond to chord sequences and that chord sequences define a fundamental representation of emotions as music. The music can also correspond to light: dark photon triplets with frequencies in range of - say - audible sounds. Bio-photons would result from the decay of these photon triplets. One can imagine that various biomolecules are named by chord sequences just like the characters in Wagner's operas correspond to themes. An interesting question is whether these dark photon triplets are negentropically entangled and can serve as analog of metabolic energy.

Music is a way to express and induce emotions. This suggests that DNA night have additional aspect corresponding to these 256 different options perhaps serving as correlates for moods. The additional aspect might relate to the magnetic body of DNA giving rise to the cyclotron frequencies from which the chords are built. The 3-chords defined by dark photons could serve as a fundamental correlate for emotions and might define fundamental control and communication mechanism based on resonance phenomenon.

7.3 Whole-Body Consciousness: Physical Evidence And Tests

Whole-body consciousness is one of the predictions of the proposed theory and anomalously low dissipation can be regarded as the most dramatic physical signature of whole-body consciousness. This prediction provides a manner to test the theory.

7.3.1 Dissipation And Consciousness

The state function reduction sequence is a binary process which at a given step splits a subsystem into a unique pair of un-entangled subsystems if the subsystem allows decomposition to free entropically entangled systems. The process is random and explains second law and dissipation as a transformation of ordered energy to non-ordered energy. In standard view about self-organization the generation of structures requires a feed of ordered energy to compensate the dissipation.

In TGD framework the function of the metabolic energy feed would be more complex than this. Energy feed is necessary in order to avoid the formation of large sized entropically bound sub-selves. The fed energy need not be ordered. The rate of dissipation depends on how small the scale of the non-decomposable systems is. If negentropic entanglement binds mental images to larger ones, the rate of dissipation is expected to be low. Ordered metabolic energy can be also transformed to the energy carried by negentropic entanglement and liberated as the entanglement transforms to ordinary free or bound state entanglement.

The overall picture is also made more complex by the simultaneous presence of several length scales in which the state function reduction process proceeds so that it makes sense to speak about quantum parallel dissipation.

EEG waves and parallel information processing

Parallel information processing requires a large number of correlated units acting in parallel. If the units correspond to sub-selves which are bound state entangled, the whole system acts like a single neuron so that the information processing is very un-effective. If the system consists of unentangled sub-selves, the correlations are absent and the system is analogous to a statistical ensemble rather than a quantum parallel computer. If the entanglement is negentropic, one achieves parallel information processing since sub-selves are correlated but have not lost their degrees of freedom.

In synesthesia synchronous firing is observed and the cognitive and memory feats of synesthetes suggest that parallel information processing and negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) are involved. Therefore synchronous firing and its EEG counterpart define candidates for the physical correlates of the negentropic entanglement. TGD inspired model for EEG and nerve pulse predicts both propagating EEG waves associated with neural circuits and non-propagating EEG waves associated with entire regions of brain (say gap junction connected cell groups) [K100].

It would be natural to assign non-propagating EEG waves to synchronous firing of neurons forming a single coherent unit. However, if neurons form a bound state they act in unisono and the information processing is very uneffective. Hence both propagating and non-propagating EEG waves should be present during parallel information processing periods and add up coherently. Synchrony would mean that standing wave part of EEG is for neurons like the rhythm of music for a ballet group. Coherence of EEG, one form of "oneness", would be the correlate for presence of both reductionistic and holistic aspects of consciousness.

Evidence and tests for a reduced metabolism as concomitant of whole-body consciousness

Consider now possible evidence and tests for the reduced metabolism as a signature of whole-body consciousness.

1. In synesthesia different sensory modalities are associated with a regular manner just as thoughts are associated with speech. A dramatic signature of synesthesia is the lowering of the cortical metabolism by as much as about 18 per cent from the average (synesthete should become blind or paralyzed if standard wisdom would hold true!). This is what is expected if the neurons of left cortex get entangled. Also a large scale entanglement with parts of limbic brain, with sensory organs associated with coupled sensory modalities, and magnetic body is possible. The extended self in state of oneness does not dissipate significantly.

2. The metabolism of trained yogis provides a test for the hypothesis: measure some signatures for neuronal or cellular dissipation occurred during the meditative state and find whether

the dissipation is reduced during meditation. The lowered dissipation rate could even lead to the lowering of the body temperature or the temperature of nearby region.

3. There are even anecdotal claims about the ability of the dead bodies of gurus to resist natural decay. I am not certainly trying to convince any sceptic and, still having very living personal body, I have no personal opinions about the reality of the claimed phenomena. It would be however good to be open-minded.

4. There is (I believe well documented) phenomenon in which persons in trance are able to dance on burning charcoals without any disastrous consequences. Certainly there are standard science explanations for this. A possible nonstandard science explanation is that state of a whole-body consciousness is involved and no dissipation in cellular scale occurs. Since dissipation is not possible, the irreversible effects caused by the heat flow from burning charcoals are not possible and only reversible and curable effects can occur.

5. The reduction of the dissipation rate in some length scales should occur also during sleep, which is one example of this kind of state (obviously a reduction of metabolism occurs).

6. Also hypnosis might involve (possibly negentropic) quantum entanglement between some part of the brain of subject person and hypnotizer. This could reflect itself as correlations between EEGs of hypnotizer and subject person.

7.3.2 EEG Synchrony And Negentropic Entanglement

If one accepts the vision about life as something in the intersection of real and p-adic worlds 40 Hz EEG synchrony can be interpreted as a correlate for the generation of negentropic entanglement between cortical neurons. Before proposing this interpretation let us first describe the experimental findings of a finnish neuroscientist Antti Revonsuo [J36].

Findings

The interpretation for 40 Hz EEG frequency inspired by the binding hypothesis is as a synchronizing frequency necessary for the generation of unified percepts. This hypothesis has been studied using auto-stereograms [J36]. There was no detectable difference in the power spectrum at 36-44 Hz range in the situation when auto-stereogram was experienced as a set of random dots as compared to the situation when it was perceived as a coherent, symmetrical gestalt. The situation was same also in 8-13 Hz and 13-20 Hz beta bands. The finding is consistent with the place coding hypothesis.

On the other hand, when the conscious percept was transformed from a random set of points to a coherent gestalt, there was a detectable increase in 40 Hz power in the occipital and right posterior sites for EEG electrodes in a time window 500-300 ms before the unified percept was reported. There could be also some time lapse between the unified percept and the report about it but probably this cannot explain the entire lapse. No increase of power in beta bands was detected: this might be due to the fact that the widths of the measured bands are much wider than the widths of the narrow sub-bands reported masked by other EEG activity according to [J149]. Note that in the model for a hierarchy of EEGs based on dark matter hierarchy beta band correspond to data communicated to the magnetic body [K37].

That the change in activity is associated with the emergence of a new percept suggests that the temporary increase of the EEG power could be assigned to the communications of the forming percept to the magnetic body.

Interpretation in terms of generation of negentropic entanglement

A fresh view about what really happens during 40 Hz synchrony came with the realization that negentropic entanglement is possible in the intersection of real and p-adic worlds. The generation of negentropic entanglement between two sub-selves means that the corresponding mental images are fused [K124, K73]. The process is experienced by the fusing sub-selves as an expansion of consciousness whereas consciousness is lost when when bound state entanglement is generated. Also the meditative states begin with enhanced 40 Hz activity and the interpretation would be same.

Quite generally, the generation of negentropically entangled neuron groups could be a correlate for the emergence of a new idea or a new holistic pattern emerging from a chaos. Synchronous firing would be a natural correlate for the synergic state resulting in this manner. The paradoxical looking reduction of the oxidative metabolism associated with 40 Hz firing could be seen as a signature of reduced dissipation when dissipating ensemble of neurons forms a single quantum coherent system.

What could then be the interpretation of the 300-500 ms time scale and synchronous firing in TGD framework?

1. If one assumes that only brain is involved, one must answer whether the new percept emerges after such a long time period. One would naïvely expect that negentropic entanglement immediately gives rise to the percept. Negentropic entanglement however means that a quantum superposition of several alternative percepts is involved. In the beginning the new percept is present with only small probability so that one would only know that the moment of eureka is quite near (this is indeed the experience that one has) and in the final situation it dominates but not completely since it requires conscious effort to preserve the percept.

2. Also magnetic body should be involved in TGD framework. The natural question is "Why this synchronous neuronal firing?". The natural answer would be that it allows to communicate the new percept as a consequence of a generation of negentropic entanglement to the magnetic body. The frequency scale of 40 Hz corresponds to a time scale of 25 milliseconds and corresponds to a length scale involved is about $.75 \times 10^7$ m, a good candidate for the size of the part of the magnetic body involved. This time scale is much shorter than 300-500 seconds. If the layer of the magnetic body in question corresponds to the fundamental 100 millisecond time scale assignable to electron as is natural in case of sensory percepts, the time lapse could be essentially due to the communication. If one takes the time scale literally the value of Planck constant which is about 3 to 5 larger than its standard value would suggest itself. Of course, the development of the percept from a fuzzy inkling to the final eureka could involve several communication loops between brain and magnetic body so that the interpretation as a lapse due the slowness of communications need not be inconsistent with the first interpretation.

3. The time scale 300-500 ms could characterize the duration of negentropic entanglement but this is not necessarily the case since negentropic entanglement would be un-necessary after the percept has been represented symbolically so that one knows what is lurking behind the chaos.

7.3.3 Synesthesia

Synesthesia [J151] seems to give a direct experimental evidence for a reduced rate of metabolism in "negentropic" states of mind. Synesthesia provides an excellent counter argument against the idea that sensory organs are primary experiencers unless one is ready to believe that cross-modal associations involve macroscopic quantum systems formed by the primary sensory organs involved and parts of brain.

TGD based quantum model for EEG and nerve pulse suggest that synesthesia is a natural by-product of the negentropic states of mind involving enhanced EEG in large regions of brain. Coherent large amplitude EEG induces synchronous neural firing in memory circuit containing hippocampus and thalamus. This leads to a "leakage" or nerve pulse activity in lateral thalamic nuclei from inducing sensory pathway to the indced sensory pathway.

An interesting possibility is that the non-propagating EEG waves predicted by TGD [K100] and possibly explaining the ability of right brain hemisphere to process information in a parallel manner are involved in synesthesia. The left brain hemisphere of synesthetes would be in some aspects like the right one during synesthesia and right and left brain could act like single conscious unit during synestesia.

Does synesthesia involve left cortex whole-body consciousness?

The following aspects of synesthesia suggest that left cortex whole-body consciousness might be involved with it.

1. Synesthesia depends on left brain hemisphere only. A dramatic signature of synesthesia is the lowering of the metabolism in the left cortex by about even 18 per cent compared to the baseline (synesthete should become blind or paralyzed if standard wisdom holds true!). This is accompanied by relatively enhanced limbic expression. Hippocampus, which is believed to be crucial for long term memories, is critical for the synesthetic experience.

2. Synesthesia is emotional: the experiences are accompanied by a sense of certainty ("this is it") feeling. This is in accordance with the observation that limbic brain expression is enhanced.

3. Holism is an important aspect of synesthesia. Synesthetes can precisely remember entire passages of text (which actually means that also reductionistic aspect is present), re-experience entire episodes of previous life, remember precise locations of various objects in a room. Synesthetic experiences are emotional. Synesthetes also tend to have "unusual experiences" like deja vu, clairvoyance and pre-cognitive dreams. This kind of personality constellation characterizes temporal-limbic epileptics.

4. Synesthetes have un-even cognitive skills. Dyslexia, dyscalculia in some degree, inability to transform words to digits, right-left confusion, etc.. Synesthetes are also non-right-handed.

A possible TGD based interpretation is that part of the left cortex is in whole-body consciousness in the sense that mental images have fused negentropically to very few larger mental images and there are very few unentangled sub-selves (mental images).

1. In this state left cortex does not dissipate as much as usually. Negentropic entanglement explains why the metabolism can be reduced during synesthesia below the level causing death under normal circumstances. The relative enhancement of metabolism in left limbic brain could relate to emotionality but does not favor negentropic entanglement in left limbic brain.

2. Also the cognitive impairments can be understood. The negentropic entanglement is both time-like and space-like so that these sub-selves have also a long duration. The resulting experience is holistic both in spatial and time direction with overall gestalt being more important than details. A good temporal resolution is essential for the mentioned cognitive skills and the explanation for cognitive dis-abilities is that entangled left cortex does not generate temporal sequences of sub-selves of short duration defining the mental clock readings or beacons. The mental images are extremely informative but the lack of linguistic expression based on the replacement of the percept with a collection of distinct objects mapped to linguistic symbols disfavors this mode of consciousness. Therefore linguistic cognition is favored by the practicalities of the everyday social life. The lack of asymmetry between brain hemispheres behind holism-reductionism dichotomy essential for language would naturally relate to non-right-handedness and the difficulty to distinguish between right and left. This inability would also conform with the view that some regions of right and left hemisphere are negentropically entangled.

3. The exceptional episodal memory achievements could be understood as a formation of large scale negentropic mental images which are stable so that long sequences of events of geometric past are re-experienced. In [K99] a model for long term episodal memories as questions sent to the geometric past inducing time-like entanglement with the self of the geometric past making possible episodal memory as a shared sensory experience is discussed. The question sent to the geometric past is coded to the light-like vacuum current associated with a stationary ME, usually in right brain but in left brain in case of synesthesia. The time like entanglement of the space-time sheets located in the geometric now and past (or future in case of clairvoyance) makes possible the episodal memory.

The proposed mechanism could also explain both the extraordinary memory feats of some autistic persons and their difficulties with the challenges of the everyday life. Dramatic example is a person able to draw from memory an area of London with size of several square kilometers as seen from air. The same person draws from memory a building having hundreds of windows and the number of windows comes out correctly although this same person is not able to count

corretly the number of three objects. As in the case of synesthetes cognitive impairments could be necessary prerequisites of the extraordinary gifts. Although the person cannot count how many windows the mental image of the building has, he can draw them correctly just by drawing along the image he sees in full concreteness.

Basic observations

The following observations provide a valuable information making possible to construct a more detailed model of synesthesia.

1. Synesthesia is in-voluntary and usually uni-directional: for instance, auditory experience creates visual association but not vice versa. Cross-modal associations, just like ordinary associations, do not change in the course of time. It has not been possible to find any rule telling which kind of associations are possible. It seems that cross-associated experiences are however generic and simple so that one can speak of form invariants which are kind of primitive building blocks of perception: for instance, visual associations tend to be blobs, lines, spirals and lattice shapes.

2. Synesthesia is projected: synesthetes experience their secondary sensory experiences in the space in the immediate surroundings of the body, never at large distances as is in principle possible in the case of vision and hearing. For instance, visual associations are seen on screen near to eyes.

3. The reduction of the metabolism is concentrated in the cortical regions whereas relatively enhanced metabolism occurs in the limbic brain, in particular hippocampus. Seizure discharges in hippocampus induce synesthesia in non-synesthetes: associations are simple experiences and become more complicated if seizures spread to the temporal lobes. The exceptional activity of hippocampus correlates with the exceptional ability to have precise episodal memories.

4. According to [J151] it is very rare that taste or smell is a synesthetic response or trigger of it. In fact that author of the articles knows no case in which smell alone would be the inducing sensory modality. This could relate to the fact that olfactorion is exceptional sensory modality in the sense that there are two olfactory pathways: the first one projects directly to amygdala whereas second projects to cortex via thalamus as do also the sensory pathways associated with order sensory modalities [J119]. Furthermore, the olfactory pathway to the thalamus projects to the medial dorsal nuclei whereas other sensory pathways project to the lateral dorsal nuclei.

5. Synesthesia can also generate sensory-motor associations. For instance, visual input can generate well defined motor outputs and synesthete can express sensory experiences by dancing!

Memory coordination circuit and Papez circuits as brain circuits possibly involved with synesthesia

Hippocampus is believed to be crucial for the formation and experiencing of long term memories. This suggests that an enhanced activity in some neural circuits involving hippocampus in a form of increased EEG amplitudes (at theta frequencies) is essential for generating the sensory leakage between neural circuits and sensory pathways leading to synesthesia. For this kind of mechanism synesthetic mode need not be the only mode of experiencing: ordinary and synesthetic modes could also alternate. If synesthetic and non-synesthetic periods alternate, synesthesia cannot interfere radically with the real experience. This is clearly the safest option and perhaps favoured by natural selection. The ability to control theta wave amplitudes in hippocampus could make possible an artificial generation of synesthesia.

There are two important circuits going through hippocampus [J62]. The first circuit is memory coordination circuit having the following structure:

1. Lateral dorsal nucleus and anterior nuclear group of the thalamus

2. Cingulate cortex

3. Subiculum and the rest of the hippocampal formation with input via entorhinal cortex and output via the subiculum and fornix

4. Back to 1.

Fornix is known to be the circuit responsible for slow theta rhythm of about 3-7 Hz, which does not correspond to a conscious experience: thus memory coordination circuit is believed to be unconscious to us under normal circumstances [J62]. Temporal cortex contains a region which projects to hippocampus and receives input from all sensory modalities. Memory circuit is believed to somehow to provide a handle to the memory constellations believed to reside in the temporal lobes. That the EEG amplitude associated with the fornix would be exceptionally large during synesthesia is in accordance with the fact that that synesthetes tend to have personal constellation of limbic-temporal epileptics. Also the abnormal episodal memories (Nabokov is one of the best known synesthetes with miraculous memory) supports resonance in this circuit. Only memory circuit projects to the thalamic nuclei receiving both sensory and motor input. Hence also the occurrence of the motor synesthesia supports the view that the sensory leakage occurs in the thalamic nuclei contained by the memory circuit.

Papez circuit is second circuit containing hippocampus. Papez circuit has following structure:

1. Anterior nuclear group of the thalamus

2. Cingulate cortex

3. Hippocampal formation

4. Hypothalamus

5. Back to 1.

The enhanged activity of the Papez circuit induced by the hippocampus could correlate with the emotionality of the synesthetic experience.

The general picture about the sensory leakage

These observations and facts suggests the following general model for synesthesia.

1. Contrary to the original expectations, the hypothesis that the primary sensory qualia are associated with the sensory organs can be defended against various objections if one assumes that brain and sensory organs quantum entangle so that a fusion of sensory mental images with cognitive mental images occurs. The hypothesis explains elegantly the differences between imagination, dreaming, hallucinations, and ordinary sensory experience. Dreams and hallucinations would involve a back projection from brain to sensory organs giving rise to a "qualiafication" of the cognitive mental images represented by the nerve pulse patterns. In the case of synesthesia the back projection would assign to a sensory input from the inducing sensory modality an artificial sensory input in the induced sensory modality.

2. If the cross-modal communication between sensory organs occurs through thalamic nuclei common to the cross-associated sensory modalities, one can understand why smells alone are never the inducing sensory modalities. Lateral dorsal thalamic nuclei would be the sites of the sensory leakage. Furthermore, in the case of hearing, vision, and tactile senses it is easy to produce artificial sensory experience than in case of chemical senses (molecules attaching to the sensory receptors would be required).

3. The possibility of the sensory-motor synesthesia suggests that the back-projection involves artificial sensory input to the motor organs inducing a motor activity, which in TGD framework corresponds to a geometric time reversal of the sensory perception starting from the level of motor organs and proceeding in a time reversed direction. Only memory coordination circuit involves thalamic nuclei receiving both sensory and motor inputs. Memory coordination circuit involves lateral dorsal nuclei (all modalities except olfaction) but not medial dorsal nuclei (olfaction). This leads to the hypothesis that the exceptionally high activity of the memory coordination circuit induces a sensory leakage in the lateral dorsal nuclei of the thalamus belonging to the memory coordination circuit.

Synesthesia as a sensory leakage between thalamic nuclei common to the memory coordination circuit and primary sensory pathways

Synesthesia could be a byproduct of an abnormally large EEG amplitude in the memory coordination circuit and possibly also Papez circuit inducing a "leakage" of nerve pulses between sensory pathways in thalamus in turn giving rise to synesthetic crossmodal associations. That synesthetic associations are projected, is consistent with the sensory leakage hypothesis.

The resonant EEG amplitude associated with the thalamic nuclei of the resonating memory coordination circuit spreads out to the primary sensory or motor pathways in the physical vicinity of the resonating pathway and generates a sensory leakage and a back projection to the sensory organs of the induced modality thus inducing synesthesia. The structure of the synesthetic association is determined by the pattern of neurons activated and thus creating the virtual sensory input back-projected to the sensory organ of the induced sensory modality. One can imagine each neuron as a pixel of a sensory picture and the pattern of activated pixels determines the synesthetic association.

The model makes testable predictions.

1. The assumption that the sensory leakage occurs in the thalamus could be tested. One could study whether the crossmodal associations change, when the sensory input from right or left side of body is lacking. For instance, one could find what happens if audio-to-visual synesthete blocks left/right ear during audio-to-visual synesthesia.

2. The generation of artificial sensory experience by back-projection to the sensory organ of the induced sensory modality means that a permanent or an artificially induced temporal loss of the induced sensory modality (by a local anaesthesia of the axons of the sensory pathway) should lead to the loss of the synesthesia.

How to understand the memory feats of synesthetes and the reduced metabolism in the left hemisphere?

Negative energy MEs can be interpreted as classical signals sent to the geometric past, and they could be crucial for an active memory recall involving a question sent from the magnetic body to the brain of the geometric past as a negative energy ME. Also chemical signals- say very slow Ca^{++} wave inside brain- could be involved and could define the classical response to the negative energy signal.

1. Memories and time mirror mechanism

Time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book), which was first developed in the framework of positive energy ontology, is the simplest quantum mechanism of memory. Its recent formulation goes as follows.

1. The mechanism of episodal memory is assumed to involve only a sharing of mental images by negentropic time-like quantum entanglement. The notion of bound state entanglement in time direction need not make sense at all: the reason is that bound state energy is assigned with the entire system rather than sub-systems and for zero energy states total energy is always zero. Hence it seems better to assume that only negentropic entanglement and non-binding real entanglement in time direction is possible.

2. The basic question is what really distinguishes between verbal (declarative) and episodal memories. Is the difference between verbal and episodal memories related only to the temporal size scale of the negentropically entangled subsystems? In this case declarative memory would consist of a sequence of short lasting episodal memories with contents which are symbols rather than direct sensory perceptions with emotional content. Or can one interpret verbal memories as purely classical communications between geometric past and future? This would make sense if declarative memories result when an entropic entanglement between future and past selves is reduced to zero so that the communications would reduce to those between non-living systems. Episodal memories would be possible in the intersection of the real and p-adic worlds and declarative memories everywhere. This interpretation is consistent with the earlier vision.

One can model the memory recall as follows.

1. The view about memory recall is that a "question" realized as a negative energy ME is sent from magnetic body to the brain of the geometric past, it is reflected back as a positive energy signal, and returns back to the magnetic body. It is essential that the signal is between different CDs - say CD and its and sub-CD- rather than future and past boundaries of single CD.

2. One must be very careful with what negative energy signal really means. This signal would be generated in quantum jump and should connect the past boundary of CD to the future boundary of a CD in the geometric past- say for definiteness a sub-CD of CD itself if personal memory is in question. The condition that the positive energy of the past boundary of CD remains unchanged means that the energy flowing to the direction of future inside CD is increased as a recoil effect. The same applies in the case of sub-CD. This interaction could be seen as an interaction between two CDs implying an exchange of energy between the positive energy parts of the states.

3. The transfer of negative energy to the past can transform the positive energy part of the state of the geometric past to a bound state in the ordinary sense of the word. If positive energy negentropic entanglement is in question this need not happen although the energy of the state is reduced. Therefore negentropically entangled mental images are especially interesting from the point of view of episodal memories. The question and answer fuse to a single negentropically entangled mental image shared by the hemispheres of the geometric past and now. The negentropy of the past state is expected to reduced as its energy is reduced so that quite literally a flow of information to future is in question.

4. Duality between memory and recognition suggests itself. What is memory from the point of view of future CD could be precognition from the point of view of past CD.

The generation of negative energy MEs would involve a phase transition to a state in which the positive MEs propagating along axons with a subluminal effective phase velocity transform to negative energy MEs leaving the brain and are reflected back in time direction. Synchronous membrane oscillations could accompany negative energy MEs [K97]. If negative energy MEs are sent by the region of the left brain hemisphere, it gains some energy by pay now-let others pay mechanism.

2. Reduction of metabolism during synesthesia

Episodal memories could relate to the reduction of the metabolism by 18 per cent during synesthesia.

1. The original interpretation proposed before the formulation of zero energy ontology was that the generation of the negative energy MEs is forced by the starvation of the neurons induced by the over-activity of the neurons of the memory coordination circuit. The miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction. The starving cortical neurons of the left hemisphere would send negative energy MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. The same mechanism might work also in the normal situation but involve a less dramatic artificial starvation.

2. The reduction of the metabolism could be also mostly due to the negentropic entanglement for the mental images in the left cortex "now" so that the episodal memories realized in the proposed manner would give only an additional reduction to metabolism.

3. Non-episodal memories

Also in the case of non-episodal memories the question to the geometric past could be communicated by the mirror mechanism using negative energy MEs but now time-like entanglement would be entropic free entanglement and would be reduced to zero in quantum jump so that the real answer would be communicated classically.

1. The classical signal could return to the magnetic body along reflected positive energy ME so that the question and answer could use the same cognitive code.

2. Second possibility is that signal returns back without leaving the brain. The classical signal sent by the left hemisphere of the geometric past to the left hemisphere of the future would propagate a finite distance L within brain in a time interval T defining the temporal span of the memory (say years) so that the ME would propagate with an effective phase velocity $v = L/T$. The velocities of Ca^{++} waves span an extremely wide spectrum and provide a natural candidate for the physiological excitations in question [J125].

3. Ca^{++} waves could be also be accompanied MEs with ultraslow phase velocities.

7.4 Self Hierarchy And The Notion Of Magnetic Body

TGD not only predicts infinite hierarchy of selves but also strongly suggests that "me" as an intentional agent should be identified as my field body, or perhaps better to say, my magnetic body having an astrophysical size. Magnetic body would also serve as an intentional agent and controlling biological body by time mirror mechanism. An entire hierarchy of magnetic bodies is predicted since the flux quanta of each body part define corresponding magnetic body. Also the magnetic body of Earth should define a conscious unit, kind of Magnetic Mother Gaia perhaps responsible for some third person aspects of our consciousness. The role of the magnetic body would be like that of a manual of an electronic instrument, that is it would provide a higher level representation for the body and its environment. Magnetic body would also serve as template for the formation of bio-structures. Magnetic body would share the mental images produced by brain as symbolic representations of the sensory input. Also time mirror mechanism of long term memories and Uncertainty Principle applied to EEG provide support for the notion. Some experimental findings supporting the notion of field body are Libet's findings, the role of Schumann resonance frequency for consciousness about time delays of consciousness, and the effects em radiation on brain and living matter at cyclotron frequencies.

This original version of this section was written much before the emergence of the zero energy ontology. A first principle justification for the notion of magnetic body is provided by zero energy ontology predicting that primary p-adic length scales are accompanied by secondary p-adic length scales (as well as time scales). For instance, in case of electron the secondary time scale is.1 seconds and correspond to a length scale of order Earth's circumference. It is natural to assign this time scale to the flux tubes of the magnetic body. This aspect will not be discussed explicitly in the sequel but should be kept in mind.

Am important question concerns about actual biological realization of the self hierarchy predicted to begin already at elementary particle level and continuing indefinitely. TGD indeed leads to rather concrete ideas about how this hierarchy is possibly realized.

7.4.1 Higher Level Selves In Biological Self Hierarchy

The basic inputs for the speculations about the higher levels of the biological self hierarchy are topological field quantization, the idea of memetic code and the observations about the effects of EFL em fields to brain suggesting that the higher levels correspond to em selves with sizes of order wavelength of photons generated by EEG currents having size of order of Earth and realized as topological field quanta. The general view about symbiosis of hierarchies of massless extremals (MEs) and superconducting magnetic flux tube structures with the ordinary matter at atomic space-time sheets provides strong constraints on the speculations. The general vision about sensory representations realized in terms of magnetic flux tube structures outside brain [K99] and having sizes of ELF wavelengths leads to rather concrete ideas about the self hierarchy and about our position in it.

7.4.2 Quantum Criticality

Quantum criticality is one of the basic guiding principles of Quantum TGD. What it means mathematically is however far from clear and one can imagine several meanings for it.

1. What is obvious is that quantum criticality implies quantization of Kähler coupling strength as a mathematical analog of critical temperature so that the theory becomes mathematically unique if only single critical temperature is possible. Physically this means the presence of long range fluctuations characteristic for criticality and perhaps assignable to the effective hierarchy of Planck constants having explanation in terms of effective covering spaces of the embedding space. This hierarchy follows from the vacuum degeneracy of Kähler action, which in turn implies 4-D spin-glass degeneracy. It is easy to interpret the degeneracy in terms of criticality.

2. At more technical level one would expect criticality to correspond to deformations of a given preferred extremal defining a vanishing second variation of Kähler Kähler function or Kähler action.

   (a) For Kähler function this criticality is analogous to thermodynamical criticality. The Hessian matrix defined by the second derivatives of free energy or potential function becomes degenerate at criticality as function of control variables which now would be naturally zero modes not contribution to Kähler metric of WCW but appearing as parameters in it. The bevavior variables correspond to quantum fluctuating degrees of freedom and according to catastrophe theory a big change can in quantum fluctuating degrees of freedom at criticality for zero modes. This would be control of quantum state by varying classical variables. Cusp catastrophe is standard example of this. One can imagine also a situation in which the roles of zero modes and behavior variables change and big jump in the values of zero modes is induced by small variation in behavior variables. This would mean quantum control of classical variables.

   (b) Zero modes controlling quantum fluctuating variables in Kähler function would correspond to vanishing of also second derivatives of potential function at extremum in certain directions so that the matrix defined by second derivatives does not have maximum rank. Entire hierarchy of criticalities is expected and a good finite-dimensional model is provided by the catastrophe theory of Thom [A21]. Cusp catastrophe (see `http://tinyurl.com/yddpfdgo`) [A1] is the simplest catastrophe one can think of, and here the folds of cusp where discontinuous jump occurs correspond to criticality with respect to one control variable and the tip to criticality with respect to both control variables.

3. Quantum criticality makes sense also for Kähler action.

   (a) Now one considers space-time surface connecting which 3-surfaces at the boundaries of CD. The non-determinism of Kähler action allows the possibility of having several space-time sheets connecting the ends of space-time surface but the conditions that classical charges are same for them reduces this number so that it could be finite. Quantum criticality in this sense implies non-determinism analogous to that of critical systems since preferred extremals can coincide and suffer this kind of bifurcation in the interior of CD. This quantum criticality can be assigned to the hierarchy of Planck constants and the integer n in $h_{eff} = n \times h$ [K44] corresponds to the number of degenerate space-time sheets with same Kähler action and conserved classical charges.

   (b) Also now one expects a hierarchy of criticalitiesandsince criticality and conformal invariance are closely related, a natural conjecture is that the fractal hierarchy of subalgebras of conformal algebra isomorphic to conformal algebra itself and having conformal weights coming as multiples of n corresponds to the hierarchy of Planck constants. This hierarchy would define a hierarchy of symmetry breakings in the sense that only the sub-algebra would act as gauge symmetries.

   (c) The assignment of this hierarchy with super-symplectic algebra having conformal structure with respect to the light-like radial coordinate of light-cone boundary looks very attractive. An interesting question is what is the role of the super-conformal algebra associated with the isometries of light-cone boundary $R_+ \times S^2$ which are conformal

transformations of sphere S^2 with a scaling of radial coordinate compensating the scaling induced by the conformal transformation. Does it act as dynamical or gauge symmetries?

Preferred extremals and criticality

Zero energy ontology (ZEO) was a great step of progress in the development of TGD. Now pairs of space-like 3-surfaces at the boundaries of causal diamond become the basic objects. It is important to notice that preferred extremal property itself in ZEO is un-necessary unless one requires Bohr orbit property: the reason is that for given pair of 3-surfaces at boundaries CD the space-time surface would be unique for deterministic dynamics. In the case of non-deterministic dynamics situation can change but this seems to relate to quantum criticality and hierarchy of Planck constants bringing in new degrees of freedom related to the non-determinism and to super-conformal symmetries acting as gauge symmetries.

Bohr orbit property would be space-time correlate for the correlations of the positive and negative energy states at the ends of CD and non-triviality of quantum dynamics so that preferred extremal property would be another name for Bohr orbit property. Therefore it seems reasonable to assume that the notion of preferred extremal indeed makes sense and is needed.

I have proposed several identifications for the preferred extremal property such as criticality of Kähler action, Hamilton-Jacobi structure space-time surface generalizing complex structure, quaternionic structure in tangent space.These characterizations might be equivalent.

2-D criticality suggests that conformal symmetries act as gauge symmetries for the deformations for which second variation of Kähler action vanishes and that there is finite number n of gauge equivalence classes which can be related to the hierarchy of Planck constants $h_{eff} = n \times h$. The space-time sheets connecting two 2-surfaces at the ends of causal diamond (CD) in zero energy ontology (ZEO) have same Kähler action and conserved charges. The n degrees of freedom would be discrete dynamical degreees of freedom and among other things could be responsible for the fractionization of charges.

Topological field quantization

Topological field quantization [K61] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prerequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized if they correspond to preferred extremals meaning that the 3-surfaces at the boundaries of CD are correlated just like for Bohr orbits.

Feynman diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, "massless extremals" [K85] representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible. This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [K14]. Also biosystems might have invented negative energy space-time sheets: in fact, so called "massless extremals" provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [K23]. An interesting possibility is that quantum entanglement has the formation of the flux tubes as its geometric correlate.

The hypothesis of topological self-referentiality stating that the topological field quanta of classical fields form a symbolic representation for the system's properties, provides a strong interpretative tool. For instance, bound state entanglement is represented by negative energy MEs and the generation of macroscopic bound states essential for the binding of the mental images is accompanied by the liberation of the binding energy as a usable energy. Hence the ability of the system to behave as a single coherent whole and non-local quantum metabolism are different sides of the same coin. The concept of field body (or electromagnetic body) consisting of the topological field quanta is also of central importance. Field body could be seen as a "manual" for the system providing a classical, topological representation for the quantum aspects of the material part of the system. The size of this field body is much larger than the material body of the system.

Topological field quanta (field bodies) could serve as templates for the formation of the biostructures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible biomatter and the visible part of biosystem might represent only a tip of an ice berg.

Topologically quantized classical fields as templates for self hierarchy?

The web like structure formed by topological field quanta representing classical fields, in particular em fields, is reminiscent of structures formed by microtubules and collagens forming the connecting tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various biostructures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4 \times 10^{-6}$ meters for $B = .5 \times 10^{-4}$ Tesla. If magnetic flux tubes of Earth have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along microtubules, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level self! One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the so narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm) to the size of human brain lobe (10 cm) as well as the ratio of the thickness of cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2}. Thus it seems that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy.

The web formed by topological field quanta of the classical em and fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [K112]. Perhaps also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

Possible geometric correlates of entanglement?

The geometric correlate for the entanglement between sub-systems is the generation of flux tubes combining the corresponding 3-surfaces to single 3-surface: this is nothing but the direct touching of the 3-surfaces. Actually, all that is needed is the fusion of the space-time sheets of same local topology (real or p-adic) to single sheet. The entanglement generated in this manner can be

preserved even when direct geometrical contact between 3-surfaces is not present anymore. In TGD based model for brain these bonds are formed between parts of brain and sensory organs.

One can consider several models for flux tubes. Topological field quantization providing general description of classical gauge and gravitational fields in TGD framework implies that magnetic and electric flux tubes and "massless extremals" (MEs) are the basic building blocks of classical em fields. All these structures can serve as flux tubes.

MEs are especially interesting candidates for space-time correlates of time like entanglement between positive and negative energy parts of zero energy states. MEs are very general solutions of field equations of TGD and have properties making them ideal for realizing basic functions of biosystems.

1. MEs represent propagation of classical gauge fields with light velocity and can carry non-vanishing vacuum em currents and hence give rise to coherent photons. A tentative identification is as bio-photons of Popp [I34]. The hypothesis is that MEs make possible generation of quantum entanglement between brain and sensory organs. In this manner they provide a realization for neuronal window idea generalizing the idea about hologrammic brain [K26]. MEs could make possible both classical (quantum) communication by the propagation of classical fields (coherent photons) along them and neuron could literally have a window to external world via sensory organ.

2. In TGD framework space-time sheets with negative time orientation are possible and carry negative classical energies (in General Relativity this is not possible). The generation of negative energy MEs provides "buy now, pay later" type mechanism for energy production. Generation of negative energy ME is classical counterpart for the generation of virtual particle and it is to be expected that the subjective lifetime of negative energy MEs is finite number of quantum jumps. Thus organism must eventually "pay", that is to compensate for the dissipation of the energy gained by the generation of the ME by metabolism. Therefore metabolism is still needed. Even more, organism must be able to give guarantees that it can pay! The ability to provide these guarantees is perhaps one of the great achievements of the biological evolution.

3. MEs carry large momentum since all Fourier components of the gauge fields have parallel light-like momenta. Since classical 4-momentum is light-like, the amount 3-momentum per energy is maximal. Thus, if the system is able to generate ME by quantum jump, it gains automatically large recoil momentum. Hence MEs could provide the fundamental mechanism making possible the coherent macroscopic motion of living systems. Negative energy ME of this kind might be identifiable as a mind-like space-time sheet representing the geometric correlate for the conscious decision to move.

4. MEs represent dispersionless propagation of a pulse preserving its shape and are thus ideal for classical communication. If negative energy MEs are possible, one can imagine a mechanism of "real subjective time" communication between selves of either geometric past or future having arbitrarily large time-like distance. This idea is not conflict with standard classical causality at given space-time sheet. Needless to say, this kind of possibility would realize concretely the idea about four-dimensional society and revolutionize our view about universe: living beings separated by billions of light years could in principle have "real subjective time" chat.

7.4.3 Support For The Notion Magnetic Body

There exists both theoretical and empirical support for the notion of magnetic body.

Theoretical support

1. EEG and Uncertainty Principle

There are good reasons to expect that EEG is accompanied by radiation, which in TGD framework has topological light rays as space-time correlates. Typical EEG frequencies correspond to wavelengths $\lambda = c/f$ which for which natural length scale unit is Earth size. Thus Uncertainty

Principle suggests that structures of at least this size are involved with the self hierarchy associated with the brain.

2. p-Adic physics as physics of cognition

p-Adic physics as physics of cognition is a fundamental key idea of TGD inspired theory of consciousness. For long time I believed that p-adic-to-real transformations of space-time sheets realized as quantum jumps could serve as correlates for the transformation of intentions to actions allow deeper understanding of also psychological time as a front of p-adic-to-real transition propagating to the direction of the geometric future. It turned out that the mathematical realization of this idea might involve unsurmountable challenges and the natural vision is based on adeles: both reals and various p-adic number fields would be present and cognition would be present already at elementary particle level as also the p-adic mass calculations suggest.

Intentional behavior means that there is unpredictability in short time scales but predictability in long time scales because system can realize its long term plans and use its partially free will to cope with the changing challenges of the everyday life.

p-Adic topology differs radically from real topology in the sense that p-adically infinitesimal is infinite in real sense.

1. The rational values of real and p-adic embedding space coordinates correspond to the same points of the generalized embedding space (essentially union of real and p-adic embedding spaces for various values of p with rational points common to all number fields and also points, in particular points with algebraic number valued coordinates, shared by different number fields in a pair-wise manner identified).

2. The points, which are p-adically close to each other can have arbitrarily long real distance since the points x and $x+kp^n$, $k \in \{0, p-1\}$, become arbitrarily near to each other p-adically and arbitrarily far way in real sense as n increases for the p-adic topology characterized by prime p.

This means that intentionality and cognition are literally cosmic phenomena and present in all scales and evolution of cognition proceeds from long p-adic length scales to short ones in real sense (but from short to long scales in p-adic sense). The carving of a statue by starting from a rough sketch and adding details gradually is a good metaphor for what is involved. Development of any motor skill, say piano playing, is an excellent example of what happens.

Zero Energy Ontology (ZEO) leads to a rather precise view about volitional action. In ZEO self corresponds to a sequence of state function reductions occurring at fixed boundary of causal diamond (CD). Volitional action begins with the first state function reduction to the opposite boundary of CD involving "death" of corresponding self and re-incarnation at opposite boundary [**?**, K10]. Volition can be also seen as a transformation of intention to action. In the original vision this transformation was identified as p-adic-to-real phase transitions of space-time sheets taking place in quantum jumps. It has however turned out that this assumption creates more problems than it solves and that it is un-necessary if one accepts the adelic view meaning that the physics associated with all number fields form a coherent whole and p-adic physics is correlate for cognition. One can say that cognition is in the intersection of reality and various p-adicities defined by strong form of holography as string world sheets with the property that the parameters involved with their mathematical characterization are in algebraic extensions of rational numbers and can be thus algebraically continued to real and various p-adic number fields.

Negative energy topological light rays (MEs) provide an example of possible space-time correlates for intentional actions. Also wormhole magnetic fields consisting of pair of space-time sheets carrying magnetic fields of equal intensity and having opposite time orientations could be generated in intentional action.

In many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also transition increasing the p-adic length scale and thus the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and

possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated. In the following only the "dropping" option is discussed.

3. Time mirror mechanism of long term memories

TGD based model of long term memory requires no storage of memories of past to the brain of the geometric now. The memories are in the geometric past as dynamical self organization patterns and subject to changes.

1. In the case of active memory recall the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

2. In the case of episodal memories active precisely targeted memory recall might be difficult since the entanglement with a correct mental image seems to require good luck. In principle it is possible to select the distance T to the geometric past where the memory comes from by selecting the fundamental frequency of ME.

3. The most natural manner to realize the time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) is to regard magnetic body as the system communicating with the brain of the geometric past serving as mirror. The fundamental frequency $f = c/L$ of associated with a topological light ray of length L would naturally code for the time span of the long term memory as $T = L/c$ in the sense that only these memories would be communicated resonantly. Thus the distance from brain along magnetic flux tubes would code the time span of the memory. Long term memories with a span of order lifetime however require that the size of the magnetic body involved is measured in light decades.

Experimental support for the notion of magnetic body

The work of Blackman and other pioneers of bio-electromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [J64] discussed in [K37], provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth having natural coupling to the magnetic flux tubes.

The lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21, ... Hz [F1] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation.

Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such micro-seizures and epilepsies [J130]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

The explanation of the effects related to water memory [I27, I23] suggests that similar magnetic effects appear at much wider frequency range than ELF frequencies which would mean that the super-conducting magnetic flux tube circuitries form a fractal hierarchy. The findings challenging the notions of ionic pumps and channels [I39] provide additional strong support for the notion of many-sheeted space-time and hierarchy of super-conducting of magnetic flux tubes. The evidence for the fractal hierarchy of magnetic flux tubes is discussed in [K21, K22].

These observations support the view that our "physical" body is only a tip of an iceberg and formed by the topological condensation of the bio-matter around electromagnetic topological field quanta serving as templates for the bio-structures.

The findings of Libet [J87] about time delays associated with the passive aspects of conscious experience suggest that our sensor perceptions are a fraction of second old (.3-.5 seconds). This could be understood if the sensory percepts from brain are communicated to the magnetic body identiable as "us". This particular time scale would correspond to a layer of magnetic body which has 3-5 times the size scale of electron's CD which is about.78 times the circumference. A possible interpretation is in terms of dark electrons with a value of Planck constant which is 3-5 times the standard value. The corresponding EEG frequencies would vary in region.33-.2 Hz.

Cyclotron resonances as key to quantum consciousness

The estimate for the thickness of the magnetic flux tubes of Earth's magnetic field based on the quantization of the magnetic flux is about cell size. There is direct evidence for the hypothesis that ions in the magnetic field of.2 Gauss (Earth) magnetic field has nominal strength of $B_E = .5$ Gauss) form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size: in fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic field corresponds to the length scale $L(169) \simeq 5\ \mu m$ rather precisely. This length scale is indeed the p-adic length scale which seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries/flux tube condensates. The work of Blackman and other pioneers of bioelectromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [J64] provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system.

The discovery of Blackman means that frequencies having special effect on biomatter correspond to cyclotron resonances for ions like Ca_{++}, Na_+, K_+ and Cl_- in magnetic field $B = 2B_E/5 = .2$ Gauss. The cyclotron frequency for Ca_{++} is 15 Hz whereas the remaining frequencies are in the range $7 - 13$ Hz (theta waves) at which also the most important Schumann resonances lie. The cyclotron frequency 5.5 Hz of iron is also a bio-active frequency and is the lower edge of theta region of EEG. Also lower frequencies resonant frequencies such as 2.4 (Iodium ion) are present. Even more remarkably, the pattern of data forces to conclude that the interaction occurs at quantum level. This conclusion is is dramatic conflict with the predictions of the standard quantum theory and with the standard view about space-time but consistent with the many-sheeted space-time concept of TGD.

A confession is in order: for years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency 15 Hz as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is.2 Gauss and thus slightly smaller than the minimum value.3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 25\ \mu$m, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [K4].

The conclusion that the effect of ELF fields on brain represents quantum effects associated with the transitions of ions confined in magnetic field in the direction of axon carrying $B = 2B_E/5 = .2$ Gauss, is supported by the following observations.

1. The frequencies $15, 30, 45, 60, 75$ Hz having effect on primates are multiples of the same basic frequency $f = 15$ Hz, which turns out to be the cyclotron frequency of Ca_{++} ion. That these frequencies come in multiples is a direct signature of quantum: in classical world only basic frequency $f = 15$ Hz should have effects (forcing ions to rotational motion around field lines with this frequency.

2. Even multiples of 15 Hz have a weak but non-vanishing effect. This can be understood as resulting from parity conservation for the simplest transitions induced by that part of the interaction Hamiltonian which does not depend on the longitudinal coordinate of the axon. The reason is that odd and even values of n for harmonic oscillator states have opposite parities and the interaction hamiltonian describing the transition has odd parity. The simplest possibility is that these transitions occur in second via intermediate virtual intermediate state and correspond to second order in perturbation theory. This observation provides additional strong support for the hypothesis that quantum transitions are involved.

These observations are consistent with the following interpretation. Ions with charge Z, spin S and mass m in the external magnetic field behave quantum mechanically like harmonic oscillator with energies quantized as multiples of

$$\begin{aligned} E &= (n+\frac{1}{2})\omega_c + \frac{S_z}{S}\omega_L \ , \\ \omega_c &= \frac{ZeB}{m} \ , \quad (\hbar = 1, c = 1) \ , \\ \omega_L &= \frac{gS\omega_c}{4} \ . \end{aligned} \tag{7.4.1}$$

Here S and S_z denote total spin and its projection to the direction of the magnetic field. The contribution to energy coming from longitudinal motion has not been written explicitly. Here g is so called Lande factor which for free elementary fermions equals to $g = 2$. The experimental findings suggests strongly that external em field induces resonant transitions from between magnetic states. By the quantization of the magnetic flux, predicted by TGD also classically, the minimal size of the magnetic flux tube for the magnetic field of Earth is of order cell size. An attractive hypothesis is that the magnetic field in question is associated with axon and is parallel to it.

It must be emphasized that this vision is forced by hard experimental facts and is in dramatic contradiction with the standard physics view about brain. The wave functions of ions in magnetic field are confined in a region of size of order

$$r_n \sim \sqrt{n/eB} \ ,$$

which is of the order of cell size for B=.2 Gauss: macroscopic quantum state is in question. In fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic fields corresponds to the length scale $L(169) \simeq 4$ μm rather precisely for minimal value of the magnetic flux quantized as $ZeBS = n2\pi$ obtained for $n = 1$ (S denotes the area of the flux tube) and $Z = 2e$. $L(169)$ seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries condensates.

The binding energies of ions in Earth's magnetic field are extremely small: of order 10^{-14} eV, which is ridiculously small energy when compared with the natural energy scale of one eV and corresponds to a temperature of order 10^{-10} Kelvin. According to standard quantum physics, Earth's magnetic field should have absolutely no detectable effects in hot, wetty and noisy environment provided by brain. Many-sheeted space-time concept provides the solution to the riddle. Ions are not on the molecular space-time sheets but have dropped to the cellular space-time sheet and it is indeed very cold, dry and silent here: an ideal place for the formation of macroscopic quantum phases. The energy scale implies the upper bound $T < 10^{-10}$ Kelvin for the temperature at cellular space-time sheets.

A further empirical input of crucial importance were the observations challenging the cherished notions of ionic pumps and channels [I39]. These findings lead to a concrete view about biosystems as three-levelled structures involving massless extremals (MEs), super conducting magnetic flux tube structures, and atomic space-time sheets containing the ordinary matter. MEs control the dynamics of the superconducting ions inside magnetic flux tube structures. Magnetic flux tubes in turn are in a many-sheeted ionic flow equilibrium with the atomic space-time sheets and thus control the ionic concentrations at these space-time sheets.

This general framework leads to a rather detailed model for the generation of nerve pulse and EEG; to a model of sensory representations based on the notion of sensory canvas realized in

terms of magnetic flux tube structures outside body with MEs serving as projectors of the cortical sensory representations to this sensory canvas; to a model of cognition including the realization of the memetic code in terms of cognitive antineutrinos and a physical mechanism translating nerve pulse sequencies to the 126 bit long codewords of the memetic code; and finally, to a model for the quantum correlates of the sensory qualia and to what deserves to be called spectroscopy of consciousness.

Electromagnetic selves

Rather remarkably, the time scale of.1 seconds predicted by the model of the memetic code and defining in the zero energy ontology a fundamental time scale of electron as well as the time scales of the photons associated with the magnetic transition frequencies, in particular cyclotron frequencies, of ions correspond to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth: the lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21, ... Hz [F1] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere.

The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, , the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such microseizures and epilepsies [J130]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

These observations suggests the identification of the relevant selves in our self-hierarchy are electromagnetic selves having the size of Earth and correspond to EEG frequencies. What happens is that Josephson currents generate classical ELF em fields represented by topological field quanta of this size (by uncertainty principle alone) which in turn couple resonantly to ions. These observations raise the question whether our "physical" body is only a tip of an iceberg and formed by the topological condensation of the biomatter around electromagnetic topological field quanta serving as templates for the biostructures [K23]. There is also neuropsycological evidence for the importance of ELF fields. In particular, the work of Michael Persinger is especially important [J133, J131, J156] [K52].

One possible scenario inspired by these observations is following.

1. The magnetic transition frequencies for the superconducting ions at the flux quanta of magnetic field B=.2 Gauss correspond to personal sensory consciousness. The magnetic flux tubes emanating more or less vertically from brain and accompanied by massless extremals could act as projectors defining personal sensory representations at the magnetic sensory canvas formed by the flux tubes (or possibly shell like topological quanta) of Earth's magnetic field.

2. Schumann frequencies associated with the oscillations of the flux tubes of Earth's magnetic field would in turn correspond to transpersonal aspect of consciousness. Schumann resonances could indeed induce a synchrony of the vertical magnetic flux tube structures associated with separate brains and even entangle them during sleep. This view is supported by some observations. In hypnagogic states (states between wake and sleep) EEG is peaked near the lowest Schumann frequency 7.8 Hz. During these states it is possible to experience hallucinations and identification experiences (I have now and then fleeting but completely "real" experiences of being someone else). The so called sleeping spindles correspond to EEG patterns at 14 Hz which is the second Schumann frequency. A possible interpretation is that during sleep collective consciousness begins to dominate and brains form a highly synchronous whole. It would be interesting to test whether there are correlations between EEGs of different persons during sleep.

7.4.4 Some Functions Of Magnetic Body

The magnetic bodies associated with various body parts, including cellular and even molecular magnetic bodies, could have several functions besides defining a hierarchy of intentional agents (for this aspect see [**?**]).

Topologically quantized classical fields as templates for the formation of bio-structures?

Magnetic bodies could serve as templates of bio-structures. For instance, blood circulation and central nervous system could have magnetic circuitries as templates. The web like structure formed by topological field quanta representing classical fields, in particular em fields, is reminiscent of structures formed by micro-tubuli and collagens forming the connective tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various bio-structures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self (mental image!) of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4\times 10^{-6}$ meters. There is direct evidence for the hypothesis that ions in a magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field, form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size. It must be emphasized that B_{end} is not equal to B_E as I erratically believed for a long time. The model for dark matter as macroscopic quantum phases with Planck constant equal to an integer multiple of the ordinary Planck constant [K44] leads to the working hypothesis that B_{end} corresponds to the dark counterpart of B_E [K37].

For $B_{end} = 2/5B_E = .2$ Gauss interpreted as a dark magnetic field with $\hbar = 5\hbar_0$ carrying 2 units of flux (the unit is $h_5 = 5h_0$) and corresponding also to the p-adic length scale $L(169)$, the radius is 25 μm, the size of a large neuron. This possibly relates to the fact that the effects of ELF em fields are observed for vertebrates (for details see [K37]).

The coupling of the neuronal layers of cortex and perhaps all cells with the flux tubes of Earth's magnetic field could make possible entanglement between brain and Mother Gaia. If magnetic flux tubes of the dark counterpart of B_E have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along micro-tubuli, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level selves.

One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm)to the size of human brain lobe (10 cm) as well as the ratio of the thickness of the cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2}. Could this mean that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy? The general ideas about self-organization indeed support this view: boundary regions are subject to the most intense external energy feed and thus self-organize most effectively.

The web formed by topological field quanta of the classical em and fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [K112]. Perhaps also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

Dark magnetic fields and living matter

A considerable sharpening of the above discussed speculative picture came with the development of TGD inspired vision about dark matter as macroscopic quantum phases with quantized value of Planck constant having arbitrarily large values coming as integer multiples of the ordinary Planck constant [K44].

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [K37] .

1. The most general hypothesis is allowed by the proposed generalization of the notion of embedding space is that the values of $r = \hbar/\hbar_0$ come as rationals [K44]. A less general alternative is that the values r of come as integers: $r = n$, where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K138]. In this case n would be a product of integers characterizing the number of sheets for singular coverings of CD and CP_2.

2. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$.

The prediction is that also rational or at least integer multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \to h = rh_0$ in the transition scaling the Planck constant by r: one manner to achieve this is by scalings $L(k) \to rL(k)$ and $B \to B/r$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [K4].

An natural working hypothesis is that B_{end} defines the dark counterpart of the ordinary magnetosphere and that the relationship $B_{end} = 2B_E/5$ holds as a time average in the entire magnetosphere. The flux quanta of B_{end} would carry dark matter and would be responsible for the quantum control of the living matter.

Magnetic flux tubes and metabolism

Magnetic flux tubes could define super-conducting circuitry making possible a many-sheeted control of homeostasis: this aspect is discussed in [K59]. The hierarchy of magnetic flux tubes could also define many-sheeted lasers, and the dropping of particles to the larger space-time sheets would define a hierarchy of metabolic energy currencies as zero point kinetic energies liberated in the process. Process would also generate radiation at the harmonics of cyclotron frequencies at the larger space-time sheet. These frequencies could define a considerable part of EEG. Also fractally scaled up versions of EEG having similar band structure are predicted. The findings of Peter [I28, I29] are consistent with this prediction [K19]. The dropping of particles to larger space-time sheets for population inverted lasers would be also ideal for the realization of bio-control by time mirror mechanism and make possible remote metabolism and remote motor control.

Magnetic flux tubes as Nature's own bio-laboratory

Magnetic flux tubes could be ideal structures for the isolation and purification of various biomolecules, and make also possible precise targeting of the reactants to reaction volumes defined by the nodes of the magnetic flux tube circuitry. Purification is made possible by the weight of the molecule if quantum-classical correspondence holds true in the sense that a magnetic flux tube carrying super-conducting bosons of mass m deforms so that it runs along a classical orbit of the particle with radius proportional to m. This would make sense for a many-sheeted magnetic field for which the fluxes associated with the magnetic flux tubes along which particles move return

along much larger space-time sheets and define the average magnetic field in which the particles move. This kind of Nature's own bio-laboratory might explain the miraculous selection of bio-molecules essential for the pre-biotic evolution. In accordance with the p-adic vision about the evolution of cognition, the evolution would have been proceeded from and guided by the magnetic flux tube structures of the Earth's magnetic field to the bio-chemical level [K45, K46].

7.4.5 The Magnetic Fields Associated With Body Parts And Higher-Levels Of Consciousness

The basic vision is that magnetic flux tubes containing ionic super-conductors, MEs carrying exotic representations of p-adic Super Virasoro algebra, and biological organisms live in a fractal symbiosis. MEs can induce cyclotron transitions amplified to quantum phase transitions inside magnetic flux tubes provided they have length above the wavelength defined by the cyclotron frequency. The exotic p-adic Super Virasoro representations with MEs have wavelength determined by the fundamental frequency which is of same order as the cyclotron frequency. The interaction of MEs and magnetic flux tubes by SQUID mechanism requires that magnetic flux of ME generates a current inside a circuit formed by magnetic flux tubes. Magnetic flux tubes to have arbitrary size scales below the size scale of ME.

Some body parts are carriers of static magnetic fields. The value of the static magnetic field associated with eye is slightly below 10^{-11} Tesla whereas the strength of Earth's magnetic field is about $.5 \times 10^{-4}$ Tesla. Also pineal gland ("third eye" also in a rather literal sense, see [K50]) contains magnetic material. Unfortunately I do know the value of the corresponding dipole strength: for a dipole having size of order micrometer the maximal dipole strength would be very roughly 10^{-9} times corresponding dipole strength for Earth's magnetic field which would mean field of order 10^{-13} T. Also head and entire body could act as static magnetic dipoles.

For purely sensory consciousness .1 seconds is the characteristic time scale and EEG is closely related with this form of consciousness. In case of B_e the magnetic cyclotron frequencies are in the range obtained by scaling the range of cyclotron frequencies in Earth's magnetic field by a factor about 2×10^{-7}. This means that the periods of the ionic cyclotron frequencies are roughly in the range 12 hours-1.6 years for ionic cyclotron frequencies corresponding to the range of frequencies $90 - 0.1$ Hz in Earth's magnetic field. These time scales are typical for the contents of higher level self consciousness involving self narrative. Notice however that these fields are perhaps not sufficiently weak for a self narrative in the time scale of several years.

The minimal thickness of the flux tubes for ULF selves associated with B_e would be roughly of the order of few millimeters, as one finds by scaling the radius for the flux tube of Earth's magnetic field which is about 5 microns.

Also bodily magnetic fields B_b could be involved. By scaling one obtains for the head's magnetic field an estimate $(mm/headsize)^2 B_e \sim 10^{-4} B_e$, which gives fT which is slightly above the thermal noise produced by body. The flux tube would have minimal thickness about 10 cm, the size scale of the head. The cyclotron frequency range would be scaled by a further factor of 10^4 factor meaning that the time scale range would be between 10 years and 10^4 years!

Higher levels of self hierarchy as levels of dark matter hierarchy

Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. The integer $n = 2^{k11}$, $k = 0, 1, 2, ...$ seem to define favored values of Planck constant in living matter. This means a hierarchy in which time and length scales are zoomed up by a factor of 2048 in the transition to the next level of hierarchy. This integer represents also fundamental constant in TGD Universe [K112].

For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of.1 seconds [K36], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in questions. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general

correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K65, K37]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

Could the flux tubes of bodily magnetic fields correlate with more abstract levels of self consciousness?

The previous observations combined with the general speculative vision about Indra's web of consciousness stimulate several questions and ideas relating to the role of various magnetic fields associated with body.

1. Could it be that the ULF selves associated with the ionic super-conductors residing at the flux tubes of the bodily magnetic fields B_e and B_b (notice also the static magnetic fields of pineal gland and of other organs) belong to the self hierarchy and represent higher level selves contributing to our non-sensory consciousness under ordinary circumstances? This translates to the question whether the flux tubes of the corresponding topological quantized magnetic fields are closed in a relatively small volume as in case of an ideal dipole field or whether part of flux tubes have astrophysical lengths.

2. The above arguments do not pose restrictions on the strengths of the magnetic fields. In case of Earth's magnetic field the magnetic flux tubes have sizes of order of the wavelength associated with a typical cyclotron frequency. Could it be that the interacting MEs and magnetic flux tubes have sizes comparable to the wavelength defined by cyclotron frequency? If this is the case for B_e and B_b, the sizes of flux tubes would be astronomical with light day serving as lower bound. One could see the flux tubes of B_e and B_b as kind of umbilical cords connecting human bodies with magnetic structures of astronomical size and perhaps also with other organisms. Could one assign the more abstract levels of human consciousness and long term memories with the ULF selves associated with both the flux tubes of B_e and B_b and with MEs? In this view biological organisms would be like sensory-motor organs of this magnetic super organism.

3. Could one possibly test this hypothesis in case of B_e by studying the interaction of ULF em fields with frequencies above the time scale defined by day? Is the daily rhythm somehow relevant at the level of these em fields? For instance, could the natural 24 hour period certainly associated with ULF em fields of eye define the analog of alpha peak in EEG? Could the strength of the magnetic fields of eye be seen as a result of adaptation to the daily rhythm or is it dictated by the size of eye and flux quantization (there is roughly unit flux over an area of order millimeter squared)?

Objection

The bodily magnetic field change with time if the location orientation of the magnetic dipoles are fixed with body. Already the rotation of Earth induces periodic rotation of the magnetic flux tubes B_e and B_b. The volitional motion during wake-up period induces further effects.

There are several ways to circumvent this objection.

1. The most convincing manner to avoid the objection is that the flux tubes relevant for ULF consciousness have size at least of order of the wavelength defined by the cyclotron frequency and thus of the same order of magnitude as the size of the corresponding MEs. In this scale the rotating motion for the end of the magnetic flux tube of B_e or B_b would have absolutely

no significance and magnetic flux tubes would be somewhat like magnetic umbilic cords (like the tunnel involved with the NDE experiences connecting patient to the deceased relatives!).

2. If the magnetic flux tubes in question have sizes comparable or smaller than Earth size, the situation changes. Only in the very special case that the flux tubes rotate around Earth in the direction of equator, B_e and B_b could remain stationary and it makes sense to speak about stationary states.

3. One could also consider the possibility that magnetic flux quanta are layer like structures around Earth rather than rotating tubular structures, and have rotational symmetry with respect to the rotations around Earth axis so that it is body which is rotating with respect to these structures rather that these structures rotating with body. In this case it would make sense to assign cyclotron frequencies to the super-conducting ions in question since local magnetic states are certainly possible. In super-conductors of type I near critical temperature complicated layer like flux structures are indeed possible and in [K21, K22] it has been suggested that epithelial sheets formed by cell membrane inside cells correspond to this kind of flux structures.

The obvious question is how the rotation of Earth affects localized stationary states of the super-conducting ions inside co-rotating magnetic flux tubes with sizes smaller than Earth size. Does the description of the system in terms of cyclotron states make sense anymore? Quantum mechanically the ion in a stationary magnetic magnetic field is in radial degrees of freedom like a harmonic oscillator.

1. A simple analog system would be a harmonic oscillator rotating with an Earth and having an oscillation period which is longer than 12 hours. By separating center of mass degrees of freedom one finds that the particle in the rotating oscillator well feels besides the ordinary harmonic force a harmonic force $m\omega^2\overline{r}_{cm}$ which means that the complete solution to the equations of motion is superposition of the harmonic oscillator motion plus a periodic oscillatory term with the frequency of the external force. The average motion is therefore just the rotating harmonic oscillator motion.

2. In quantum case one has harmonic oscillator coupled to an external harmonic force having a frequency much larger than the oscillator frequency. Time dependent perturbation theory allows transitions only between the states whose energy difference $n\omega_0$ equals to the forcing frequency and transitions thus possible only if one has $\omega = n\omega_0$. Thus no quantum jumps would occur in the generic case.

3. The guess motivated by these considerations is that the magnetic state in a rotating magnetic field is in a good approximation obtained by applying time dependent rotation to the ordinary magnetic state and that in the time scale defined by the cyclotron frequency the average effects to the state cancel also now. Thus effective adiabaticity holds true.

Further questions related to vision

One can make several interesting questions related to vision and the magnetic fields of eye.

1. What is the role of the rapid eye movements during REM sleep, in particular during dreams? Could it be that the communication of long term memories from ULF level is involved with dreams and that the rhythmic eye movements are essential for establishing this communication?

2. The motor control associated with eyes is decoupled from the motor control of the remaining body. Therefore persons who are totally paralyzed can still move their eyes and can even communicate in this manner. Could the special role of the eye-motorics relate to the remaining ability to stay in contact with ULF selves associated with eyes?

3. What is the interpretation of the rays of light characterizing the visual perception of intense light. Perhaps there is some natural explanation for this but since I do not know about it, I can entertain myself with the idea that these rays could directly correspond to MEs

representing rays of light and connecting me with the objects of the external world. The correspondence between sensory experience and reality would be amazingly simple, if this is true.

NDE experiences and magnetic consciousness

NDE experiences [J160, J152] involve vision in an essential manner. This suggests that the dominating component of NDE consciousness could correspond to ULF selves associated with B_e and or B_b and give rise to the typical bird's eye of view about own body involved with the OBE and NDE experiences. The cyclotron frequency time scale associated with B_b would indeed fit with the life review experienced in NDE experiences. Body would be seen by ULF selves in bird's eye of view through the magnetic flux tubes of B_e and B_b. There would be a strange resiprocity resembling to the resiprocity encountered in the techniques of radio communications where the antennae sending messages can also serve as receiving antennae. NDE experiences involve also meeting of the dead relatives. Magnetic flux tubes can connect patient also to other organisms. and it would not be too surprising if magnetic flux tubes starting from the body could serve as an umbilic cord connecting the patient with living relatives or magnetic structures representing deceased relatives.

NDE experiences involve also the experience of travelling through a tunnel. The tunnel is experienced also during epilepsy and migraine, during meditation and relaxed state of mind, and with certain drugs like LSD, philocybin and mescaline.

I have also personal "tunnel experiences" every-daily: when I close my eyes in a half-meditative state achieved by writing at computer terminal, I can see a dim flow consisting of points. Typically this flow enters to or emergences from a tunnel. It can be rotating spiral like flow or simple sink or source. Source or sink can be also linear structure. The experience is not stable and tends to fade away all the time, and after few minutes I am not anymore able to achieve it. During my great experiences this flow was much more complicated and completely visible and formed a stable background of the ordinary visual experience and of hallucinatory visual images.

There is however no experience of entering into the tunnel in this case so that the tunnel need not be the same as encountered in NDEs. I have pondered quite a many times about the possible interpretation of this background flow. The basic observation was that it resembles liquid flow to a very high extent. Liquid flows are usually incompressible in an excellent approximation and this means that the velocity field is divergence free. This is the basic property of also magnetic fields and means that magnetic flux through a circuit moving along magnetic flux lines is conserved. This has stimulated the obvious guess that the background flow indeed represents magnetic field. The question which I have not made is whether this magnetic field resides inside my brain or outside it. In light of the above considerations the most natural answer to the question is that the magnetic field visualized by the flow is precisely where it seems to be. The flow would represent nothing but the magnetic field associated with my own eyes or more probably head, or rather how the self associated with the flux tubes of this magnetic field experiences the world.

The thickness of the flux tubes of B_b would be roughly the size of the head and this fits with idea that the tunnel experience represents directly the magnetic flow without any scaling factors involved. The fractality of TGD Universe suggests that these magnetic fields contain flux tubes of stronger magnetic fields inside them, so that the tunnel experience would represent the flux tubes of these magnetic fields experienced as sub-selves by the ULF self contributing to my visual consciousness in this altered state of consciousness. Of course, it might well be that also during the ordinary consciousness the experiencer is this magnetic ULF self and that sensory input dominates the content of the conscious experience and creates the illusion about body as self. In the absence of a sensory input the contents of consciousness of a clinically dead person is determined by these magnetic field and bird's eye of view about body results.

What remains after the physical death could therefore be determined by the magnetic fields involved with body. Magnetic flux conservation allows configurations of the closed magnetic flux loops containing ionic super-conductors as the counterpart of soul continuing existence after death. Wormhole magnetic fields and p-adic variants of these magnetic fields would also make it possible to store information about the magnetic fields originally associated with body. The overall view suggesting itself that our bodies are like sensors and motor organs of a gigantic electromagnetic organisms of astrophysical size and represent its sub-selves (mental images). This interpretation

conforms with the fact that in EMDR method rhythmic eye movements induce experiences involving the meeting of deceased relatives [J38].

The experimental study of what happens to the magnetic fields associated with eyes, head and other body parts after the physical death would obviously provide interesting information in this respect, perhaps one can someday even develop refined methods of communication with the deceased.

What about magnetic fields of heart?

The magnetic fields associated with eyes are not the only bodily magnetic fields with peak intensities higher than the non-static magnetic fields generated by brain. Heart generates a periodically oscillating magnetic field B_h of order $.5 \times 10^{-10}$ Tesla which is almost ten times higher than the static magnetic field generated by eyes. I do not know whether B_h contains a static component and if so, what is its strength. In any case, the absence of the static component means that the possibly super-conducting ions inside flux tubes of heart's magnetic field are in a periodically oscillating dipole field (most probably with respect to the geometric time!).

Also here my "great experience", which has turned out to be an extremely valuable repertoire of altered states of consciousness, provides an illustrative example. During the second great experience which lasted only one night, I experienced what might be called "heart consciousness". In the beginning of the experience my whole consciousness was filled by the rhythmic "..aqua-aqua-aqua..". It took some time to recognize that this rhythm was the rhythm of my own heart. Involved was also the mystical experience about the fundamental importance of water for life (said jokingly, heart is an organ specialized to deal with liquid!) and the precognition of the notion of infinite primes. Could it be that the MEs associated with heart dominated the contents of my consciousness during this experience.

Chapter 8

Quantum Model for Sensory Representations

8.1 Introduction

This - as also the other chapters of "TGD Inspired Theory of Consciousness" - was written for the first time for more than a decade ago. The recent version is an outcome of an updating motivated by the progress taken place in quantum TGD proper during the period 2005-2010. Several new elements are involved. The improved understanding of the quantum TGD itself at the fundamental level; zero energy ontology including the notion of causal diamond (CD) defined as the intersection of future and past directed light-cones; the hierarchy of Planck constants requiring a generalization of the notion of imbedding space and involving the identification of dark matter as phases with non-standard values of Planck constant; and the progress in the understanding of p-adic physics- especially the realization that life could be seen as something residing in the intersection of real and p-adic worlds. The fact that number theoretic entanglement negentropy has a positive value in the intersection has profound implications for the TGD inspired theory of consciousness and quantum biology since the quantum measurement theory is modified profoundly.

8.1.1 Overall View About TGD Inspired Theory Of Consciousness

TGD inspired theory of consciousness allows to construct a general model of conscious experiences based on some very general principles.

1. The original view was that notion of quantum jump defines "microscopic" theory of consciousness whereas the notions of self and self hierarchy allow to understand "macroscopic" aspects of consciousness absolutely essential for brain consciousness. It however seems that zero energy ontology and the hierarchy of Planck constants allow to identify these notions by replacing the quantum jump as a fractal structure consisting of quantum jumps within quantum jumps. Despite this I will prefer to talk about these notions as separate ones in the sequel. The assumptions about how the contents of consciousness of self is determined allow to understand the basic structure of conscious experience at general level. One can understand intentionality and volition as closely related to the p-adic nondeterminism. Negentropic quantum entanglement is stable under state function reduction if governed by Negentropy Maximization Principle (NMP) so that state function reduction is not a random process anymore. The implications are obvious for understanding how conscious intelligence emerges. Theory leads to a very general model of sensory experience - including a vision about qualia - and the so called whole-body consciousness involving in an essential way negentropic entanglement explains the basic characteristics of altered states of consciousness.

2. The understanding of the relationship between subjective and geometric time has evolved via several proposals and leads to the notion of psychological time involving in an an essential way the new view about space-time. Symbolic representations at space-time level required by quantum classical correspondence are made possible by the classical nondeterminism of

Kähler action. All space-time sheet are assigned to CDs in zero energy ontology and correspond to mind-like space-time sheets in the earlier terminology. They serve as geometric correlate of selves. The notion of psychological time forces to view the entire many-sheeted space-time surface as a living system so that the standard notion of linear time is illusory and reflects the restricted information content of our conscious experience rather than fundamental 4-dimensional reality.

The paradigm of 4-dimensional brain provides a completely new understanding of the long term memory: no memory storage mechanisms are needed and one avoids the basic difficulties of neural net models. There are two kinds of memories: subjective and geometric. Also geometric memories come in two types: episodal and declarative. Time-like negentropic entanglement make possible episodal memories as a direct re-experiencing in the intersection of real and p-adic worlds, and state function reduction trivializing time-like entropic entanglement gives rise to declarative, verbal memories mediated by classical communications. Massless extremals (MEs) are proposed to serve as space-time correlates for both kinds of memories. The fact that the temporal duration of the light-like self associated with ME can be arbitrarily long, is very probably of significance. The hierarchy of Planck constants allows to overcome the objection due to the fact that the photons with the required extremely low frequencies are below the thermal threshold in living matter and therefore should not have any role for consciousness. Emotions might be understood as resulting from the comparison of geometric memories (the expectation) with the subjective memories (what really happened). The positive-negative coloring of the emotions could relate directly to whether the mental images corresponds to a system with negentropic or entropic entanglement.

3. An essential element is macro-temporal quantum coherence accompanying the formation of bound and negentropically entangled states. Already zero energy ontology assigns macroscopic time scales of coherence to elementary particles and the hierarchy of Planck constants and the stability of negentropic entanglement against state function reduction bring in additional elements. Quantum spin glass degeneracy lengthens the lifetimes of the resulting bound states.

4. Subjective time development by quantum jumps implies quantum self-organization which can be regarded as a sequence of quantum jumps between quantum histories. This evolution corresponds to a sequence of superposition of macroscopic space-time surfaces associated with the final state quantum histories assignable to the hierarchy of CDs. Quantum jumps imply dissipation at fundamental level. As in standard approach dissipation serves as a Darwinian selector of self-organization patterns, which can represent both genes and memes. Jumping from the bottom of a valley of the 4-D quantum spin glass energy landscape to the bottom of another valley by a temporary de-localization in zero modes explains phase transition like processes ranging from a change of protein conformation to the replacement of a habit routine by a new one. Further new elements to the standard view about self-organization are brought by zero energy ontology, negentropic entanglement, and hierarchy of Planck constants implying that second law does not hold true in the standard form anymore. An especially interesting prediction is that the CDs assignable to elementary particles correspond to macroscopic time scales. For instance, electron corresponds to the fundamental.1 second bio-rhythm.

   The role of energy feed in self-organization becomes more complex in TGD framework. Learning becomes a fundamental process since state function reduction for negentropically entangled states is not random process anymore and in the first approximation the powers of unitary process define an iterative self-organization process. In this framework one can in principle understand how habits, skills and behavioral patterns are gradually learned. The possibility of the reversal of the arrow of the geometric time below p-adic time scale characterizing the system brings in time reversed dissipation identifiable as a healing. Bio-rhythms could quite generally correspond to dissipation-healing cycles. Motor action could be understood as geometric time reversal for the build-up of sensory representation in an appropriate time scale.

This process gives deep insight to a repertoire of widely different phenomena.

1. The formation of bound and negentropically entangled states implies subjecto-temporal fractality of consciousness meaning that the basic anatomy of quantum jump is replicated in various time scales, even that of human life cycle.

2. Both kinds of entanglements mean fusion of mental images. In entropic fusion sub-selves lose their consciousness whereas negentropic fusion accompanies the experience about expansion of consciousness. Depending on the character of entangling selves (real or p-adic for some p), one can assign to the negentropic entanglement some positively colored experience, say experience of understanding or experience of love. Telepathic sharing of mental images and remote mental interactions become possible. Sexual and spiritual experiences can be seen manifestations of the same basic process of fusion of selves and sex would be present even at the molecular level. For instance, information molecules and receptors entangling negentropically could be seen as having opposite molecular sexes with the binding of the information molecule to receptor giving rise to the experience of "oneness" and favoring co-operation instead of competition.

3. If the randomness of the outcome of the ordinary state function reduction means free choice, then self can choose to some degree whether sub-self ends up to a state in which it can decompose to sub-selves by state function reduction or becomes a entropic or negentropic sub-self stable against state function reduction. Maybe this choice could be seen as a choice between good and evil.

4. For negentropically bound states the powers of unitary process U define a sequence quantum computer type processes. More concretely, the combination of the notions of magnetic body and hierarchy of Planck constants leads to a model of DNA as topological quantum computer [K3]. Zero energy ontology and 4-dimensionality of the ensemble of computations assignable to sub-CDs mean deviations from the standard model for quantum computation.

5. The binding energy liberated in the formation of bound state entanglement is usable energy: this means quantum metabolism based on buy now-pay later mechanism. Negentropic entanglement in turn can carry positive energy and there is a large temptation to assume that metabolic energy is transferred in this way so that the somewhat nebulous notion of high energy phosphate bond would involve new physics.

The general vision about different types of conscious experiences and about qualia was discussed in [K68]. In this chapter a general model of personal sensory representations is considered: in [K50] a more detailed model for these representations is discussed. The so called magnetospheric sensory and memory representations possibly responsible for the third person aspect of consciousness are discussed in [K64].

8.1.2 The Quantum Hardware

The model involves the following basic notions and ideas about the quantal hardware of consciousness.

1. TGD universe is quantum spin glass and the plasticity of the brain is in accordance with a model of brain as point moving in an infinite-dimensional spin glass energy landscape. Inhibitory and excitatory nerve pulses induce motion in the energy landscape and justify the notion of frustration characterizing spin glass. The picture differs from ordinary neural net in that spin glass energy landscape has also time as one dimension in a well defined sense (this is due to the failure of the classical determinism in standard sense for the Kähler action defining the dynamics of the system). This allows a new view about what happens in learning.

2. The general model of sensory experience relies on the music metaphor. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes in magnetic fields of $\simeq .2$ Gauss (Earth's magnetic field has nominal value.5 Gauss) and this generates EEG MEs at EEG frequencies serving as entanglers to the

sensory magnetic canvas, and the variation of these frequencies could code for the distance to the object of the perceptive field.

A stronger interpretation of the metaphor should be that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a particular sensory modality and corresponding higher level cognitive representations associated with it. Primary sensory qualia can be associated with sensory receptors or primary sensory organ if brain and sensory organs are quantum entangled with each other. Nerve pulse patterns would build up what could be regarded as notes representing the music whereas the music (primary sensory qualia) is produced by the primary sensory organs. This leads to a generalization of the idea about brain as an associative, cognitive net.

3. The notion of self hierarchy is central for the model and allows to understand quantum correlates of the sensory qualia.

   (a) Self hierarchy is very much analogous to the hierarchy of subprograms of a computer program and defines a hierarchy of increasingly abstract experiences. Self hierarchy allows to understand computational aspects of brain although connectionistic picture realized as quantum association network seems to work at various levels of the hierarchy.

   (b) The empirical results [J64] about the effects of oscillating em fields on brain suggest that cyclotron frequencies, and more generally magnetic transition frequencies, of biologically important ions in magnetic field $B \simeq .2$ Gauss, which is by a factor 2/5 weaker then the magnetic field of Earth, correspond to important oscillation frequencies of Josephson currents or some other perturbations acting on the system. Also the magnetic transition frequencies of electronic Cooper pairs seem to be important as perhaps also Z^0 magnetic transition frequencies of neutrino and various ions and atoms and even molecules. Classically cyclotron frequency for Josephson current corresponds to resonance.

   (c) The role of massless extremals (MEs) have become more and more central in TGD inspired theory of consciousness as I have gradually understood their properties. Very briefly, MEs are ideal for both classical and quantum communications, they give rise to quantum holograms both in quantum gravitational and "technological" sense. MEs make also possible the realization of long term memories as communications between future and past. The notion of conscious hologram makes these ideas very concrete.

   (d) The strange findings challenging the notions of ionic channels and pumps lead to the view about biosystem as a symbiosis of MEs, superconducting magnetic flux tube structures, and atomic space-time sheets. The latter two are in many-sheeted ionic flow equilibrium controlled by MEs and very elegant control mechanisms based on the classical em interaction between MEs and flux tubes inducing supra currents emerges.

   (e) Self hierarchy has as its geometric correlate the hierarchy of CDs the level of embedding space and the hierarchy of space-time sheets at space-time level. The fact that Josephson currents associated with ELF frequencies generate photons with wavelengths of size of Earth which by uncertainty principle correspond to topological field quanta with size of Earth. The only possible conclusion seems to be that our sub-selves correspond to (at least) these topological field quanta so that we are much more than our neurons.

   (f) It took years to arrive to the conclusion that also magnetic flux tube structures associated with various parts of brain could have same size as EEG MEs and serve as sensory canvas in the sense that the positions of objects of perceptive field are represented as sub-selves at the magnetic flux tubes of varying thickness woken-up by MEs generating magnetic transition frequencies. Obviously MEs and magnetic flux tubes associated with the sensory projectors must be very closely related (perhaps they are parallel to achieve Alfven wave resonance). Various attributes associated with the object of the perceptive field are associated with these magnetic sub-selves and brain, or rather entire central nervous system, can be seen as a collection of pre-existing features of perceptive

field which can be activated. Also long term memory recall can be understood in this framework as a communication between geometric now and geometric past made possible by MEs (which correspond to light-like selves) and magnetic flux tube structures associated with brain, both having astrophysical sizes.

8.1.3 Me As A Computer Sitting At Its Own Terminal?

It became as a surprise that the vision resulting from a long lasting thought experimentation is actually very much what the original, now twenty five year old, altered state of consciousness experience about myself as a computer sitting at its own terminal, when taken very literally in some aspects, actually suggests. This vision adds to the standard view about brain an additional layer responsible for the sensory representations and brings in the quantum level of control (possibly from magnetic body) so that nerve pulse patterns are only part of the control loop.

1. Magnetic flux tube structures serve as a sensory canvas analogous to the computer screen. The control commands realized by activating MEs, in which state they create coherent states of photons and possibly also other gauge bosons, generate magnetic quantum phase transitions, and induce supra currents, Josephson currents and Ohmic currents, provide a realization for the keyboard of this computer. Brain serves as central processing unit: the computations carried out are parallel computations and program modules are replaced by various self-organization patterns.

2. Motor actions and sensory representations differ in that they are time reversals of each other in a relevant p-adic time scale.

3. What imagined motor actions and sensory experience mean is not quite clear.

   (a) The first view is that for imagined motor actions and sensory experiences the first (rather than last as one might think!) step in the sequence of commands is simply not realized. For sensory experiences the first step means sensory input assuming that primary sensory qualia are at the level of sensory receptors. A real motor action proceeds like a geometric time reversal of the sensory input and starts from motor organs if it is real, and from some higher level if it is imagined. p-Adic-to-real phase transition is the basic step initiating neural activity leading to imagery.

   (b) A more quantal view about imagination is based on the notion zero energy states with time-like negentropic entanglement. In this case qubits and more general states are always fuzzy so that Schrödinger cat is never completely alive or completely dead. Suppose one takes a zero energy for which nothing happens and adds to it a little bit of state for which the imagined event happens. The higher the probability of the imagined event is, the nearer the imagined event is to a real event.

4. Cortex can be seen as a collection of pre-existing cognitive features which are activated when they appear in the perceptive field or form a part of motor action. The basic task of cortex is to identify these features from the sensory input, entangle them with sensory input, and project to the magnetic body.

5. The decomposition of the perceptive field into objects is one of the basic aspects of sensory experiencing and TGD provides a mechanism generating these objects as mind-like space-time sheets: the boundaries of these objects correspond to regions of strong Kähler electric field whose strength is assumed to correlate with the intensity of the neural input. It might be that even the objects of perceptive field or thoughts could be regarded as features. At the neuronal level one ends up to a model in which neurotransmitters at the ends of magnetic flux tubes attach to receptors at the ends of magnetic flux tubes connecting cell membrane and DNA and give in this way rise to a fusion of the pre- and post-synaptic mental images. In contrast to standard neuroscience view, gene level would be involved in an essential way in the information processing. U process could be described as a generalized Feynman diagram in which synaptic transmissions replace particle exchanges and for negentropically entangled states learning would correspond to a sequence of powers of U.

6. The computational activities associated with the construction of the sensory representations (say estimating distances and directions of the objects of perceptive field) and virtual sensory representations representing the goals of motor action are presumably realized as iterated processes in which virtual sensory inputs characterizing the expected experiences are compared with the real world sensory input. In a similar way the goal of the motor action is compared with the sensory representation resulting from effect of a virtual motor action on the representation of the recent state of world and body. This comparison does not necessarily require sensory representation at any level of the self hierarchy and could be based on comparison circuits defined by parallel supra currents in which the inputs which are sufficiently near to each other generate constructive interference giving rise to a large Josephson current. The fractal hierarchy of CDs coming as octaves of CD size and the hierarchy of Planck constants in principles makes possible zooming up and down possible so that simulations can be carried out in time scales smaller than that characterizing self.

7. The neural realization of long term memories has remained to a high extent a mystery and TGD suggests that the fundamental realization is not in fact neural. TGD allows the geometric memory storage in the geometric past, where the things happened and still happen. MEs suggest several candidates for the memory recall mechanisms and the quantum communication between geometric future and past is one of the most promising ones. Active memory recall might involve a question sent to the geometric past as a classical signal, perhaps MEs are involved at this stage. In the case of episodal memory the answer would involve the generation of time-like negentropic quantum entanglement: the recalled experience is shared by the experiencer now and in the geometric past. For declarative memories outside the intersection of real and p-adic worlds the communication of the memory would be classical.

8. The model of intentionality is mirror image of the model of long term memories obtained by real→ p-adic and geometric past→ geometric future replacements.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

8.2 General Ideas About Hardware Of Consciousness

In this section general ideas and metaphors about what quantum brain and quantum brain functioning might be, are summarized. These ideas have developed gradually during last decade and continue to do so. The recent view about brain conforms with the great sixteen years old vision about self as a computer sitting at its own terminal.

This vision, if taken completely seriously, means that the ultimate sensory representation conscious-to-us is outside the brain: that this is the case became clear quite recently (the geometric now when I am writing this is October, 2001). The title of this section is "General ideas about hardware of consciousness". rather than "General ideas about brain". The reason is that brain and body in TGD Universe form only a tiny part of a system involving hierarchy of MEs and magnetic flux tube structures having astrophysical sizes controlling the matter at the atomic space-time sheets defining brain and body in the usual sense of the world.

I defend this radical deviation from the standard wisdom by the fact that the world "consciousness" has ceased to be a taboo only during the last decade. It would be really astonishing if the materialistic view about consciousness as an illusion and brain as a computer would generalize to a general theory of consciousness just by adding one candle to the birthday cake of one century of brain science. Just like the creation of physics at the times of Kepler meant revolution in Earth centered world picture, also the creation of the general theory of consciousness is bound to mean thoroughgoing changes in the basic prejucides about human consciousness.

8.2.1 Brain As A Computer

Brain as a computer metaphor in sense of Turing machine has been one of the dominating metaphors about brain functioning. In TGD this metaphor makes sense as far as general func-

tional architecture of modern computer is considered. Programs must be however replaced by self-organization patterns.

Brain as a computer sitting at its own terminal

My personal great experience involved the realization that I am in some sense a computer sitting at its own terminal. It took more than one and half decades to realize what this self-referential idea having deep mystic coloring in it might mean in practice. Actually I realized the connection only after having ended up to this kind of view about brain by quite different routes.

To be precise, "computer" does not mean in the recent context the abstract Turing machine, but a real world personal computer. The concrete functional and geometric architecture seems to be mimicked by personal computers, not the detailed data processing. the deterministic computer programs are replaced by much more flexible self-organization patterns.

1. Brain corresponds to the central processing unit of this computer. The data in computer memory are typically represented at computer monitor which is outside the central unit, can have much larger size and be located arbitrary far away. In the case of brain this means that the ultimate, conscious-to-me sensory representations are realized outside brain at superconducting magnetic flux tube structures associated with various parts of brain. This view is inspired by very simple observation: when my eyes or my head move, I do not experience that the sensory image of external world moves although its physical representation in brain moves. As if I were an external observed looking the projection of sensory data on canvas inside brain so that the motion of canvas does not matter.

   The standard argument is that the fact that brain constructs sensory representations about the motion of eyes, head, and body, is enough to generate the experience that the world is not moving. At least in TGD framework it is extremely difficult to understand how the sensory image of the external world in motion would not give rise to the experience that the world is in motion. I see the failure to realize this point as one of the fatal consequences of computationalism decoupled from physics: the ability to calculate what really happens does not simply give rise to the experience what really happens in the world of physics.

2. In computer the representation of the data on monitor, printing of data, and even various control actions such as the control of a robot reduces to sending of files to various kinds of receivers: the data is just expressed in various ways. In case of brain this means that that the processes leading to sensory experience or motor action differ only in their last steps. If the last step is not present, imagined motor action or sensory experience is in question.

This picture leads to a very general view about sensory representations and motor actions. In this picture also "features" reduce to MEs and this might be too strong an assumption.

1. Brain can be regarded as a collection of standard feature records represented by MEs. These features represent basic features of objects of perceptive field and primitive elements of motor actions. The set of feature MEs is pre-existing and realization of the sensory image or motor action only activates a subset of these MEs. In principle the locations of feature MEs could be more or less random which means extreme flexibility and ability to adapt to new situations.

2. The basic frequency associated with a particular sensory ME codes for the distance of the object of the perceptive field and the direction of ME codes for its direction. Sensory MEs are naturally organized in radial bundles, files, representing various directions for the objects of perceptive field at given distance. Feature MEs with nearly the same frequency generate magnetic quantum phase transitions waking up magnetic self in the desired distance on the magnetic sensory canvas and thus assign to the object of the perceptive field various kinds of attributes. This means nothing but frequency binding and leads to what might be called spectroscopy of consciousness: EEG acts like a spectrogram allowing to deduce information about the functional state of brain.

3. Support for the view that sensory input and motor activities are very similar comes from motor synesthesia in which person can represent the sensory input by dancing it! More concretely, the realization of intention as motor action reduces to generation of MEs propagating

along axons and generating desired membrane oscillation and nerve pulse patterns. There might be however a crucial difference also: motor action could be a geometric time reversal for the construction of a sensory representation and start from a rough sketch in the geometric now and develop quantum jump by quantum jump to a detailed plan in the geometric past. Time reversed dissipation would polish a sketch to a precise plan. Motor action would start from the motor organs and proceed to the level of brain.

4. Brain can be said to contain a collection of passive sensory and motor features which it activates selectively. This brings in mind computer game containing large number of extremely simple files, for instance sound files producing *Aaaargh* 's and *Auuuch* 's. The activation of ME record could mean ME is color rotated by coherent state of WCW photons to electromagnetic ME which in turn generates coherent state of photons and WCW photons acting as a control command; activates magnetic quantum phase transitions; induces supra currents; or something else. Similar mechanism works even at the level of DNA where genes can be coded to various kinds of control commands by activating the associated MEs.

What this view implies that there is no need to worry about how brain realizes ultimate sensory representations inside brain as neural activities. What remains to be understood how brain develops into a collection of the standard features; how brain recognizes the standard features from the incoming sensory input; how brain evaluates the distances and orientations and other data related to the objects of the perceptive field; how brain decomposes the perceptive field into objects; and many other things not listed here.

1. Feature recognition might be based on comparison circuits based on supra current circuits. Expected features would be represented as standard patterns of supra currents. When the pattern of supra currents associated with the sensory input and running parallel to those of expected sensory input is sufficiently near to the expected one, a resonant generation of Josephson currents occurs and gives rise to a recognition of the feature.

2. The positions and other geometric data about the objects of perceptive field are presumably estimated by an iterative process in which the sensory input from the virtual world construct of the perceptive field is compared with the real sensory input which could be sustained in the sensory circuits. Cortico-thalamic communications might relate to this iteration. The comparison takes place by comparison circuits and when the two inputs resemble each other sufficiently, a sensory output at the magnetic canvas is generated. The consistency of these two representations should be gained gradually through learning and by the requirement of consistency between different sensory inputs. Similar comparisons are involved with the development of motor action to yield the final action giving rise to the desired goal.

Brain as a motor and sensory organ of higher level selves

Certainly the most dramatic deviation from the standard neuroscience implied by this view is the prediction of an entire hierarchy of MEs and magnetic selves using brain as a generalized sensory and motor organ. We correspond to only one level in this hierarchy making decisions and controlling the behavior of our body in certain time scale. For instance, long term goals and socially acceptable behavior could be seen as forced by selves at the higher levels of the hierarchy. Drives could perhaps seen as activities forced by lower level selves in the hierarchy (amygdala and other parts of paleobrain contra neocortex). What makes this so dramatic is that the sizes of our magnetic bodies could be astrophysical (here one must of course be very cautious: the realization of long term memories however encourages strongly this view). For instance, EEG ME and corresponding magnetic flux tube structures would both have sizes measured using Earth size as a unit.

A possible mechanism for the motor control from our own sensory canvas as well as from the sensory canvases of higher level selves is provided by MEs. The classical gauge fields entering to brain and body would represent very high level commands, and might be transformed to endogenous sounds by piezoelectric effect identifiable as internal speech (internal speech could also correspond to p-adic MEs). This is only one possibility. The construction of the model of nerve pulse and EEG leads to quite general model for the interaction of MEs as bridges between two

space-time sheets characterized by different p-adic primes, and inducing a flow of charge between the two space-time sheets, inducing in turn a flow of em charge, and in case of cell membrane a change of membrane potential leading to the triggering of the nerve pulse. The reduction of the effective phase velocity of ME to the conduction velocity of nerve pulse or of some other excitation involves the shift of entire ME to future occurring in each quantum jump. If the shift occurs in the direction of geometric past, a super-luminal effective phase velocity results. Both cases might be involved, and would correspond naturally to propagating and standing EEG waves and to the space-like and time-like soliton sequences predicted by the model for Josephson junctions.

Boolean mind and memetic code

The original proposal for the realization of Boolean mind was in terms of sequences cognitive neutrino pairs. These can be interpreted as wormhole contacts carrying neutrino and antineutrino at the light-like wormhole throats and would thus represent boson like entities. In the framework of the standard model the proposal looks of course completely non-sensical. TGD however predicts the existence of long range classical electro-weak fields, and one might imagine that inside neutrino- whose Compton length corresponds to length scale of cell- intermediate gauge bosons behave like massless fields. Although neutrinos could be important, the time scale of corresponding CD - about 10^4 years - suggests that cognitive neutrinos might be important in much longer time scale than the.1 second time scale assignable to the memetic code.

The recent view about TGD allows a much more general view. Zero energy ontology allows to interpret the fermionic parts of zero energy states as quantum superpositions of Boolean statements of form $a \to b$ with a and b represented in terms of positive and negative energy parts of the zero energy state. If one has negentropic entanglement this kind of state has interpretation as an abstraction - a "law of physics" - representing as a quantum superposition various instances of a more general law.

The simplest situation corresponds to a CD having only single positive energy fermion and negative energy fermion at its light-like boundaries. The fermion number or spin or isospin of the fermion could represent qubit. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy, when combined with p-adic length scale hypothesis, led to a prediction of order .1 seconds for the duration of the "wake-up" period of sub-self corresponding to the codeword of the memetic code. Since the CD assignable to electron has time scale.1 seconds and the CD assignable to u and d quarks has time scale 1/1.28 milliseconds there is a temptation to proposed that the quark-like sub-CDs of electronic CD give to a realization of memetic code word as a sequence of 126 quark like sub-CDs. u and d quarks would be assigned to the magnetic flux tubes connecting DNA and the lipids of the cell membrane in the model of DNA as topological quantum computer. Clearly, beautiful connection between new elementary particle physics, genetic code, nerve pulse activity, DNA as topological quantum computer, logical thought, and the basic time scales of speech are suggestive.

This codeword consists of 126 bits represented by quarks such that the two possible magnetization directions correspond to the two values of Boolean statement. This implies that the duration of single bit should 1/1260 seconds. The duration of the nerve pulse is slightly longer than this which might mean that the full memetic code is realized as membrane oscillations rather than nerve pulse patterns. Both hearing and vision have .1 second time scale as a fundamental time scale and sounds are indeed coded to membrane oscillations in ear.

One can consider also the realization of genetic code with six bits of the codon represented by various scaled up versions of quark CD coming as size powers of 2. In this case the ordering of the bits would come from the size of sub-CD whereas in previous example temporal ordering would define the ordering. It is not however clear whether the powers of two can be realized physically.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20.000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-, 5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is.1 seconds. This could be seen as a support for the realization of some degenerate version of the memetic code as nerve pulse patterns.

The model for the memetic code encourages the following conclusions.

1. Membrane oscillation/nerve pulse patterns correspond to temporal sequences of magnetization directions for quarks representing yes/no Boolean statements.

2. The spin polarization of quarks is changed from the standard direction fixed by the spontaneous magnetization in the direction of axon by a ME moving parallel to axon, and inducing membrane oscillation or even a nerve pulse. Nerve pulses could correspond to a degenerate memetic code resulting by frequency coding for which the number of distinguishable code words is 64, and would thus naturally correspond to the reduction of the memetic code to the genetic code.

A very precise correspondence with the basic structures of the genetic code results. mRNA $\rightarrow$ protein translation corresponds to the translation of temporal sequences o magnetization directions to conscious cognitive experiences. Under very natural constraints the mapping to cognitive experiences is not one-to-one and the predicted degeneracy (2^{126} sequences correspond to $(2^{126}-1)/63$ cognitive experiences) can be understood.

One might think that the full memetic code is an evolutionary newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. The full memetic code could be realized for certain regions of brain only. These regions certainly include auditory pathways responsible for the comprehension of speech [K52, K96, K97, K100].

8.2.2 Brain, MEs, And Quantum Holograms

MEs represent a communication link in the control hierarchy formed by the magnetic body having onion like structure consisting of superconducting magnetic flux tube structures and flux sheets carrying dark matter, and space-time sheets carrying visible matter, and would be thus involved with the fundamental control operations. EEG MEs and they fractal variants could mediate classical signals and act as time-like entanglers assigning mental images to the points of the magnetic body with distance to the magnetic body being coded by the length of ME and the direction of the point by the direction of ME. Of course, also the deformations of magnetic flux tubes could mediate classical signals as counterparts of Alfven waves, and magnetic flux tubes are natural space-like entanglers - the model of DNA as topological quantum computer as an example about this function.

A possible vision about how MEs act as communication links between magnetic body and biological body

One can imagine large number of options for how the MEs are concretely involved with biology and I have done so. The recent view about TGD inspired biology allows to consider a highly unique model for how MEs could perform their role as a communication link.

1. The most plausible one is that MEs associate with the communications between biological body and magnetic body are generated by genome acting as a kind of relay station. For this option MEs attached to the flux tube going through the passive DNA strand would mediate sensory data from the cellular environment to the magnetic body. The sensory data from environment would arrive through magnetic flux tubes connecting biomolecules and lipids of cell membrane to the passive DNA strand analogous to sensory areas of cortex.

2. Magnetic body could induce nerve pulse activity as one particular form of gene expression by ME attached to the flux sheet going through the active DNA strand. Rapid signalling along flux tubes connecting DNA nucleotides and lipids would make this gene expression much faster than the ordinary one. Also nerve pulse activity would be communicated to the magnetic body from the lipid layers of neuron membrane via genome and magnetic body could generate it It is of course possible that also reflex like nerve pulse activity which does not involve magnetic body is present. From the time scale of the nerve pulse the size scale of the layer of the magnetic body involved with nerve pulse activity must correspond to quark CDs and would be about 10^{-5} meters. This fits nicely with the vision about DNA as topological quantum computer.

3. EEG MEs could be automatically generated as an outcome of nerve pulse activity, when ions drop to the flux quanta of magnetic field $B \simeq .2$ Gauss (Earth's magnetic field has nominal value.5 Gauss), and entangle mental images with the points of the sensory magnetic canvas.

This vision is of course not the only one that one can imagine. As discussed in [K97], genetic/memetic code could also have translation to control commands represented by pairs of MEs orthogonal to DNA strand/axon. In latter case orthogonal pairs of MEs must move along axon with the same velocity as nerve pulse pattern. Stationary EEG MEs translate the nerve pulse patterns to the patterns of light-like vacuum currents. TGD based model of EEG and nerve pulse [K97] predicts two kinds of EEG waves: moving and stationary, and it might be that they correspond to these two kinds of codings. The properties of moving/stationary EEG waves suggest their association to left/right brain hemisphere. Left brain might favour the coding of memetic codons to moving EEG ME pairs whereas right brain might favour the coding of nerve pulse patterns to stationary EEG MEs.

The notion of neural window

The notion of neural window, which was the original form of the hologram idea, allows to see information processing in brain from a slightly different point of view.

1. Massless extremals act as quantum antennae and generate coherent light and also provide waveguides along which BE condensed photons can propagate like Cooper pairs in super conductor. The photons radiated by the space-time sheets representing objects of the perceptive field and propagating along microtubules could provide neurons with a neuronal window. This picture would abstract just the bare essentials of the idea of holographic brain: small piece of hologram is like a small window yielding the same picture as larger window but in blurred form.

2. Massless extremals associated with neural activity could also represent or be accompanied by association sequences making possible geometric memories representing simulations of future and past. What is mysterious from the point of view of the standard neuroscience is that left part of the body sends sensory stimuli to the right brain hemisphere and vice versa. In TGD framework the mystery disappears: the maximization of the axonal lengths maximizes the durations of the association sequences and hence optimizes geometric memory.

3. Neuronal window idea would perhaps make it possible to realize the idea about iterative computation of conscious experiences involving guesses and comparisons. Neuronal windows would generate representations of various perceptive landscapes in disjoint parts of thalamus (sensory organs feed their input in separate parts of thalamus) and mental imagery would construct guesses for the cognitive representations for the objects of the external world realized in the cortex as mind-like space-time sheets radiating coherent light. The neural pathways from cortex to thalamus would provide thalamus with a neural window to cortex and comparison of the landscapes from cortex and sensory organ would be possible. Simple comparison circuits might be at work: neuron would fire when its neural windows to the cortex and sensory organ give sufficiently similar views.

4. One can sharpen the neuronal window idea by combining it with the music metaphor. This would mean that the massless extremal associated with a given axon would correspond to a Bose-Einstein condensate of photons (or WCW photons) with one particular frequency. This would mean vision at neuronal level (nothing to do with our vision realized in EEG frequency scale). Thus one can say that each neuronal window is either covered by curtains or provides a view to single sensory landscape at single frequency.

The experiments of Mark Germine

MEs could also serve as a communication link between living matter and magnetic bodies representing levels of collective consciousness responsible for the cultural aspects of our consciousness.

The experiments of Mark Germine [J129] provide evidence for the notion of ELF self and associated collective memory. What was studied was the evoked EEG response to a series of

random quantum stimuli, which consisted of series of identical stimuli with randomly located deviant stimulus. Two subject persons, A and B, were involved, the first one experienced stimuli as pictures in computer monitor, the second one as sounds. In case that A observed the differing stimulus 1 second before B, the evoked EEG response of B became incoherent. Since evoked stimulus was oscillation at EEG frequency of about 11 Hz in case that A had not observed the stimulus, one could understand the mechanism as a direct evidence for collective "ELF ME" at this frequency interacting with brains of both A and B. When ELF ME had already heard the stimulus once, it did not react to it in similar manner. Rather interestingly, 11 Hz corresponds to the 10.7 Hz cyclotron frequency associated with Fe_{++} ion in a magnetic field of.2 Gauss (Earth's magnetic field has nominal value of .5 Gauss). Ca^{++} cyclotron frequency in this field is equal to 15 Hz and would explain the effects of ELF fields on vertebrate brain occurring at harmonics of this frequency.

MEs and long term memory

MEs provide a mechanism of long term memory which differs from ordinary sensory perception only in that the ME giving rise to a geometric memory has much longer duration with respect to the geometric time than the ME giving rise to ordinary sensory perception. To remember classically is to look at a mirror located at a distance of light years. The ends and branching points of magnetic flux tubes are good candidates for the mirrors where MEs are reflected.

In TGD framework synaptic strengths code only cognitive representations and learned associations, not genuine information about events of the geometric past. Long term memory is coded in the classical em field and in coherent light generated by ME in hologram like manner. Any finite space-time region receiving the classical em field of coherent light generated by it gets hologram like picture containing info about entire geometric time interval spanned by ME. If vacuum current is localized to some restricted space-time region (it can be!), the holographic information is about this region and receiver anywhere along the ME gets more or less the same information since hologram is in question. ELF selves can perhaps control this localization. Note also that the light-likeness of the boundary of ME implies that ME selves have temporal extension defined by the length of ME.

The fact that memory is stored to the moment of geometric time at which event occurred explains why we know that mental image is memory. It is quite possible that MEs are involved with sensory perception, say vision and auditory experience, and make possible to develop time-like entanglement (possibly negentropic) with the sources of light as belonging to the external world. Geometric memory allows also understand identification experiences and transpersonal experiences in which person can experience events of the distant past not related to the personal history. Anticipation of future in turn could be also understood as particular kind of geometric memory, the MEs involved are now p-adic representation intentions, plans, and expectations. Later a more detailed model of long term memories will be developed.

8.2.3 Generalized Notions Of Sensory Experiencing And Motor Activity

The general view about brain is as a system moving of a fractal energy landscape of quantum spin glass containing valleys inside valleys inside... Brain is not only an on observer of the external world but also of its own position in the spin glass landscape. Brain is not only activator of ordinary motor programs but generates also movements in the spin glass energy landscape. Thus the general functional division sensory experience-motor action generalizes and provides completely new insights to the brain circuitry and functioning. For instance, one could perhaps understand why neural loops are bi-directional. The first loop provides sensory information about the position of brain region in its spin glass landscape and the second loop mediates the motor action: just like in case of the spinal chord.

The sensory experiences giving information about spin glass landscape can be interpreted as giving rise to a generalized sensory and emotional input. Emotions correspond to entropy gradients of various types for selves. A mental image with a positive/negative emotional color results from negentropy/entropy feed to sub-self. If the sign of entropy feed to mental images correlates with the entropy gradient of the system represented by sub-self, emotions become sensory qualia. Emotions provide perhaps the most important "Is it going well" type information about the state of brain

and body. Entropy gradients can be also used as an active control tool: sub-selves are rewarded by negentropy feed and punished by a entropy feed. Note that the generalized motor action inducing motion in the spin glass landscape is identifiable as emotional expression and generates entropy gradients and thus emotions.

8.2.4 The Paradigm Of Four-Dimensional Brain

Four-dimensionality of brain is crucial for the understanding long term memories as multitime experiences receiving contributions from several moments of geometric time. This identification makes it unnecessary to have any memory storage mechanisms. Rather, the activities of the memory circuits can be seen as increasing the probability that memory recall occurs. Reverberating memory circuits in which experience is echoed indeed do this by extending the deep memory valley in spin glass landscape to a long canyon in time direction. This increases the probability that mind-like space-time sheets enter in the region of four-dimensional spin glass landscape representing the memory. The deepness of the spin glass valley correlates with the emotionality of the memory. Childhood memories are especially emotional and therefore stable. Memories are result of creative action and memory circuit involving hippocampus seem to be active in carving out the art works representing geometric memories worth of remembering. TGD based approach solves the basic problems of the neural net approach resulting from the fact that the formation of new memories destroys old memories and from the fact that it is difficult to understand how the component of experience is known to be a memory.

Four-dimensional brain provides a completely new view about how gemeralized sensory experiences are generated, how generalized motor actions are planned and how memories are constructed. This process is like creating an artwork. *Four* -dimensional spin glass landscape representing a rough scetch is gradually refined by adding details and corrections in increasingly shorter time scales: this corresponds to neural activities of four-dimensional brain generating motion leading to the desired part of spin glass energy landscape. This picture is consistent with the observed $1/f$ noise and fractality of nerve pulse patterns. Absolutely essential is self-organization and related dissipation forcing the Darwinian selection leading to end product which is charicature rather than photo.

8.2.5 Music Metaphor And The Function Of The Nerve Pulses And EEG

Music metaphor allowing to see brain as a music instrument. gradually changed from a guiding principle to a prediction of TGD inspired theory. In case of brain the music played is EEG and ZEG spectra. EEG frequencies serve as resonant frequencies at which various quantum phase transitions occur resonantly. Various sensory qualia correlate with EEG frequencies and place coding and possibly also temporal coding by cyclotron frequency scale is possible. Stochastic resonance and pendulum metaphor, which are discussed in [K97], allow to understand the mechanisms for the transformation of EEG waves to nerve pulse patterns and vice versa.

The picture about brain as self-organizing system suggests that neurons are subject to strong selective pressures and specialize to produce highly specialized fixed components of our experience so that music metaphor holds true. If music metaphor holds true generally, the nerve pulses involving fast transmitters can be said to pick the strings of the sensory instrument represented by axons and spatio-temporal patterns of nerve pulses determine the overall pattern of the sensory experience. Nerve pulses inducing motor action in sensory landscape represent pushes and pulls in spin glass energy landscape. These pushes and pulls induce motion in the spin glass landscape and generate both neuronal and our emotions. It seems that simplest emotions with no association telling the cause or object of emotion, are determined by the nerve pulse pattern only.

This picture suggests for neurotransmitters two obvious basic functions: they mediate nerve pulses from presynaptic neuron to postsynaptic neuron and modify the properties of synapse and postsynaptic neuron. Fast neurotransmitters controlling directly ion channels are involved with mediation and the relevant time scale is one millisecond: no long term change of the postsynaptic neuron is involved. Sensory experiences and motor actions are mediated by direct neurotransmitters. Slow neurotransmitters involving second messanger action are involved with modulation of

the response of the postsynaptic neuron and the time scales can be of order minutes. In this case the properties of the postsynaptic neuron are changed.

Emotional reactions involve typically slow transmitters and the effect of them can be regarded as a generalized motor action inducing motion of neuron in the spin glass energy landscape of the neuron. The large information flows associated with neurotransmitters imply entropic gradients and thus also emotions. Some neurotransmitters such as serotonin and dopamine, which generate sensations of pleasure, should reduce entropy and thus fight against the second law of thermodynamics. This presumably occurs at the neuronal level and could be only represented at the level of the sensory selves, where some other mechanisms of the entropy reduction and generation could be at work. An interesting question relates to the warriors in the war against second law. Could glial cells play key role here as is suggested by the observations that depression (in which mental images becomes very entropic and emotional flatness and emptiness results) involves abnormally small amount of glial cells in forebrain and abnormally strong emotional reactions of amygdala.

One can see associations at neuronal level as formed by the pairs of input and output. Input corresponds to the sensory experiences associated with active presynaptic neurons and output to the activity in the axons. The postsynaptic receptors serve as sensory receptors and each neuron could be specialized to its own sensory modalities which are same for the entire sensory pathway. Alternatively, primary qualia are associated with the sensory receptors or sensory organs: this option provides very elegant understanding of what imagination and dreams are. Boolean axons give rise to "Boolean modality" representing thoughts. Typically sensory-Boolean associations are associated with the associative regions of brain and are realized as a fusion of mental images. The formation of an association corresponds to the fusion of space-time sheets representing pre- and post-synaptic neurons to single space-time sheet. The space-time sheets formed by the orbits of synaptic vesicles form the 4-dimensional flux tube. Fusion to single space-time sheet makes possible conscious association containing both inputs and output as a single experience. This picture also explains the time directedness of association. "Our" associations are superpositions of neuronal associations associated with various neuronal circuits.

8.2.6 Connection With The Functionalistic View About Brain

The basic counter argument against quantum theories of consciousness is that the so called classical theories of brain can quite well explain all the relevant aspects of brain functioning whereas quantum theories of consciousness seem to add very little if anything to this understanding. It seems that huge misunderstandings are involved on both camps.

The notion of self is fundamental for consciousness. For some reason the proponents of quantum consciousness (including me hitherto) have however failed to realize that they should perhaps try to formulate this notion as a quantum-physical concept. Indeed, "What is the quantum counterpart of self" was the bottleneck question in TGD approach and led to the final breakthrough.

Neuroscientists (and also many quantum physicists) in turn seem to have wrong view about what the term "classical" means. This wrong view reflects the wrong view about time and dissipation, which in TGD framework can be understood elegantly in terms of the subjective time development identified as a sequence of quantum jumps between quantum histories. It is of crucial importance that this development can occur only inside selves! Dissipation is the basic correlate of consciousness and consciousness is the basic prerequisite of "classicality" understood in the erratic manner. Thus, from the TGD point of view, Hodkin-Huxley equations have nothing to do with genuinely classical world. Rather, they model phenomenologically the development of neurons by quantum jumps between quantum histories. Quantum jumps (and dissipation) inside neurons is possible only because neurons act as sub-selves and dissipate. Our self can be regarded as a system making something like 10^{38} quantum jumps per second. This implies macrotemporality but this macrotemporality has absolutely nothing to do with classicality in the sense as it appears in the field equations of say General Relativity.

The notion of self as quantum self-organizing system justifies the use of cybernetic notions such as circuits, loops, feedback, feedforward, inhibition and excitation. The general neuroscientist's view about brain as a complex neuronal circuitry finds justification and one ends up with rather concrete identifications for what kind of conscious (not necessary conscious to us –) experiences are associated with various brain circuits. The essentially new elements are 4-dimensionality

of brain and realization of qualia and Boolean mind in terms of macroscopic quantum phases and these additional elements lead to genuine understanding of what happens in brain.

The randomness of the quantum jump is certainly a strong argument against quantum theories of consciousness and for me it took quite a long time to realize how serious this objection actually is. One can quite well claim that it leaves only one option: standard non-equilibrium thermodynamics in which dissipation in the presence of external energy feed selects the self-organization patterns. The possibility of negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) in the intersection of real and p-adic worlds is what changes the situation and removes the randomness of quantum jump so that unitary process U and its powers define an iterative self-organization process leading to generation of fractal structures and quantum computation like processes possible. This makes also possible conscious goal directed actions and the existence of genuine information rather than only lack of dis-information is what makes possible also learning at the fundamental level.

8.2.7 Brain As An Associative Net

Brain can be regarded as an associative net. At neural level association is a pair of incoming axons and outgoing axon: during synaptic transfer the space-time sheets of pre- and postsynaptic neuron fuse to form a larger space-time sheets and the corresponding conscious experience is association formed by the experiences determined by pre- and postsynaptic neurons. Neurons have their own sensory qualia associated with transmitter-receptor combinations: also neuronal seeing and hearing is possible. These qualia are probably not ours. From the point of view of our consciousness, nerve pulse patterns are most important and give rise to symbolic representations of sensory input. Frequency coding is involved and memetic code is reduced to genetic code. Membrane oscillations correspond to full memetic code and higher level cognition. Emission of at least slow neural transmitter gives rise to neuronal emotion. During synaptic firing the association pair becomes conscious. The most elegant option is that sensory qualia are at the level of primary sensory organs.

Also motor actions, in particular the transformation of Boolean statements to speech, can be regarded as associations of this kind. Motor action would be time reversal of sensory perception in appropriate time scales, and the motor actions initiated from some level higher than muscle cells correspond to motor imagination. Speech represents translation of memes to motor actions analogous to the translation of genes to proteins. For instance, logical reasoning develops as associations respecting basic rules of logic. This could explain why we are so poor in performing conscious logical deduction. On the other hand, rules of logic could be unconsciously inherited at the level of experience pairs from the physical world which obeys logic.

The most general possibility is that he output of a complex neuron is some function of the inputs. Music metaphor however suggests much simpler possibility: output is the same always and represented by nerve pulse pattern inducing postsynaptic qualia which depend on the receptor-transmitter combinations involved. This assumption has very strong consequences. Especially interesting are the sequences of associations associated with closed neural loops. The assumption that projections are topographically organized and that given axon is always in the same state mean that all closed circuits are reverbatory. Thus elementary single neuron association sequences associated with various brain circuits would be fixed and nerve pulse patterns should be determined the content of various conscious experiences constructed from these elementary experiences: the analogy with music would be very close. This would have quite strong consequences as far as the general structure of the brain circuits are considered.

1. Memories could quite correspond to asymptotic nerve pulse patterns reverberating in memory circuits. Nerve pulse patterns in closed would determine the content of memory and memories would result as fixed point patterns of self-organization. Very probably also microtubular representations of long term memories are important.

2. Motor plans would be represented by nerve pulse patterns reverberating in motor circuits and selected by self organization and realized as genuine motor actions only in case that the geometrically time reversed process starts from the muscle cells.

3. In case of Boolean thoughts reverberating circuits correspond to tautologies so that one can question the hypothesis that axons are permanently in the same state. Of course, there is no need to assume that thoughts correspond to closed circuits.

Negentropic space-like quantum entanglement between neurons, neuronal membranes and DNA strands, and DNA strands and magnetic body adds to this picture a further element necessary if one wants to speak about conscious brain able to learn. Synaptic transmission becomes the molecular counterpart of enlightenment experience in which neuronal sub-selves experience an expansion of consciousness. Learning as gradual evolution of synaptic strengths can be understood as the space-time correlate for the evolution defined by the unitary process U and its powers in the space of zero energy states representing M-matrices allowing an interpretation as abstractions describing the "laws of physics" as experienced by brain.

8.3 Quantum Tools For Biocontrol And -Coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps corresponds to quantum control. More precisely, the non-dissipative Josephson currents associated with weakly coupled super conductors would be the key element in coordination whereas resonant dissipative currents between weakly coupled super conductors would make possible quantum control.

This view allows to consider more detailed mechanisms. What is certainly needed in the coordination of the grown up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [I57]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in case of the vertebrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

8.3.1 Massless Extremals, Magnetic Flux Tubes, And Electrets

Massless extemals (MEs), magnetic flux tubes and magnetic body, and electrets define the basic new notions of TGD inspired theory of consciousness and quantum biology and it is good to introduce them first before discussing the quantum tools.

Massless extremals

The identification of mind-like space-time sheets as "massless extremals" (MEs) together with the notion of magnetic body leads to a very general vision about bio-consciousness and an explanation for the fact that the effects of ELF em fields on biomatter occur only for certain amplitude windows [J57] (these effects are discussed in detail in [K21, K22]

1. What MEs are?

Massless extremals (MEs) define a very general solution set of field equations associated with Kähler action [K55] and representing various gauge fields and gravitational [A32] [K85]. Being scale invariant, MEs come in all size scales. The geometry has axial symmetry in the sense that CP_2 coordinates are arbitrary functions of two variables constructed from Minkowski coordinates: light-like coordinate $t - z$ and arbitary function of the coordinates of the plane orthogonal to the z-axis defining the direction of propagation. The polarization of the electromagnetic field depends on the point of the plane but is temporally constant. MEs represent waves propagating with velocity of light in single direction so that there is no dispersion: preservation of the pulse shape makes MEs ideal for classical communications.

Electric and magnetic parts of various gauge fields are orthogonal to each other and to the direction of propagation. Classical gauge has as its source light-like vacuum current. The time dependence of the vacuum current is arbitrary, this is only possible by its light-likeness. This makes it possible to code all kinds of physical information to the time dependence of the vacuum current. MEs can have finite spatial size and in this case they are classical counterparts of virtual photons exchanged between charged particles and represent classical communication between material space-time sheets. MEs carry gravitational waves and various classical color and electroweak gauge fields propagating with light velocity.

MEs can also carry constant electric and magnetic fields but in this case the boundaries of ME contain necessarily the sources of this field. Light-like vacuum currents or elementary particles in massless phase could serve as sources MEs could also form double-sheeted structures with wormhole contacts serving as effective sources. It took quite a time to realize that the wormhole contacts have interpretation as gauge bosons and their super partners. Therefore quantum classical correspondence between classical fields and field quanta emerges automatically. In the case of single-sheeted MEs the interpretation is as a space-time correlate for fermion or a super-partner of fermion.

TGD allows the possibility that the two sheets have opposite time orientations and therefore also opposite classical energies. In zero energy ontology this might be always the case for the double sheeted MEs assigned to bosons and their super-partners. The opposite sign of the energy makes it possible to realize virtual particles as pairs of on mass shell particles of opposite sign of energy and this of utmost importance in the recent formulation of quantum TGD [K126, K13]. A natural guess would be that pairs of positive (negative) energy MEs correspond to massless on mass shell particles and pairs of MEs with opposite energies represent naturally virtual particles. The objection is that it is difficult to understand how the spin of on mass shell gauge boson could be represented in terms of fermion and anti-fermion spins associate with the throats of the wormhole contact. Massless Dirac equation seems to allow only longitudinal net polarization for the resulting gauge bosons. The resolution of the problem is based on Kähler-Dirac action which mixes M^4 chiralities. This mixing is also behind the massivation of elementary particles. Quite generally, the exchange of a double-sheeted ME between material space-time sheets can correspond to arbitrary value of the exchanged momentum. Also fermions and their superpartners are assumed to topological condense in in the interaction region and become temporarily double-sheeted but the other sheet need not be ME anymore.

This kind of structures are obvious candidates for cognitive structures since classical non-determinism is localized in a finite space-time volume and direct connection with the notion of virtual particle characterizing the non-determinism of quantum theories emerges. World should be full of MEs with all possible sizes since they have vanishing action: addition of ME with finite time duration yields new absolute minimum of Kähler action since Kähler action does not change in this operation. This suggests that MEs should be of crucial importance in TGD Universe.

2. Interaction of MEs with matter

The basic interaction mechanisms of MEs with superconducting flux tubes are magnetic induction generating supercurrents, the action of MEs as Josephson junctions between magnetic flux tubes, and magnetic quantum phase transitions stimulating radiation of coherent light which in turn BE-condenses on MEs and defines a feedback loop.

Many-sheeted ionic flow equilibrium defines the basic control mechanism with superconducting magnetic flux tubes taking the role of master and atomic space-time sheets taking the role of slave. Magnetic phase transitions could make possible chemical senses based on an endogenous NMR type spectroscopy. Also other than magnetic quantum transitions, such as changes of protein (in particular enzyme-) conformations, could occur coherently at superconducting space-time sheets, so that superconducting space-time sheets could allow an extremely effective high precision quantum control of the biochemistry. Magnetic quantum phase transitions make possible place coding by if the thickness of magnetic flux tube varies and this coding is crucial in the model for how various features are associated with objects of perceptive field at a given position.

MEs allow at their light-like boundaries representations of super conformal– and super-symplectic algebras with gigantic almost-degeneracies of states due to the almost-commutativity of Poincare algebra and super-symplectic algebra. Super-symplectic states define genuine quantum gravitational state functionals in the space of 3-surfaces, the "world of classical worlds", and

correspond to a higher abstraction level than ordinary quantum states defined in the "world" (space-time). This "world of classical worlds" aspect of quantum gravitational states explains why quantum gravity is crucial for consciousness.

3. Possible functions of MEs

MEs serve as receiving and sending quantum antennae [K85]. Light-like vacuum current generates coherent light. Also coherent gravitons are generated. MEs serve also as templates for BE condensation of photons and gravitons with momenta parallel to the light-like vacuum current. Linear structures, say DNA and microtubules, are natural but not the only candidates for structures accompanied by MEs. Since MEs are massless, they carry maximal possible momentum. This makes exchange of ME ideal mechanism for locomotion. The possibility of negative energy MEs is especially fascinating since it suggests "buy now, pay later" mechanism of energy production: perhaps living matter uses MEs to generate coherent motions [K89, K88].

Perhaps the most important function of MEs in living matter is communication and control. MEs can connect different parts of biological body at various levels. For instance, they can be attached to magnetic flux tubes. MEs would be also involved with the communications between magnetic body and biological body and EEG would represent one particular example of this kind of communication. MEs would be also ideal quantum entanglers in time direction and could serve as correlates for the mediators of negentropic quantum entanglement. The communication of sensory data to magnetic body could take via MEs and also the control actions of magnetic body could be mediated by MEs to biological body via MEs.

The original idea was that MEs could induce Josephson junctions and more general current carrying bridges between bio-structures. This is possible but magnetic flux tubes are more natural looking structures in this respect because they can be stationary.

1. Since the electric field of ME is orthogonal to the direction of the propagation of vacuum current, the Josephson junction with potential difference is formed most naturally when super conductors are joined by flux tubes to ME in the direction of the electric field associated with ME. MEs can in principle be arbitrary thin so that the thickness of Josephson junction can be much smaller than the dominating wavelength of ME.

2. The electric field of ME can contain also a constant component. This is possible if there is a vacuum charge density or ordinary elementary particles in a massless phase in the time scale considered (Higgs field vanishes) at the boundaries of ME generating the field. If this charge density is absent, ME is necessary double sheeted with the constant electric and magnetic fields created by the wormhole throats at the boundaries of ME serving as effective charges. Both single and double sheeted MEs could give rise to the Josephson junctions with a constant potential difference. The coding of the transversal potential difference associated with ME to Josephson frequency could be a fundamental information coding mechanism in living matter. ME can contain also oscillating electric field over Josephson junction at magnetic or some other transition frequency so that MEs are ideal for control purposes.

4. MEs and the interaction of the classical em fields with biomatter

MEs acting as Josephson junctions and containing oscillating em field at ELF frequency give rise to a harmonic perturbation inducing quantum jumps of the magnetic states of ions and explains the effect of ELF em fields on biomatter. Also the presence of the mysterious intensity windows [J74, J50] can be understood. Josephson current paradigm allows to understand this effect if radio frequency or microwave MEs associated with the external field act as Josephson junctions.

1. The external electric field oscillating with frequency ω (now radio frequency) defines slowly varying potential difference over Josephson junction of length d acting as Josephson junction provided that the condition

$$\omega \ll \omega_J(max) = ZeV = ZeEd$$

holds true. This gives

$$d \gg \frac{\omega}{ZeE} \quad .$$

For $E \sim .1$ V/m and $\omega \sim GHz$ which are typical values used in experiments [J57], this condition gives $d \gg 10^{-6}$ meters which is satisfied if Josephson junctions have size not smaller than cell length scale.

2. For fixed length of Josephson junction amplitude window results if the maximal Josephson frequency $\omega_J(max)$ is slightly above some transition frequency since in this case the stationary maxima and minima of amplitude lead to long lasting resonant excitation of quantum transitions. Denoting the relative width of the resonance by $\Delta\omega/\omega = P$, the ratio of the time spent in resonance at $\Omega_J(max)$ to the time spent off resonance at Ω_J is of order

$$\frac{t(max)}{t} \sim \sqrt{1 - \frac{\Omega_J^2}{\Omega_J^2(max)}} \times \frac{1}{\sqrt{P}} \quad .$$

For a narrow resonance width this ratio can be very large so that amplitude window results for fixed value of d.

3. Amplitude window results if there is a correlation between the thickness of ME and transversal electric field so that $\omega_J(max) = ZeEd(E)$ satisfies resonance condition for some values of E only, if any. In absence of this correlation Josephson junctions must have discrete spectrum of effective lengths for amplitude window to result.

4. For electric fields in the range .1 V/m the frequencies ω_J are above GHz for d larger than 3×10^{-5} meters and correspond to the frequencies for the conformational dynamics of proteins. There are obviously a large number of frequencies of this kind and several intensity windows. EM fields with these strengths should have special effects on living matter: it could be even that some kind of feature recognition process involving self-organization occurs at these field strengths. Note that the minimal size of Josephson junctions corresponds to the p-adic length scale $L(173) \simeq 1.6 \times 10^{-5}$ meters characterizing structures next to cells in the p-adic length scale hierarchy.

5. MEs and quantum holography

Sokolov and collaborators [B14] have proposed a model of quantum holographic teleportation in which the *classical* photocurrents from the sender to receiver take the role of a dynamical hologram. The connection with MEs is obvious.

1. MEs are carriers of classical light-like vacuum currents (one of the basic differences between TGD and Maxwell theory). This suggests that MEs could be interpreted also as *classical* holograms, which are *dynamical* as in quantum information theory. Light-like current would be like a dynamical (four-dimensional) diffraction grating. Light-like vacuum currents and vacuum Einstein tensor generate also coherent states of photons and gravitons and MEs serve as templates for the topological condensation of photons and gravitons to the Bose-Einstein condensate of photons collinear with ME. The Bose-Einstein condensation of collinear photons and their generalizations to colored WCW photons should affect the vacuum current by adding to the reference current what might be called evoked response. This condensation process could generate conscious experience and higher level qualia. Thus it would seem that MEs have a triple role as receiving and sending quantum antennae as well as classical holograms.

2. The proposal of [B14] generalizes to the case of MEs provided one can device a method of coding quantum states of photon field to the vacuum currents. The high efficiency photodetector matrix is in which each pixel gives rise to a photocurrent [B14], is replaced with ME or set of parallel MEs. The neural window hypothesis states that neuronal axons are accompanied by parallel MEs carrying information between sensory organs and brain and various parts of brain. This is only a less standard manner to say that ME represents classical

dynamical hologram. The possibility of local light-cone coordinates allows also MEs which define curved deformations of the simplest cylindrical MEs.

The concrete realization of holographic teleportation proposed in [B14] brings strongly in mind the architecture of the visual pathways. Thus one can wonder whether brain is performing internal teleportation of photonic quantum states with spike patterns being directly coded to the pattern of the vacuum currents flowing along MEs. If spike patterns code the dynamical hologram, a surprisingly close relationship with Pribram's views about hologrammic brain results. Nerve pulse patterns could be seen as specifying the necessary classical aspects of the quantum teleportation (in TGD classical physics is essential part of quantum physics, rather than some effective theory).

3. The light-like vacuum current at a 3-dimensional time-like section of ME as a function function of time defines a dynamical 3-dimensional hologram. This is consistent with the fact that our visual experience is two-dimensional: the information is always about outer boundaries of the objects of the perceptive field. The values of the vacuum current at a given point are non-deterministic which means that vacuum current is ideal for coding information. Classical data also propagate without dispersion with light velocity obeying the laws of geometric optics and MEs imply channelling so that MEs are tailor-made for classical information transfer.

4. Space-time sheets can have both positive and negative time orientations and the sign of energy depends on time orientation in TGD framework. This means that classical communication can occur both in the direction of the geometric future and past: this is essential for the classical model of the long term memories as a question commmunicated to the geometric past followed by answe. The dynamical nature of the holograms means that there is no need to combine 2- or 3-dimensional holograms associated with several moments of geometric time to single hologram. To remember is to perceive an object located in the geometric past. Of course, fractality might make possible temporally scaled down versions of the geometric past but the principle would remain the same.

5. Quantum hologram view suggests that the super-symplectic representations at the light-like boundaries of MEs characterized by gigantic almost-degeneracies are the real carriers of biological information. According to the general theory of qualia [K50] this information would become conscious since elementary qualia would correspond to quantum jumps for which increments of the quantum numbers correspond to the quantum numbers labelling super-symplectic generators in the complement of Cartan algebra. In this view superconducting magnetic flux tubes could perhaps be seen as intermediate level in the control circuitry controlled by MEs and controlling atomic level.

6. The model for visual qualia leads to the hypothesis that, besides ordinary photons, also colored WCW photons are possible and characterized by WCW Hamiltonian which is labelled by orbital spin quantum number J (in two-dimensional sense) and by color quantum numbers. The coherent states of these massless WCW photons would be responsible for visual colors and polarization sense and the corresponding holograms might be the crux of quantum control in living matter.

Magnetic flux tubes and the notion of magnetic body

The notion of magnetic/field body is one of the features of TGD inspired biology challenging the standard views about living matter.

1. Magnetic body has a fractal onion like structure with decreasing magnetic field strengths and the highest layers can have astrophysical sizes. Cyclotron wave length gives an estimate for the size of particular layer of magnetic body. $B = .2$ Gauss is the field strength associated with a particular layer of the magnetic body assignable to vertebrates and EEG. This value is not the same as the nominal value of the Earth's magnetic field equal to.5 Gauss. It is quite possible that the flux quanta of the magnetic body correspond to those of wormhole magnetic field and thus consist of two parallel flux quanta which have opposite time orientation. This is true for flux tubes assigned to DNA in the model of DNA as a topological quantum computer.

2. The layers of the magnetic body are characterized by the values of Planck constant and the matter at the flux quanta can be interpreted as macroscopically quantum coherent dark matter. This picture makes sense only if one accepts the generalization of the notion of embedding space.

3. In the case of wormhole magnetic fields it is natural to assign a definite temporal duration to the flux quanta and the time scales defined by EEG frequencies are natural. In particular, the inherent time scale.1 seconds assignable to electron as a duration of zero energy space-time sheet having positive and negative energy electron at its ends would correspond to 10 Hz cyclotron frequency for ordinary value of Planck constant. For larger values of Planck constants the time scale scales as $\hbar$. Quite generally, a connection between p-adic time scales of EEG and those of electron and lightest quarks is highly suggestive since light quarks play key role in the model of DNA as topological quantum computer.

4. TGD predicts also hierarchy of scaled variants of electro-weak and color physics so that ZXG, QXG, and GXG corresponding to Z^0 boson, W boson, and gluons appearing effectively as massless particles below some biologically relevant length scale suggest themselves. In this phase quarks and gluons are unconfined and electroweak symmetries are unbroken so that gluons, weak bosons, quarks and even neutrinos might be relevant to the understanding of living matter. In particular, long ranged entanglement in charge and color degrees of freedom becomes possible. For instance, TGD based model of atomic nucleus as nuclear string suggests that biologically important fermionic could be actually chemically equivalent bosons and form cyclotron Bose-Einstein condensates.

The list of possible functions of the magnetic body is rather impressive.

1. Magnetic body controls biological body and receives sensory data from it. Together with zero energy ontology and new view about time explains Libet's strange findings about time lapses of consciousness. EEG, or actually fractal hierarchy of EXGs assignable to various body parts makes possible communications to and control by the various layers of the magnetic body. WXG could induce charge density gradients by the exchange of W boson.

2. The flux sheets of the magnetic body traverse through DNA strands. The hierarchy of Planck constants and quantization of magnetic flux predicts that the flux sheets can have arbitrarily large width. This leads to the idea that there is hierarchy of genomes corresponding to ordinary genome, supergenome consisting of genomes of several cell nuclei arranged along flux sheet like lines of text, and hypergenomes involving genomes of several organisms arranged in a similar manner. The prediction is coherent gene expression at the level of organ, and even of population. In this picture the big jumps in evolution, in particular, the emergence of EEG, could be seen as the emergence of a new larger layer of magnetic body characterized by a larger value of Planck constant. For instance, this would allow to understand why the quantal effects of ELF em fields requiring so large value of Planck constant that cyclotron energies are above thermal energy at body temperature are observed for vertebrates only.

3. The strands of DNA could serve as intermediation structure analogous to brain hemispheres with active strand analogous to motor areas and passive strand analogous to sensory areas of cortex. The passive strand would serve as a relay station through which sensory data about the cellular environment is transferred to the magnetic body. Here MEs topologically condensed to the flux sheets could be in key role. The flux tubes connecting DNA nucleotides and cell membrane and various biomolecules would mediate the sensory data to the passive DNA strand.

4. Magnetic body makes possible information process in a way highly analogous to topological quantum computation. The model of DNA as topological quantum computer assumes that flux tubes of wormhole magnetic field connect DNA nucleotides with the lipids of the lipid layer of nuclear or cell membrane. The flux tubes would continue through the membrane and split during topological quantum computation. The time-like braiding of flux tubes makes possible topological quantum computation via time-like braiding and space-like braiding makes possible the representation of memories. The model allows general vision about the deeper meaning of the structure of cell and makes testable predictions about DNA.

One prediction is the coloring of braid strands realized by an association of quark or antiquark to nucleotide. Color and spin of quarks and antiquarks would thus correspond to the quantum numbers assignable to braid ends. Color isospin could replace ordinary spin as a representation of qubit and quarks would naturally give rise to qutrit, with third quark would have interpretation as unspecified truth value. Fractionization of these quantum numbers takes place which increases the number of degrees of freedom. This prediction would relate closely to the discovery of topologist Barbara Shipman that the model for the honeybee dance suggests that quarks are in some manner involved with cognition. Also microtubules associated with axons connected to a space-time sheet outside axonal membrane via lipids could be involved with topological quantum computation and actually define an analog of a higher level programming language.

5. The strange findings about the behavior of cell membrane, in particular the finding that metabolic deprivation does not lead to the death of cell, the discovery that ionic currents through the cell membrane are quantal, and that these currents are essentially similar than those through an artificial membrane, suggest that the ionic currents are dark ionic Josephson currents along magnetic flux tubes. A high percent of biological ions would be dark and ionic channels and pumps would be responsible only for the control of the flow of ordinary ions through cell membrane.

6. These findings together with the discovery that also nerve pulse seems to involve only low dissipation lead to a model of nerve pulse in which dark ionic currents automatically return back as Josephson currents without any need for pumping. This does not exclude the possibility that ionic channels might be involved with the generation of nerve pulse so that the original view about quantal currents as controllers of the generation of nerve pulse would be turned upside down. Nerve pulse would result as a perturbation of kHz soliton sequence mathematically equivalent to a situation in which a sequence of gravitational penduli rotates with constant phase difference between neighbors except for one pendulum which oscillates and oscillation moves along the sequence with the same velocity as the kHz wave. The oscillation would be induced by a "kick" for which one can imagine several mechanisms.

   The model explains features of nerve pulse not explained by Hodkin-Huxley model. These include the mechanical changes associated with axon during nerve pulse, the outwards force generated by nerve pulse with a correct prediction for its order of magnitude, the adiabatic character of nerve pulse, and the small rise of temperature of membrane during pulse followed by a reduction slightly below the original temperature.

   The model predicts that the time taken to travel along any axon is a multiple of time dictated by the resting potential so that synchronization is an automatic prediction. Not only kHz waves but also a fractal hierarchy of EEG (and EXG) waves are induced as Josephson radiation by voltage waves along axons and microtubules and by standing waves assignable to neuronal (cell) soma. The value of Planck constant involved with flux tubes determines the frequency scale of EXG so that a fractal hierarchy results.

   The model forces to challenge the existing interpretation of nerve pulse patterns and the function of neural transmitters. Neural transmitters need not represent actual/only) signal but could be more analogous to links in quantum web. The transmitter would coding the address of the receiver, which could be gene inside neuronal nucleus. Nerve pulses would build a connection line between sender and receiver of nerve pulse along which actual signals would propagate. Also quantum entanglement between receiver and sender can be considered.

7. Acupuncture points, meridians, and Chi are key notions of Eastern medicine and find a natural identification in terms of magnetic body lacking from the western medicine. Also a connection with well established notions of DC currents and potentials discovered by Becker and with TGD based view about universal metabolic currencies as differences of zero point energies for pairs of space-time sheets with different p-adic length scale emerges.

   Chi would correspond to these fundamental metabolic energy quanta to which ordinary chemically stored metabolic energy would be transformed. Meridians would most naturally correspond to flux tubes with large $\hbar$ along which dark supra currents flow without dissipation and transfer the metabolic energy between distant cells. Acupuncture points would

correspond to points between which metabolic energy is transferred and their high conductivity and semiconductor like behavior would conform with the interpretation in terms of metabolic energy storages. The energy gained in the potential difference between the points would help to kick the charge carrier to a smaller space-time sheet. It is possible that the main contribution to the of charge at magnetic flux tube is magnetic energy and slightly below the metabolic energy quantum and that the voltage difference gives only the lacking small energy increment making the transfer possible. Also direct kicking of charge carriers to smaller space-time sheets by photons is possible and the observed action spectrum for IR and red photons corresponds to the predicted increments of zero point kinetic energies.

8. Magnetic flux tubes could also play key role in bio-catalysis and explain the magic ability of biomolecules to find each other. The model of DNA as topological quantum computer [K3] suggest that not only DNA and its conjugate but also some amino-acid sequences acting as catalysts could be connected to DNA and other amino-acids sequences or more general biomolecules by flux tubes acting as colored braid strands. The shortening of the flux tubes in a phase transition reducing the value of Planck constant would make possible extremely selective mechanisms of catalysis allowing precisely defined locations of reacting molecules to attach to each other. With recently discovered mechanism for programming sequences of biochemical reactions this would make possible to understand the miraculous looking feats of bio-catalysis.

9. The ability to construct "stories", temporally scaled down or possible also scaled up representations about the dynamical processes of external world, might be one of the key aspects of intelligence. There is direct empirical evidence for this activity in hippocampus. The phase transitions reducing or increasing the value of Planck constant would indeed allow to achieve this by scaling the time duration of the zero energy space-time sheets providing cognitive representations.

The list of nice things made possible by the magnetic body is impressive and one can ask whether there is any experimental support for this notion. The findings of Peter Gariaev and collaborators give evidence for the representation of DNA sequences based on the coding of nucleotide to a rotation angle of the polarization direction as photon travels through the flux tube and for the decoding of this representation to gene activation [I29], for the transformation of laser light to light at various radio-wave frequencies having interpretation in terms of phase transitions increasing $\hbar$ [I28, I3], and even for the possibility to photograph magnetic flux tubes containing dark matter by using ordinary light in UV-IR range scattered from DNA [K129] , [I41].

Electrets

Electrets are by definition spontaneously electrically polarized structures. Living matter is full of electrets. Practically all important biomolecules are electrets. Cell membrane is an electret and liquid crystal. Microtubules are electrets as are also various larger structures such as collagens.

The dipolar nature of bio-molecules and induced polarization are basis prerequisites for the formation of gels. Ling raises the cohesion between water and protein molecules caused by electric dipole forces as a fundamental principle and calls this principle association-induction hypothesis [I42]. This cohesion gives rise to liquid [F2] [D3] like structure of water implying among other things layered structures and internal electric fields orthogonal to the plane of the layers [I58, I45, I42] . For instance, cell membranes can be understood as resulting from the self-organization of liquid crystals [K23]. The fundamental importance of electret nature of biomatter was also realized by Fröhlich [I44] and led him to suggest that macroscopic quantum phases of electric dipoles might be possible. This concept, which is in central role in many theories of quantum consciousness, has not been established empirically.

In TGD framework electrets could serve as sensory receptors. In capacitor model of sensory qualia the flow of quantum numbers between the plates of this kind of capacitor would give rise to sensory qualia. The process would be self-organization process with energy flow replaced with a more general flow of quantum numbers.

8.3.2 Homeostasis As Many-Sheeted Ionic Flow Equilibrium?

The experimental work of Ling, Sachs and Qin [I42, I64] and other pioneers [I32, I26] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! this challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why it is so difficult to get the water out of it?

These puzzling observations can be understood if the homeostasis of cell and its exterior is regarded as an ionic flow equilibrium in the many-sheeted space-time. Ionic super currents from superconducting controlling space-time sheets flow to controlled atomic space-time sheets and back. Currents are of course ohmic at the atomic space-time sheets. One can understand how extremely small ionic densities and super currents at cellular space-time sheets can control ionic currents and much higher ionic densities at atomic space-time sheets. Immense savings in metabolic energy are achieved if the ohmic currents at the atomic space-time sheets flow through the cell membrane region containing the strong electric field along superconducting cell membrane space-time sheet (rather than atomic space-time sheets) as a non-dissipative supra current. This clever energy saving trick makes also the notion of ionic channels obsolete for weak ionic currents at least.

Superconducting space-time sheets contain a plan of the biosystem coded to ion densities and magnetic quantum numbers characterizing the super currents. Biocontrol by em fields affects these super currents and one can understand the effects of ELF em fields on biosystem in this framework. The model relies crucially on the liquid crystal property of biomatter (hamburger mystery!) making possible ohmic current circuitry at the atomic space-time sheets as a part of the many-sheeted control circuitry. There is a considerable evidence for this current circuitry, Becker is one of the pioneers in the field [J45]: among other things the circuitry could explain how acupuncture works.

One can add several new elements to this picture.

1. The phase transition changing the value of Planck constant induces a change of the length of the magnetic flux tube scaling as $\hbar$. Therefore the reduction of the Planck constant for a flux tube connecting two biomolecules can bring them near to each other. This suggests that biomolecules form a kind of Indra's net and that these phase transitions together with the reconnection of magnetic flux tubes changing the topology of this net are the basic mechanisms explaining the miracles of bio-catalysis and induce various phases transitions typically accompanying contractions and expansions of the matter in the cell interior. One could actually see the phase transitions of living matter as being induced from the motor actions of the magnetic body.

2. Zero energy ontology predict is that the CDs assignable to elementary particles have temporal size scale given by the secondary p-adic time scale. For electron and quarks (assigned to the ends of magnetic flux tubes in the model of topological quantum computation) these time scales are 100 milliseconds and 1 millisecond respectively and identifiable as fundamental biological time scales. A deep connection between biology and elementary particle physics seems to exist.

3. Negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) transforms the bio-molecules from dead matter to conscious entities so that the nano-scaled molecules are just what they seem to be in light of experimental nano-biology: intelligent conscious entities having intentions and plans and willing and able to collaborate.

8.3.3 Quantum ModelFor Pattern Recognition

The general neuroscience based model for recognition relies one learning made possible by synaptic plasticity. It is expected to have a TGD based quantum variant [K105]. The model of pattern

recognition to be discussed below relies on supra currents and Josephson currents assignable to cell membrane and various other binary structures, and could define a building brick of the general model. For instance, the model of nerve pulse relies on Josephson currents [K97].

Time translation invariant pattern recognition circuit can be realized by using two coupled super conductors. The first superconductor contains the reference supra current and second superconductor contains the supra current determined by the sensory input. Supra currents are assumed to have same spatially and temporally constant intensity. If the supra currents have spatially constant phase difference, also Josephson currents are in the same phase and sum up to a large current facilitating synchronous firing. The temporal phase difference of supra currents does not matter since it affects only the overall phase of the Josephson current. Therefore patterns differing by time translations are treated as equivalent. Quite generally, the requirement of time translational invariance, favours the coding of the sensory qualia to transition frequencies.

The destructive interference of supra currents provides an tool of pattern cognition in situations when the precise timing is important. The pattern to be recognized can be represented as a reference current pattern in some neuronal circuit. Input pattern determined by sensory input in turn is represented by supra current interfering with the reference current. If the interference is destructive, synchronoous generation of nerve pulses in the circuit occurs and leads to a conscious pattern recognition. Obviously the loss of time translation invariance makes this mechanism undesirable in the situations in which the precise timing of the sensory input does not matter. One can however imagine situations when timing is important: for instance, the deduction of the direction of the object of the auditory field from the phase difference associated with signals entering into right and left ears could correspond to this kind of situation.

In both cases one can worry about the regeneration of reference currents. The paradigm of four-dimensional quantum brain suggests that sensory input leads by self-organization to a stationary spatial patterns of supercurrents and this process depends only very mildly on initial values. Thus self-organization would generate automatically pattern recognizers.

8.3.4 General Mechanism Making Possible Biological Clocks And Alarm Clocks, Comparison Circuits And Novelty Detectors

Weakly coupled super conductors and auantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two superconductors provides a way to realize a biological clock. Josephson current can be written in the form [D13]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{8.3.1}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of superconductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the super conductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [D13]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s \Delta}{d} \ . \tag{8.3.2}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the super conductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two super conductors. By the previous arguments the density of the Cooper pairs is an ideal tool of biocontrol and a rhythmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \tag{8.3.3}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both super conductors carry parallel supra currents or whether only second super conductor carries supra current.

1. If both super conductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second super conductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector "wakes-up" into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second super conductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the instability of the structure. When the supra current in the circuit dissipates below a critical value, instability emerges. This provides a general mechanism of biological alarm clock.

   Assume that the second super conductor carriers a supra current. As the time passes the reference current dissipates by phase slippages [D12, D13]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to a non-stability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The instability itself can regenerate the reference current to the clock. If the alarm clock actually "wakes-up" the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second super conductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is non-vanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

8.4 Sensory Representations

In this section concrete model for the sensory representations is developed on basis of the general vision already outlined. What is new as compared to the earlier vision is the role of zero energy ontology and CDs as embedding space correlates for sub-selves.

8.4.1 Where Me Is?

The motion of eye or head does not induce the sensation that the world is moving although the sensory image moves around the cortex. Rather, brain acts like a (possibly moving) canvas at which the sensory input is projected and monitored by an external observer. This very simple observation is a strong objection against the idea that the ultimate sensory representations reside inside brain, and leads to the view that the magnetic flux tube structures associated with the primary and secondary sensory organs define a hierarchy of sensory representations outside brain. The question is where these representations are realized and one can imagine two alternatives.

Are higher level sensory representations realized at the magnetic body?

Magnetic flux tube structures would serve as the sensory canvas to which sensory images are projected from brain and possibly sensory organs and even neurons. MEs serve as projectors and place coding by magnetic transition frequency associated with ME wakes-up sensory sub-selves at various positions of magnetic flux tubes having varying thickness and associate thus various sensory qualia and even more complex attributes to the objects of the perceptive field.

This view can be defended also by the neat separation of the information processing from its representation occurring also in case of the ordinary computers as well as by Uncertainty Principle for EEG waves. If primary qualia are at the level of primary sensory organs and entangled with cortex, one can understand why imagination, which involves much the same neural processes as perception, does not give rise to sensory qualia.

EEG MEs correspond to our level in this hierarchy of projections. The simplest possibility is that the sizes of these sensory selves are of the order of EEG ME sizes ($L(EEG) = c/f(EEG)$) and thus can be of the order of Earth size! Thus the ultimate sensory representations are magnetic gigants in TGD and diametrical opposites of the neurophysiological dwarfs of standard neuroscience populating also TGD brain.

The known strange effects of large scale perturbations of Earth's magnetic field on consciousness (say, statistics about the effects of magnetic storms in mental state and tectonic activity inducing UFO experiences) provide a rich palette of anomalies supporting this view. The conservation of magnetic flux makes the magnetic flux tube structures of Earth size (or even larger) very stable: thus physical death presumably means only that our magnetic body redirects its attention to something more interesting. Near death experiences discussed in more detail in [K23] indeed support this view.

Two requirements must be satisfied for this scenario to work.

1. The projectors to the magnetic body cannot rotate when head rotates so that a fixed direction of perceptive field corresponds to the fixed direct at the magnetic body. This can be achieved if the projectors are magnetic structures with a fixed orientation with respect to the Earth's magnetic field.

2. Retinae must act like windows for this scenario to work. This means that the primary qualia mental images (sub-selves) at retina are entangled with the corresponding cognitive mental images at cortex, keep their attention directed to that part of the perceptive field that they represent as the direction of the gaze changes. Perhaps the retinal mental images are stationary with respect to the liquid phase not comoving with the eye ball. The retina-external world entanglement would also keep retinal attention fixed. This applies also to the saccadic motion, and the loss of visual consciousness when saccadic motion is prevented, could mean simply that retinal mental images lose consciousness when their motor activity with respect to eye ball is prevented: just like we lose our consciousness if not allowed to move!

Could the sensory representations about position of the object be realized in the perceptive field?

There is also a more conservative realization of sensory representations (if I had invented it first, I would probably have never considered the representations at the magnetic body!).

1. If retina-external world entanglement is present as suggested by the argument above, sensory canvas for the primary sensory representations could be provided by the perceptive field itself. The series of quantum entanglements from sensory organs to brain to magnetic body would define the entire sensory-cognitive representation involving also the cognitive aspects. There would be no absolute need for topographic representations at the magnetic body although the appearance of a hierarchy of topographic representations in brain suggest that topographic representations continues. The magnetic representations could however be more abstract higher level representations: somewhat like the manual of an electronic instrument as compared with the photograph of the instrument.

2. One can also imagine that the magnetic body is not involved at all since also in this case the sensory representation would be organized topographically by the entanglement with the objects of the perceptive field. Now brain would entangle to the objects of the external world cognitive mental images. One could say, that me is the entire perceptive field plus physical body. In this case however the function of EEG remains unclear. Also the model of long term memories also suggests that EEG MEs in length scales of light life-time are involved.

Of course, neither of these views about human consciousness is new. In particular, the first one is shared by all spiritual practices. What is new is the concrete physical model realizing this view physically. Here I cannot avoid the temptation to fall for a moment in manifesto mood: what makes me sad is that the materialistic neuroscience so strongly advocates the brain centered view about consciousness with physical death meaning the absolute end. The belief in this world view deprives life from its meaning and reduces it to a vulgar fight for survival or, depending on one's tastes, to a pre-determined performance of a robot. It is also deeply frustrating that the stubborn belief on materialism prevails despite the fact that this dogma contains so many internal contradictions that it would not even deserve to be called world view.

8.4.2 Concrete Realization Of Sensory Representations

The vision about the concrete realization of the sensory representations conscious-to-us has developed rather slowly. A good measure for the uncertainties involved is that the sizes of the primary sensory organs and EEG ME lengths $L(EEG) = c/f$ have represented the two extreme options for the size scale of the sensory representations conscious-to-us. It seems however more and more clear that TGD forces a dramatic deviation from the prevailing view about cortex as the seat of the ultimate sensory representations. The sensory representations conscious-to-us are outside the body and that the relevant length scale could be most naturally the length scale $L(EEG) = c/f$ defined by the EEG frequencies. In case of long term memories much longer length scales in the range of the light lifetime are necessarily involved and the realization of long term memories forces to conclude that human sensory consciousness is a cosmic phenomenon.

Qualia as quantum phase transitions and as discharges of quantum capacitor

In TGD framework the meaning of the primary quale is associated with the mental images created by the self-organization process. If the quale corresponds to an average increment of quantum numbers or zero modes in a long quantum jump sequence, the quantum jump with same increment must occur repeatedly. One can imagine at least two mechanism inducing qualia.

1. Quantum phase transition produce qualia

Quantum phase transition in which single particle transition occurs coherently for some macroscopic quantum phase produces qualia defined by the increments of quantum numbers in the transition. Quantum phase transition could be induced by the transition frequency: quantum phase transition leading to the generation of new kind of macroscopic quantum phase is in question. Transition frequencies themselves as such serve as symbols initiating this process, much like subprogram call initiates subprogram. They act like the name of dog: when dog hears its own name, dramatic self-organization process is initiated.

2. Discharge of quantum capacitor produces primary qualia

Quantum capacitor discharge provides an attractive model for how the primary sensory qualia at the level of sensory receptors emerge.

The flow of particles with fixed quantum numbers between "electrodes" of what might be called a quantum capacitor induces qualia defined by the quantum numbers of the particles involved. The "electrodes" carry opposite net quantum numbers. Second electrode corresponds to the sub-self defining the quale mental image. Obviously cell interior and exterior are excellent candidates for the electrodes of the quantum capacitor. Also neuron and postsynaptic neuron. In fact, living matter is full of electrets defining capacitor like structures. The model of sensory receptor as a quantum capacitor will be discussed later. The model applies to various chemical qualia and also to color vision and predicts that also cells should have senses. Ordinary cells would sense only the nearby chemical environment whereas neurons would experience via synapses also representations of external world chemically: at our level of conscious experience these representations could give rise to emotions. The strange behavior of ionic currents leads to the view that even ionic channels and pumps are actually ionic and voltage receptors.

3. Higher level qualia at the level of brain and magnetic body

Higher level sensory qualia at the level of magnetic body are expected to relate to the geometric aspects of sensory input such as shape or size of objects of the perceptive field.

The capacitor model in principle generalizes to the level of brain and magnetic body. What is needed is a phase transition transforming one Bose-Einstein condensate type phase with definite quantum numbers to a second one. Music metaphor suggests that only the ratios of transition frequency to, say, cyclotron frequency can code for qualia. Only the ratios of Larmor and cyclotron frequencies and frequencies characterizing CDs and the intensities of the Fourier components for various harmonics can affect self-organization process. Furthermore, quale together with its emotional aspects depend on a simultaneous occurrence of several quantum phase transitions induced by the EEG pattern containing several magnetic transition frequencies. Different values of Planck constant could define a hierarchy of representations.

Zero energy ontology and geometric qualia

Zero energy ontology is a new element of quantum TGD and states that all physical states have vanishing net values of conserved quantum numbers. Zero energy ontology provides a firm justification for the notion of negative energy signals consisting of (say) phase conjugate photons propagating to the geometric past. These negative energy signals are crucial element of the time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) playing a central role in the general mechanism for intentional action, remote metabolism, and long term memory.

Causal diamond (CD) defined roughly as the intersection of future and past directed light-cones serves as an embedding space correlate for zero energy state. Space-time sheets representing zero energy states are inside CD and the future *resp.* past boundaries of CD carry positive *resp.* negative energy parts of zero energy states. What is important from the point of view of consciousness theory is that CDs serve as embedding space correlates of selves and sub-CDs as those for sub-selves (mental images). Sub-CDs are very much analogous to music instruments in the sense that the frequencies which come as harmonics of the fundamental frequency defined by the proper time distance between tips of CD (coming as powers of two) resonate with the geometry of CD and put it to "ring". Sub-CDs could be seen as an analog of radio receiver as far as sensory representations are considered and sending antenna as far as the motor control of biological body is involved. This allows to communicate sensory data from brain to sub-CDs at magnetic body CD in a highly selective manner. MEs (massless extremals) mediating the communications between magnetic body and biological body are also very much like strings of a music instrument. This picture generalize the earlier music metaphor applied to axonal pathways.

A more precise definition of CD is as the Cartesian product of the intersection of future and past directed light-cone with CP_2. The hierarchy of Planck constants brings in additional structure. There is identification of preferred $M^2 \subset M^4$ defining a preferred time direction (rest system/quantization axis for energy) and spin quantization axis. The preferred geodesically trivial sphere $S^2 \subset CP_2$ and the selection of point assigned with CP_2 at the future and past boundaries of CD gives rise to a selection of quantization axes of color isospin and hyper charge.

Sensory representations are a key element of the consciousness theory and the moduli space of CDs charactering what kind of CDs are possible brings in new representational resources.

1. The moduli space of sub-CDs involves the position for the either tip of the sub-CD and the naïve expectation is that this position could code for the position of the perceptive field. If so the representation would be very concrete and since the size of CD is already for electron with.1 lightseconds the representations is realized automatically in astrophysical scale.

2. The moduli space of sub-CDs assignable to the mental images with another tip fixed could represent geometric qualia. Without any further restrictions this space corresponds to proper time constant hyperboloid of future light cone. The values of time parameter come in powers of two. One can however quite well consider the possibility that only a discrete lattice of the hyperboloid is realized.

3. A Lorentz boost for sub-CD induces scaling of frequency and scaling of the object in the direction of the boost. Therefore boost coded to the fundamental frequency of CD could code for various shapes of a figure obtained by scaling. Boost of sub$-CD$ leaving the other tip of sub$-CD$ invariant could also code for the velocity of object.

4. The moduli space of CDs contains also the choice of quantization axes of energy (preferred rest system) and spin as well as the choice of quantization axes of color isospin and hypercharge identifiable as flag manifold $SU(3)/U(1) \times U(1)$. Mathematician Barbara Shipman has proposed that this flag manifold is involved with the representation of geometric data in honeybee dance [A10] and I have proposed a model for what might be involved [K50].

The moduli space of CDs is thus highly relevant for the representation of the geometric data associated with the objects of the perceptive field and the this data would be communicated using MEs with harmonics of the fundamental frequency of sub-CD so that sub-CD would act like radio receiver. This includes the position of the real object codable to the position of sub-CDs at magnetic body, the velocity of the object of the perceptive field codable to the Lorentz boost changing the shape of sub-CD and represented as scaling of the frequency assigned with the stationary object. Also the shape of perceptive field would represent this kind of geometric data. This picture supports the interpretation of sub-CDs as spotlights of attention giving information about many-sheeted space-time inside the regions defined by the sub-CDs. It would seem that sub-CDs are dynamical objects created, destroyed, and shifted in quantum jumps. This picture is also consistent with the explanation for the arrow of psychological time based on zero energy ontology [K133].

Place coding by cyclotron frequency scale

One of the basic aspects of conscious information processing is concrete geometric representation of even very abstract concepts and information as imagined objects of perceptive field. The observations about geometric qualia suggest to magnetic transition frequencies code for positions of sub-selves represented by magnetic flux tubes. Particular EEG frequency wakes-up particular sub-self in a specific position and orientation and gives rise to a "feeling of existence" in some part of the virtual world of brain of magnetic body. The sensation of motion of object of perceptive field cold result automatically when sub-self moves inside self. Alternatively, Lorentz boost for the sub-CD could represent the velocity of motion of object represented by it. For instance, one could represent coordinate curves as magnetic flux tubes with varying thickness: by magnetic flux conservation thickness codes the coordinate to magnetic field strength to cyclotron frequency.

Cortex as a collection of attributes assigned to the objects of perceptive field represented at magnetic canvas

One of the basic problems related to the understanding of the information processing in brain is how various attributes are assigned to the object of the perceptive field. What is known that brain recognizes features and these features/attributes seem to be located in a more or less random looking manner all around cortex. This brings strongly in mind random access memory or

computer game in which various little program modules realized as records in random access memory represent collection of standard sound effects. A strong hint is the empirical evidence for the view that the resonance frequencies associated with the autocorrelation functions of nerve pulse patterns, and thus presumably also coding EEG frequencies, are same for the features associated with a given object of the perceptive field. The challenge is to understand how the picture based on a collection of MEs projecting features to the magnetic canvas could allow to understand what is behind these observations.

The view about MEs associating attributes to the object of the perceptive field by waking up sub-selves in the magnetic flux tube structure serving as a sensory canvas suggests an elegant interpretation for these facts.

1. Cortex can be regarded as a collection of regions specialized to represent various kinds of standard features. Features need not be simple qualia: arbitrary complicated collections of them, such as familiar faces are also possible features. Even entire dynamical processes (selves) could serve as features.

2. Basic feature-regions are like computer records. The information about the position of the feature in perceptive field could be represented by the entanglement of the feature with a particular part of, say, primary sensory area representing a point of the perceptive sphere.

3. The direction of the point of the perceptive field could be coded basically by the direction of the magnetic flux tube emerging from the particular position of the sensory area providing map for solid angles of the perceptive field. The mechanism would be based on resonance with Alfven waves associated with the magnetic flux tubes of personal magnetic body amplifying MEs in the direction of magnetic flux tubes. The length (fundamental frequency) of ME would code for the distance of the point of the perceptive field to the distance of the point of the sensory magnetic canvas. Frequency coding could be achieved by varying the local value of the magnetic field responsible for generating the cyclotron frequency. This coding could be either dynamical or static in which case distance could be most naturally coded to linear structures, most naturally in direction orthogonal to the cortical surface.

4. Features would be basically associated with sensory organs, various neural pathways and brain areas and coded partially by nerve pulse patterns. Features could be practically all kinds of sub-selves generated by brain activity. Primary qualia could be realized at the level of sensory receptors if entire sensory pathways entangle with the magnetic body.

5. Projector MEs would be orthogonal to the sensory area where they emanate. The topographic mapping of the perceptive field to sensory areas would guarantee that sensory images would remain stationary under rotations of head: although sensory magnetic sensory canvas would move the image projected to it would be stationary. MEs and magnetic flux tubes must be parallel if Alfven wave resonance is involved. In this manner the sensory experiences can be private and the contribution from the other brains remains negligible. Note however that people in very intimate contact could gradually share there magnetic sensory canvases: the anecdotes about gradually developing telepathic communications between the teachers and students of the meditative practices could involve this kind of sharing of computer screen between several users.

6. In this coding EEG MES would entangle with essentially all information about the perceptive field and the spectroscopy of consciousness to be discussed below would be realized in rather strong sense.

7. The model becomes even more predictive if it is assumed that DNA double strands act as a relay station. This encourages to think that also the decomposition of brain to motor and sensory areas has a counterpart at the level of the magnetic body so that the sensory input coming from the cell membrane is mediated through flux sheets going through the passive strand to the sensory magnetic body and motor actions of the motor magnetic body are mediated through theflux sheets going through active strand. One would have a closed loop in which the phase transition induced by the sensory input coming via the passive DNA strand to the sensory magnetic body generates cyclotron radiation inducing a phase

transition in the motor part inducing cyclotron radiating inducing effect in the active DNA strand.

Of course, the extreme flexibility of the entanglement mechanism of binding means that one can imagine almost unlimited number of variants about this basic option and the proposed variant can be defended only as the simplest one found hitherto. One can also allow the possibility that the sequence of entanglements begins from the perceptive field with the primary mental images at the level of sensory organs being entangled with objects of perceptive field.

Fractality suggests that there is a hierarchy of sensory representations. In particular, cortex areas, brain nuclei and even cells could possess their own sensory representations. The inactivity of the primary sensory areas during REM sleep could mean that during dream state sensory representations are non-cortical lower level representations or realized at higher sensory areas. Of course, lower level structures could define the projections to the magnetic sensory canvas also during wake-up consciousness. For instance, relay station like nuclei could act as relay stations for the projections realized at the magnetic body. Any brain area defining topographical map of sensory data is could candidate for defining a sensory representation.

The projector regions would serve as kind of central entanglers. Also the nuclei believed to somehow generate EEG resonance frequencies responsible for the binding of mental images are good candidates for the central entanglers. In standard neuroscience thalamus is believed to generate 40 Hz rhythm and is thus a good candidate for the central sensory entangler and projector. In TGD framework this rhythm would be more naturally generated by the magnetic body assignable to thalamus. Hippocampus -or more naturally its magnetic body- generates hippocampal theta and could be the central memory entangler and projector. Frontal lobes generate slow EEG waves during cognitive activities and could act as cognitive entanglers and projectors.

This kind of architecture is expected to be realized at various length scales. The metaphor for consciousness as a computer sitting at its own terminal, which originally stimulated my attempts to understand consciousness, conforms this picture. Computer screen would correspond to the sensory magnetic body. The one who sits there presumably could be identified as the motor part of the magnetic body (as far as conscious-to-me intentions are considered). The central unit corresponds to the brain and DNA double strands are the fundamental hardware responsible for communication and control and through which all information flows. They intronic parts of DNA strands would also provide the hardware for topological quantum computation programs. Sensory projector MEs are generated automatically by the nerve pulse activity and code the picture at the monitor. MEs would be active quantum holograms acting as control commands on the active DNA strand serving as the keyboard generating nerve pulse patterns. Thus it would seem that those aspects of the computer (monitor, keyboard, etc), which are usually not regarded as fundamental in Turing machine paradigm are the most crucial for understanding the consciousness and computer programmers could be mimicking what happens inside (and outside) their own brain.

Anomalous visual percepts and sensory canvas hypothesis

Sensory canvas hypothesis means that at the perceptual level we see using ELF– rather than visible light. Of course, if primary sensory qualia are at the level of sensory receptors, this seeing has the character of imagination. Even in this case brain could use feedback to the sensory receptors assign sensory qualia with the imagination like perception. This would occur during dreaming and what is regarded as hallucinations.

One can also consider the possibility of "vision" based solely on the ELF input from brain and body having no correlate with the visible light entering into retina or even with neural activity. Even genuinely three-dimensional vision in which own body is seen as it would be seen by the external world suggests itself. The dropping of ions from the atomic space-time sheets to the magnetic flux tubes so that they end up to high n cyclotron states decaying via the emission of photons at frequencies which are harmonics of the cyclotron frequency would generate the projector MEs needed for the sensory representation of the physical body or part of it as seen by the environment.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero

point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated. In the following only the "dropping" option is discussed.

There is some evidence for this kind of anomalous vision.

1. Yogis have reported altered states of consciousness in which they see their own body three-dimensionally, that is simultaneously from all directions. This might have interpretation as ELF vision involving a feedback from magnetic sensory canvas to brain to "qualiafy" the percept.

2. Becker tells in his book "Cross currents" [J158] about a young cancer patient who told that he can see the interior of his own body. The patient could also locate the remnant of the tumour correctly. If sensory receptors are necessary for visual qualia, the needed data must be received from somewhere by brain, and be projected to the visual receptors like during dreaming. The simplest option is that body parts can in some sense "see" each other. In particular, brain can "see" body parts (note that bacteria possess a primitive IR vision based on microtubules). Bio-holography provides support for the body as a hologram. For instance, an electric stimulation of ear during Kirlian imaging of a finger tip creates a Kirlian photo from which it is possible to abstract a hologram of ear (see [I66] and [K58] .

3. Also the OBE experiences, for instance those associated with NDEs, could have an analogous interpretation. The sensory input from eyes would be absent but brain would give feedback to visual receptors to "qualiafy" the input which it might receive from other levels of self hierarchy. If even the input from neural activity is absent during NDEs so that the visual experience should be determined by the background ELF component emanating from the brain and body. The third person perspective associated with OBEs might be always present but be masked by the strong sensory input or by the absence of feedback to visual receptors. It is possible to have experiences about contact with deceased by a therapy based on rhythmic eye movements [J38, J97]. The function of eye movements might be to establish a feedback to certain brain regions serving as receivers of input from magnetic bodies of deceased or from magnetosphere.

4. I have proposed thousand and one explanations for the beautiful flow visible when I close my eyes in a calm state of mind. During my "great experience" this background flow was accompanied by extremely vivid visual hallucinations. An additional item to the long list of explanations is following. The information characterizing the flow enters from or via brain to the visual receptors and is in this manner "qualiafied".

What has been said about magnetospheric third person aspect applies also to other senses. Interestingly, I often wake-up partially and realize that I hear my own snoring as an outsider (quite a dramatic experience!). Sometimes I have an experience which might be interpreted by saying that the hearing in the first perspective is superposed with the hearing in the third person perspective. The third person hearing has a time lag so that a kind of double breathing results.

Place coding of features inside brain

Place coding for various geometric parameters characterizing simple geometric "features" inside brain could be realized using the variation of the cyclotron frequency along a magnetic flux tube of varying thickness. The hierarchy of the sensory canvases allows a modular structure in which a geometric feature such as triangle, line, or ellipse represented at a lower level sensory canvas is projected to a *single* point of "our" sensory canvas.

Becker tells in his book "Cross Currents" [J158] about a technique discovered by Dr. Elizabeth Rauscher, a physicist, and William Van Bise, an engineer. The technique uses magnetic fields generated by two coils of wire, each oscillating at a slightly different frequency and directed so as to intersect at the head of the subject person. When two energy beams with different frequencies intersect at some point in space, a third frequency, so called beat frequency is formed as the difference of the frequencies. What Bise and Rauscher found that this ELF frequency (unfortunately, I do not know what the precise frequency range was) generates simple visual percepts like circles,

ellipses and triangles and that the variation of the second frequency induces the variation of the shape of the percept.

The simplest interpretation is that the beat frequency is extracted by nonlinear effects in brain and induces a magnetic quantum phase transition at magnetic tubes whose thickness varies and codes for a parameter (say scaling in some direction) characterizing the geometry of the primitive percept (or "feature"). An analogous phenomenon occurs also for auditory inputs with slightly different frequencies fed into ears and makes it possible to "hear" sounds below the audible range. The mechanism could be the same.

If primary sensory qualia are realized only at the level of the primary sensory organs, one can make two conclusions. ELF wave wakes up a "feature" analogous to an imagined percept, and presumably realized as a particular nerve pulse pattern. ELF wave also induces a projection from the brain to the retinae "qualiafying" this feature. Blind subjects should not have these extra-sensorily induced percepts.

One can imagine two options concerning the ultimate representation of a simple geometric feature depending on whether the feature corresponds to a *collection* of points or *single* point at "our" sensory canvas.

1. The visual percept corresponds to a *collection* of activated points at "our" sensory canvas and activated geometric point corresponds to a standard mental image represented at brain level and assigned to a point of sensory canvas. The magnetic phase transition would initiate a process eventually activating particular projectors and the position of the quantum phase transition at the magnetic flux tube would determine the shape of the feature. One can criticize this option. The brain applies modular hierarchy in the information processing and simple percepts like triangles and circles which are also fundamental in the elementary geometry, are ideal for basic features assignable with a *single* point of "our" sensory canvas rather than being represented as composites of elementary features (points). The very fact that the place coding for the geometric shape of the feature is involved, suggests the same.

2. The visual percept is represented as a mental image inside brain or, more probably, at some lower level sensory canvas so that the hierarchy of the sensory canvases would directly relate to the modularity of our sensory representations and sensory canvases would be in an intense interaction by quantum entanglement much like various subprograms of a computer program. This geometric mental image is assigned with a *single* point of "our" sensory canvas by quantum entangling it with a projector ME projecting to a particular point of "our" sensory canvas. The position of the feature at the sensory canvas might be determined by the position of the volume of intersection for the beams.

Since sinmple objects are in question and the change of the shape corresponds to a scaling in one direction, the representation of the change of shape of the object could be in terms of a Lorentz boost of sub-CD representing the object and leaving the tip of the sub-CD invariant.

The relation of mental imagery to sensory experiences

Mental imagery is something which is difficult to understand in the framework of the standard neuro science. There are empirical results suggesting that mental images correspond to patterns of activity inside cortex, which are three-dimensional and continuous so that neural activation provides a concrete recognizable image about object [J168]. Rather remarkably, also imaginative thought resembles very much visual imagery as is clear from the fact that language is full of visual metaphors [J168]. It is also known that imagery uses same regions of the cortex as real sensory experience and the problem is to understand why there is almost sensory experience involved with imagery.

In the framework of the standard neuroscience the obvious question is why the pattern of the imagery activity is not accompanied by a direct sensory experience. Also the boundary between direct sensory experience and imagination is sometimes problematic. For instance, in the state between sleep and awake sensory images often enter into mind. During dreams one can have sensory images and eidetic memory is essentially sensory memory. I have a personal experience about an extended state of consciousness, or rather whole-body consciousness (this experience actually made me consciousness theoretician!). During this state I could see my thoughts as vivid

visual images and had also peculiar odour and taste experiences also reported to occur during mystic experiences.

The original belief was that imagination could involve p-adic-to-real phase transitions transforming p-adic imagery to nerve pulse patterns or membrane oscillations. The genuinely p-adic aspect of imagination would be analogous to a free choice of initial values in a computer simulation, which are then transformed to their real counterparts initiating neural activity.

It has truend out that this view is probably wrong. In the adelic vision about world both real and p-adic sectors for all p-adic number fields are present simultaneously. Imagination involves both cognitive and sensory aspect.

Why imagination does not involve sensory qualia could be explained in several ways.

1. Primary sensory qualia are realized at the level of sensory receptors and brain constructs only higher level symbolic representations of the sensory input and quantum entanglement binds these representations together. For imagination sensory receptor level is absent. This would also explain rapid eye movements during dreams as being related to the construction of visual qualia. Dreaming is indeed a cognitive activity which is learned gradually (at young age dreamer sees only static images). One could understand why motor activities are not accompanied by sensory experiences associated with motor pathways. The obvious reason for why sensory imagination should not create lively images is that this would lead to a dangerous mixing of the real and virtual. If this interpretation is correct, the study of whether feedback from brain to sensory organs occurs during sensory hallucination, provides a way to test whether sensory hallucination is a telepathic experience resulting from the sharing of mental images or whether it might be constructed in brain by feedback to sensory receptors.

2. Imagination could rely on membrane oscillations just as higher level cognition. The finding that imagination does involve patterns of activity at visual cortex similar to those associated with ordinary visual perceptions does not support this idea.

3. If higher level sensory representations are realized at the magnetic canvas, the difference between imagination and real sensory experience could result from the absence of the projection to the sensory canvas. Also the absence of negentropic entanglement could be the reason. This state of affairs could have a detectable EEG correlate: for instance, in 40 Hz resonance band. The projector MEs responsible for the cognitive representation could be activated but be p-adic and project only cognitive images. One can however wonder why magnetic body is at all conscious about imagined mental images if it does not share these mental images.

   If this explanation is correct, it would be also possible to have sensory experiences at brain level only. For instance, unconscious seeing would would be possible. This kind of blind vision is indeed known to be possible and will be discussed later.

Motor output and the ultimate output giving rise to our sensory experience might be very closely related: motor action could be like printing or some control activity and sensory and cognitive representations like pictures at the monitor screen. This picture looks attractive but might neglect some deep differences suggested already by the anatomy of the central nervous system. There are reasons to expect that the construction of sensory percepts and motor activity could be geometric time reversals of each other at some levels of the self hierarchy (MEs in certain time scales). This view would mean that motor action starts from a rough sketch for the outcome of the motor action and quantum jump by quantum jump ends up to the complete performance by a process which might be regarded as a gradual carving of a four-dimensional sculpture relying on both ordinary and time reversed dissipation serving as a Darwinian selectors so that the very many sketches would lead to the same outcome. Both these views might make sense: which view is correct depends on what time scale one is considering.

Are the space-time sheets and sub-CDs representing objects of the perceptive field generated automatically?

One of the poorly understood aspects of sensory perception is how objects of the perceptive field are generated at the level of cognitive representations. The problem is especially difficult in the

computational approach to consciousness. Natural idea is that the objects of cognitive representation directly reflect the objects of the physical world and that direct physical interaction creates these objects automatically. Various visual illusions demonstrate that also apparent objects are generated by sensory experience which suggests that it is nerve pulse patterns at the level of cortex which give rise to the objects of the perceptive field. In neural net approach to brain consciousness it is however far from trivial what these objects could be.

In TGD approach objects of the perceptive field correspond to mental images and thus sub-selves. sub-selves in turn naturally correspond to mind-like space-time sheets. Therefore the problem reduces to that of understanding how sensory input gives rise to mind-like space-time sheets: in particular, how the sensory input or nerve pulse activity induced by it determines the boundaries of the mind-like space-time sheets.

On of the basic laws about sensory experiencing is that only changes are experienced. Quantum model for the contents of consciousness of self implies this law at quantum level: only the averages of the increments of quantum numbers and zero modes are experienced consciously. By "Ontogeny recapitulates phylogeny" principles this law should have realization also at the level of dynamics of the space-time surface.

A possible space-time level counterpart of this law is that the primary at the level of primary sensory organ or secondary sensory stimulus at the level of cortex generates Kähler electric field proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go? The answer is simple: mind-like space-time sheet is generated and the flux goes to the mind-like space-time sheet through wormhole contacts! Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mind-like space-time sheets and give rise to selves, mental images in the cognitive representation! Several cognitive representations with different decomposition into objects are possible.

Also an alternative formulation of the title is as a question whether the sub-CDs serving as embedding space correlates for the mental images are generated automatically. One could argue that quantum jump sequence generates these sub-CDs and that directed attention could induce them. Negentropy Maximization Principle suitably generalized to state that the difference for the negentropies of the final and initial state is as large as possible for a given CD might favor the generation of negentropic sub-CDs. Also the argument for the arrow of psychological time suggests that NMP should have this kind of generalization.

Spectroscopy of consciousness

In its original form the spectroscopy of consciousness stated that one could assign to various qualia - say colors, tastes, or odors- frequencies so that the frequency patterns would provide a spectroscopic signature of the microscopic structure of conscious experience just like frequency patterns allow to deduce highly detailed information about the structure of a distant star. Spectroscopy of consciousness could be for the brain science what atomic spectroscopy has been for physics and chemistry.

In its original form this idea turned out to be un-realistic. Sensory qualia as such do not seem to correspond to frequencies. Rather, frequencies would code for the geometric data. For the cyclotron frequencies at least only the frequency ratios seem to have a deeper meaning. The fundamental frequencies assignable to CDs however define an exception in this respect. Spectroscopy of consciousness in a more realistic form would relate to the coding of geometric data such as positions, size scales and state of motion for the objects of the perceptive field. Frequency scales could also distinguish between higher level sensory representations assigned to brain regions of various size scales. The basic frequencies would be fundamentals and their harmonics assignable to CDs, cyclotron frequencies, and Josephson frequencies.

1. Spectroscopy of consciousness and size scales of brain structures

The size scales for various parts of brain could mapped to frequency scales characterizing the sizes of the parts of dark magnetic body so that a kind of collection of zoomed up images of brain regions would be obtained. Images of brain regions would be mental images assignable to

them to the sensory receptors entangled with them.

1. In [K100] it is found that a simple scaling law $v = \lambda f$ relating the apparent wavelength and phase velocity of EEG wave and more general em waves with its frequency allows to understand the basic anatomical structure of the central nervous system as reflecting evolution regarded as the emergence of new p-adic length scales. Scaling law allows also to predict which frequencies correspond to qualia experienced at a given level of the p-adic self hierarchy for a given conduction velocity of nerve pulses identified as an effective propagation velocity of EEG waves. Scaling law could also relate the sizes $L(magn) \sim L(EEG)$ of the radial magnetic flux tube structures (magnetic canvas or magnetic body) associated with the secondary sensory organs of size $L \sim \lambda$: $L(magn) \sim L(EEG) = c/f = (c/v)L$. Wave length of EEG could code for the size of the structure defining a kind of zoom-up of the brain region in question at the magnetic body.

2. The hierarchy of Planck constants allows to understand how photons for which the energies $E = hf$ are much below the thermal energy in standard quantum theory can be so important biologically. EEG photons would obviously have a rather large value of Planck constant. This hypothesis encourages the identification of the above defined velocity ratio as $r = c/v = \hbar/\hbar_0$. $\hbar$ would be Planck constant for say ELF photons communicating the signal to the corresponding dark layer of the magnetic body. In brain the dark photons could be transformed to ordinary short wave length photons by a leakage to $r = 1$ page of the Big Book in an energy conserving manner. The part of the magnetic body at a particular page of the Big Book would represent an r-fold zoom up of the brain region considered. If one takes seriously the proposal that DNA double strands act as relay stations between the brain and magnetic body, these values of Planck constants could be assigned with the flux tubes assigned to DNA nucleotides. I have proposed a similar scenario but with motivations coming from an attempt to understand how the realization of the genetic code at the level of dark nucleon physics discovered for few years ago could relate to the biochemistry and DNA [L3, K53, K129], [L3].

3. The fundamental frequencies would be most naturally cyclotron frequencies of charged elementary particles and biologically important ions at the magnetic flux tubes with large $\hbar$. TGD based nuclear physics predicts also the possibility of exotic chemically equivalent bosonic counterparts of the ordinary fermionic ions so that Bose-Einstein condensate of also these ions at cyclotron states could define macroscopic quantum phases. The corresponding higher level qualia would correspond to phase transitions changing cyclotron quantum numbers. Cyclotron energies scale as $\hbar$ so that energy scale would distinguish between different pages of the Big Book whereas frequency would be the same form them if the strength of the magnetic field is same for all the pages. Energy coding would be in question. These photons would be naturally generated at the magnetic flux tubes which suggests that they could be used for communications from the magnetic body to biological body.

2. Spectroscopy of consciousness, CDs, and Josephson junctions

Zero energy implies the notion of CD as embedding space correlate of self and the moduli space of CDs should play a key role in the understanding of the geometric qualia. Hence the spectroscopy of consciousness could relate very closely to the scales of CDs.

1. For a fixed value of $\hbar$ rather few size scales for CDs would be involved (nuclei, quarks, electron plus their possibly existing p-adically scaled up variants). The fundamental frequencies assignable to CDs would correspond to the time scales of CDs and would scale like $1/\hbar$ whereas energy would not be affected in the scaling of $\hbar$.

2. The problem is that for energies above thermal energy at physiological temperatures the size scale of CD should correspond to those assignable to very heavy particles. If only photon energies above thermal energy are relevant for biology the frequencies 10 Hz and 1 kHz assigned to electron and quarks would be excluded. If the leakage of classical em oscillations of given frequency leaking between different pages of the Big Book automatically generates

photons with scaled up energies, the problem disappears. Each of the r sheets of the many-sheeted covering would carry single quantum with the original frequency. The frequency would be r-fold harmonic of the frequency of the fundamental for the scaled up CD.

3. Also Josephson frequencies associated with the cell membrane identified as Josephson junction (also flux tubes connecting the membrane to DNA strand could serve as Josephson junctions) are involved. Josephson energies do not depend on $\hbar$ since the frequencies behave like $1/\hbar$ so that a hierarchy of representations at the pages of the Big Book in different time scales would be obtained as kind of spatio-temporal zoom-ups. In this case the communications would be naturally from the biological body tothe magnetic body and sensory data could be communicated in this manner.

4. The photon energy $E \sim .05$ eV assignable to the cell membrane potential energy is at the border of the thermal threshold and corresponds to a wave length $\lambda = 2.4 \times 10^{-5}$ meters. For M_{89} corresponding to intermediate gauge bosons one has $L(89,2) = L(178) \simeq 1.2 \times 10^{-4}$ m - the size scale of a large neuron and only 5 time longer than λ so that $r = 5$ would allow to overcome the thermal threshold. Could even intermediate gauge boson length scale be relevant for biology? The lifetime of intermediate gauge boson is much shorter than this time scale but one can ask whether photons could correspond to M_{89}.

3. Spectroscopy of consciousness and the moduli space of CDs

Consider next the concrete realization of the spectroscopy of consciousness in terms of the moduli space of CD.

1. The moduli space of CDs which is Cartesian product of part associated with M^4 degrees of freedom and CP_2 dgrees of freedom.In M^4 degrees of freedom one has the position of say lower tip parameterized by M^4 and the coordinates for the relative position of tips defining sub-set of the future directed light-cone M^4_+. The position in M^4 for the lower tip of sub-CD could code for the position of the object of the perceptive field.

2. The quantization of the proper time distance between the tips in octaves reduces the situation to a union of hyperboloids and a further discretization to a lattice of hyperboloid is suggestive by number theoretical considerations. The interaction of a photon with this kind of hyperboloid representing sub-CD is resonant if the frequency corresponds to the temporal difference between the tips as measured in the rest system of CD so that frequency coding of the Lorentz boost performed for sub-CD results.

3. One particular application would be the coding of the velocity (including its direction) of an object of perceptive field to the boost applied to sub-CD leaving its lower tip invariant. The positions of sub-CDs would not be updated continually and the sensation about continuous motion would result from the separate representation of the velocity. This interpretation is supported by a syndrome in which patient does not perceive motion and the positions for the objects of the perceptive field are updated with so long time intervals that the ordinary street traffic is too dangerous for the patient. The size scales of sub-CDs would give rise to a natural length scale hierarchy characterizing the sizes of the details of the representation. $M^2 \subset M^4$ fixed partially by the tips of CD defines preferred quantization axes for energy and spin and this choice would be relevant for purely quantal aspects of the sensory representation. The Lorentz boosts of discrete spectroscopies would code for the motion of the objects of perceptive field.

4. In CP_2 degrees of freedom moduli would correspond to $CP_2 \times CP_2$ such that for both factors a preferred point and a homologically trivial geodesic sphere S^2 has been selected. Thes choices give rise to flag manifold $SU(3)/U(1) \times U(1)$ labeling the choices of the quantization axes. In the recent case color rotations for the tips would represent the geometric data at the basic level. Also now discretization for the CP_2 points assignable with the second tip would be natural. $M^8 - H$ duality is fundamental element of quantum TGD and means that CP_2 points code for hyper-quaternionic planes of hyper-octonionic M^8 containing a preferred M^2. This would suggest that CP_2 could also code for geometric data as is suggested by the

findings of Barbara Shipman concerning the role of the flag-manifold $SU(3)/U(1) \times U(1)$ in the model of honeybee dance [A10]. The hyper-quaternionic plane assignable to the point of space-time surface at given point identified as a plane spanned by the Kähler-Dirac gamma matrices would correspond to a point of CP_2.

Spectroscopy of consciousness is considered in detail in [K100] - the spirit is of course extremely adventurous since so little is known and potential reader can take this as a mere exercise perhaps helping to identify the rules of the game. Especially fascinating is the possible connection of the theory of the magnetic qualia with atomic and nuclear spectroscopy: the structure of the periodic table could reflect itself directly itself in the spectroscopy of consciousness via cyclotron frequencies inversely propotional to the masses of ions. Various full electronic shells (He, Ne, Ar, Kr, Xe) correspond to a hierarchy of geometric qualia relating directly with the band structure of EEG. The periods also could also relate to the five-layered structure of sensory cortex (primary, secondary, etc... areas).

8.4.3 Is The Pain In The Toe In The Toe, In Brain, Or Somewhere Else?

The basic question concerns about the seat of the primary sensory experience. There are three options.

1. Standard neuroscience says that our sensory experience can be localized to cortex.

2. The apparently very naïve view is that sensory experience receives a contribution also from the primary sensory organs. Certainly primary sensory organs could be experiencers in TGD framework (and probably are) but this experience need not contribute to our sensory consciousness unless there is a negentropic entanglement between brain and sensory organs. Let us assume further that magnetic body plays no role.

3. The notion of magnetic suggests that sensory representations conscious-to-us correspond to a sequence of entanglements connecting the magnetic body and the primary sensory organ and perhaps including even to the object of the external world. This pictures differs in even more radical manner about the view of standard neuroscience. As far as the analysis of the sensory data is considered, this view need not differ in an essential manner from the standard view: magnetic sensory canvas could be analogous to a passive monitor screen. Magnetic body could also participate actively to the construction of the percept by sending virtual sensory feed-back through brain to the sensory organs.

The view 2) is not automatically excluded in TGD framework as it is in standard neuroscience.

1. The experiments of Libet about passive aspects of consciousness [J87] could be seen as supporting the hypothesis that the data is sent to the magnetic body, which causes the time lapse meaning that the sensory data is.3-.5 seconds old [K133].

2. The location of primary qualia to the level of sensory receptors would also allow to understand why sensory pathways are specialized to definite qualia despite the fact that there seems to be no obvious structural or functional differences at neuronal level. As already found, one could also understand the difference between imagination and sensory experience and why feedback to visual receptors (REM) is present during dreaming.

3. The identification of long term memories as multitime experiences containing contributions from the distant geometric past forces to consider the possibility that sensory organs are primary sensory experiencers whereas the standard dogma of the neuro science is that all sensory experiences occur at brain level at geometric now. The idea that also primary sensory organs are seats of the primary sensory experiences, could explain Libet's experiments, explains the observation that persons who have become blind gradually, lose their ability to have dreams and also the rapid eye movements and feedback from brain to auditory organs during REM sleep. It must be emphasized that these phenomena can be understood also in options 1) and 3).

One can represent several objections against the identification of the primary sensory organs as seats of our primary sensory experience (Option 2)[1].

1. The first class of objections is that our sensory perception involves a lot of computation (consider stereo vision as an example) and this computation cannot be performed at the level of the sensory organ. These objections look at first rather convincing but relate only to the cognitive aspects of sensory perception, not the to the primary sensory qualia. The computation can be carried out and involve also magnetic body and the back-projection to the primary sensory organs could allow to construct the percept as an artwork at the level of primary sensory organ.

2. The second class of objections is related to the explanatory power of the idea of standard neuroscience that entire sensory pathways containing also neurons of cortex are seats of the sensory experience (For option 1) they are involved with the construction of the sensory experience). This idea allows to regard brain as kind of musical instrument such that each neuron produces its characteristic sensory experience so that our experiences are combinations of the primitive neuronal experiences. For conscious information processing this is a crucial advantage: for instance, incoming nerve pulse patterns in associative regions of brain are consciously differentiated from each other as different modalities so that same nerve pulse pattern can have different meaning as sensory modalities. This objection suggests that the idea of restricting sensory experiences at the level of primary sensory organs is wrong. On the other hand, neuronal pathways and brain could be specialized to build cognitive representations and primary sensory qualia could be at the level of sensory receptors. The feedback from brain to the sensory receptor level could also make possible to manipulate the sensory input.

3. The view about brain as a collection of standard features which are activated by the sensory input and projected to the magnetic canvas and thus associated with the objects of perceptive field is in conflict with the idea that our experience receives a direct contribution from the primary sensory organs. Situation of course changes if one allows entanglement of brain with sensory organs.

4. The phenomena like dreams, hallucinations, synesthesia, phantom limb, and the experiences generated by stimulating neurons of sensory pathways and projected pain are obvious counter arguments against the idea that sensory organs are primary sensory experiencers (or form parts of them). The identification of the long term memories as multitime experiences allows in principle to overcome these objections, and a more detailed discussion of this point is in order.

In the following the explanations of various strange phenomena of sensory consciousness are studied and the explanations provided by the options 1), 2) and 3) are compared. It must be emphasized that the possibility that even sensory organs (and even neurons) have senses is not excluded by these arguments: what is however clear that *our* sensory landscape is constructed in cortex.

Back projections and cross projections

During REM sleep rapid eye movements occur and are thought to accompany dreaming. It is not however clear to me whether the correlation between rapid eye movements and visual dreaming is one-to-one. The ringing of the ears is a real physical process occurring in ear and these oto-acoustic emissions, as they are called, can be sometimes heard by even outsider [K96]. Rapid eye movements during dreams and oto-acoustic emissions can be regarded as back-projections from brain to primary sensory organs.

1. These phenomena can be understood without any difficulties in the options 1) and 3). For instance, rapid eye movements could be understood as feedback generated by a visual dream.

[1]The topic of discussion might look rather academic from the point of view of neuro science but it is not that in TGD framework: it took years to decide whether this idea could make sense or not.

2. For the option 2) rapid eye movements could be seen as necessary prerequisite of dreaming and to "qualiafy" imagined mental images.

   Synesthesia involves cross-modal associations of form $A \to B$ (say visual to auditory).

1. In option 2) both dreams, hallucinations, and synesthesia rely on the feedback from brain to sensory organs to "qualiafy" the mental images. The prediction is that there should be a feedback, not only between sensory areas, but between sensory organs or the cross-associated qualia. This prediction is certainly testable. For instance, auditory-visual synesthesia should be lost if eyes are damaged.

2. The simplest view allowed by options 1) and 3) is that this kind of sensory leakage occurs at the level of neuronal connections.

Projected pain and phantom leg

Projected pain and phantom leg provide a further test for the proposed options.

1. For the standard explanation (option 1)) one must assume that the experience of pain is localized to the somato-sensory map in brain. The explanation of the projected pain is based on the observation that projected pain is felt in the body part which was very near to the body part contain the actual cause during early developmental stages. If somatosensory maps are not updated properly, projected pain becomes possible. This applies also to option 2).

2. For option 2) the explanation of phantom pain as a remembered pain and thus as a real pain in the geometric past when the limb still existed, is the simplest one. Projected pain cannot be however interpreted as a remembered pain since the physical cause of pain is in the geometric now. The assumption that the sensory pain (as distinguished from psychic pain) is a cortical sensation whereas only pure sensory experiences would be located in the primary sensory organs looks rather strange taking into account the universality of emotions as entropic qualia. What goes wrong with this argument is that the experience of pain is confused with the experience about where the pain is. The wrong location could result when the mental image about pain is projected in a wrong manner to the body map. A leakage between sensory pathways could cause the wrong localization.

3. Also for option 3) the simplest explanation of the phantom leg phenomenon is that the pain is geometrically remembered pain from the period when the leg still exists and thus would have a real cause. These memories would be analogous to the sensory memories of idiot savants allowing their memory feats and to the sensory memories created by the stimulation of temporal lobes. Why sensory memories are so rare has a simple explanation: their interference with sensory input from recent moment could have disastrous effects. Most memories are non-sensory sine they can be distinguished from the sensory input.

   Also other possibilities can be imagined. The loss of the physical limb need not mean the loss of its magnetic counterpart so that phantom pain might be caused by either by a sensory input from other parts of leg projected to the part of the magnetic sensory canvas representing the lost leg. This could explain also the projected pain. The magnetic map of body coded by MEs could be partially out-of-date so that some parts of this map correspond to the structure of biological body during the early developmental periods. The pain in left arm during heart attack could be understood in this manner.

Color constancy and sensory organs as primary experiencers

The phenomenon of color constancy [J7], which forms one of the most important aspects of vision, is a further objection against the identification of sensory organs as primary sensory experiences. At least if one believes that colors are primary sensory qualia. If the object of the visual field is illuminated with a monochromatic light of constant intensity, its color does not change. This is quite contrary to what one might expect on basis of what is expected to happen in the color sensitive cones in retina detecting wavelengths concentrated around blue, red and green. A particular case of the color constancy phenomenon arises when entire visual field is illuminated with a monochromatic

light of a constant intensity: what is experienced is complete darkness. The ability to see the real colors of the objects of the external world, which is made possible by the color constancy phenomenon, is of course extremely valuable for survival purposes.

1. For option 1) color constancy is a challenge. Color constancy suggests that retina cannot be the primary sensory experiencers of color qualia since in this case our subjectively experienced world would be changing its colors continually. This conclusion might be too hasty. In fact, one could defend the hypothesis about sensory organs as primary sensory experiencers and use color constancy as a guide line in the attempts to guess how sensory representations for the objects of the external world are generated as sub-CDs residing at the retina.

2. In option 2) and 3) it can be assumed that the subtraction of the background involves computational processing at the level of brain. If the objects of the perceptive field are generated at the level of brain by nerve pulse patterns, this is probably the case. The subtraction of the background is possible to realize by excitatory and inhibitory projections and mathematically one can regard the sensory image of a colored object of a perceptive field as an integral function for the gradient of the intensity of the sensory input. For a monochromatic constant input the derivative vanishes as also integral function. The task therefore is to realize this integral function in terms of a neural circuit using excitatory and inhibitory inputs and outputs.

The explanation of the color constancy could reduce to the hypothesis that sensory qualia correspond to increments of quantum numbers rather than quantum numbers themselves.

1. If the color perception generated by the illumination at a particular wavelength depends only on the spatial gradient of the illumination, color constancy follows as a consequence. Since the eye is performing saccadic motion, this translates to a temporal gradient of illumination. The temporal change of the illumination at a particular wavelength should thus induce a particular color quale. But this is consistent with the assumption that color qualia correspond to the increments of color quantum numbers in the quantum jump. This model explains also why the saccadic motion is necessary to generate color qualia, and qualia at all. Quite sensory percepts result only when physical change is involved. Saccadic motion maps the gradients of illumination to increments of color quantum numbers.

2. One might also understand why a rotating Benham top containing only black and white regions can produce color sensations. Since both the saccadic motion and the motion of disk are involved, one can imagine that for a rotating disk the proportions of various primary qualia are affected such that a net color is perceived. For instance, the intensity of the perceived color could depend on the velocity with which the eye crosses the intensity gradient and this dependence could depend on wavelength.

All geometric aspects of sensory experiences should reduce to representations generated by zero modes, in particular zero modes characterizing classical Kähler field, which can reduce to pure electromagnetic (vision?) or Z^0 field (auditory experience?). Color constancy could be understood if the incoming light intensities associated with the wavelengths around three basic colors generate Kähler electric fields proportional to the gradient of the intensity. If the gradient is strong, as it is on the boundary of the retinal or neural image of the object, the conservation of the Kähler electric flux forces the generation of mind-like space-time sheet at which part of the flux goes.

Thus retina would automatically create representation for the objects of the visual field as mind-like space-time sheets, which in turn could give rise to sub-selves representing objects of the visual field as mental images! These objects need not however correspond to our conscious experiences. In fact, the boundaries of all objects of perceptive field should be generated by strong gradients and same principle would apply also to the higher level representations of sensory information. A gradient of Kähler (electric) field proportional to the gradient of primary/secondary sensory stimulus is generated in primary/secondary sensory organ and automatically generates mind-like space-time sheets, which give rise to sub-selves representing the decomposition of the perceptive field to objects.

Blind sight and Anton's syndrome

In blind sight cortically blind patient claims to be blind but is actually able to locate objects in the visual field when asked to do that. By training the patient can even develop some kind of primitive conscious experience of motion, shape and color.

1. For option 1) blind sight looks first problematic since the basic assumption is that primary visual qualia are generated at the level of retina. If the entanglement with retina is lost the visual qualia at retina are not assigned with the magnetic sensory canvas and the person is not conscious that his eyes see. The primitive conscious experiences of motion, shape and color would arise at the sub-cortical level make it possible to locate objects in the visual field. Blind sight would be also vision without cortical cognition (such as feature recognition). Training would generate gradually entanglement between sub-cortical areas and the cortical areas responsible for projections to the sensory magnetic canvas.

2. In option 2) the explanation for the blind sight would be the existence of two separate visual systems. Possible candidates for these systems as regions of cortex have been even identified [J32].

3. In option 3) blind sight has several explanations. The simplest explanation is that the negentropic entanglement between magnetic body and brain is absent so that brain would see consciously but not the magnetic body representing us. Blind sight could thus be interpreted as a support for the notion of magnetic body. A test for the magnetic canvas hypothesis might be based on the elimination of the MEs responsible for the sensory projection to the magnetic canvas somehow. This option is of course not the only possible one. There is entire p-adic hierarchy of increasingly refined visions involving retinal vision, amygdalar vision, and various visions corresponding to sensory areas of cortex.

The patient suffering from Anton's syndrome is cortically blind but claims that he sees but behaves as if he were blind and confabulates all kinds of explanations for his behavior.

1. The advocate of option 1) could argue that patient sees at the subcortical level and hence has pure experience of vision without any cortical cognitive processing of what he is seeing. Person is cognitively blind. There would be no recognition of objects in the visual field, to say nothing about associations and memories related to these objects. Therefore sensory (or subcortical) seeing would not help the patient much and he would behave effectively as a blind person. One could even consider the possibility that patient gradually loses the ability to see because this ability is not useful anymore. A possible test (probably already carried out) for the hypothesis is to check whether patient can show the direction of an intensive light source (even this might require "cognitive seeing").

2. The standard explanation (option 2) is that patient is not conscious about being blind: the fact that patent seems to gradually accept the situation that he does not see, supports this explanation. It would be possible to have the experience of seeing without actually seeing.

3. Option 3) would allow the possibility that the parts of the cortex responsible for projecting sensory data to the sensory magnetic canvas remain intact and that the visual images are visual memories. It would not be surprising that this useless vision would be gradually lost. Note however that lower level visual systems might work.

Woman without body

In his book "The man who mistook his wife for a hat" [J141] Oliver Sacks tells about a tragic situation in which his patient lost totally her body image. Body image is provided by proprioception together with vision and sense of balance. The sensory neurite suffered by the patient destroyed patient's proprioceptive sensory pathways. Patient did not however lose tactile senses. The proprioceptive homunculi in patient's parietal lobes suffered no injury. Patient learned to cope with everyday activities by using vision and sense of balance and all kinds of clever feedback and feedforward mechanisms to compensate the lost proprioception. For instance, patient regained her

ability to speak, to keep her bodily posture and walk. She however lost her balance immediately if she closed her eyes. Patient did not however get back her phenomenal body image in this manner.

The loss of body image is not a problem for option 2) since neural pathways are prerequisites of quantum entanglement between brain and sensory receptors (also these might have been destroyed). Options 1) and 3) can explain the loss of body image without difficulties. These options could even allow to regain the body image artificially, for instance by artificial neuronal stimuli providing a representation for the positions of various body parts. In both cases artificial electric stimulation of cortex should generate tactile sensations of some kind.

Chapter 9

General Theory of Qualia

9.1 Introduction

Macroscopic quantum phases are an essential element of most quantum theories of consciousness and Topological GeometroDynamics (TGD) is not an exception in this respect. TGD based theory of consciousness relies crucially on the notion of self hierarchy whose geometrical correlate is the hierarchy of space-time sheets realized as a 4-surface in certain 8-dimensional space. The notion of many-sheeted space-time indeed predicts new types of macroscopic quantum phases. This has led to guesses for the quantum correlates of sensory qualia (colors, tastes, odors,..) and conscious thought as various macroscopic quantum phases predicted by TGD but the lack of direct experimental evidence for the macroscopic quantum phases has made more detailed models impossible. The breakthroughs in TGD and TGD inspired theory of consciousness inspired the first trials to construct a general theory qualia. Preliminary and incomplete versions of this theory are published in [**?**] and in [L1]. During subsequent years the theory got a rather stable shape.

Dark matter hierarchy with levels labelled by the values of a dynamical quantized Planck constant have been the basic theme of the year 2005. TGD inspired theory of consciousness and TGD based view about quantum biology provide perhaps the most fascinating applications for this concept. It must be however added that condensed matter applications, say the models for the anomalous properties of water and for high T_c superconductivity, are of utmost relevance also for TGD based view about living matter. Dark matter hierarchy allows profound insights about the evolution of consciousness and life as the emergence of new levels of dark matter hierarchy, and deepens the view about the anatomy of quantum jump making it also possible to develop a more detailed view about qualia.

The recent progress in the understanding of the hierarchy has led to the discovery of a fractal hierarchy of quantum criticalities whose levels are labelled by the values of $h_{eff} = n \times h$ and understanding of evolution taking place as spontaneous integer scaling of h_{eff} reducing the criticality. This view allows to understand basic aspects of living systems elegantly. Further closely related step of progress relates to the p-adic physics as physics of cognition. The adelic view about space-time and quantum physics allows to understand cognition and imagination as basic aspects of existence also at space-time level. ZEO based view about state function reduction leads automatically to the notion of self as a sequence of state function reductions at the same boundary of CD and death of self as the first reduction to the opposite boundary where time reversed self is generated. Sensory-motor cycle could correspond to the sequence having as basic step the death of sub-self representing sensory mental image and birth of time-reversed sub-self representing motor mental image.

These advances force to modify the original view about qualia. Qualia do not correspond to increments of quantum numbers in quantum jump as state function reduction as believed first. Rather, the flow of quantum numbers between subsystem representing sub-self and environment during the life-time of self representing sensory mental image gives rise to qualia. Typical lifetime of sensory mental image is about .1 seconds. This picture is consistent with the capacitor model of qualia introduced already before explicit formulation of the modified view about qualia. This implies some modifications to the identification of qualia. For instance, in the earlier model visible

colors were identified as increments of quark color quantum numbers of quark color and representable as gluon quantum numbers. In the recent model same color quantum numbers correspond to those for gluons. Furthermore, also color quantum numbers fo quarks as such can correspond to visual colors. quantum numbers in the recent picture.

9.1.1 The Notion Of Self And Qualia

The notion of self has been problematic and the recent progress in this respect clarifies also the situation concerning qualia. In ordinary quantum measurement theory repetition of state function reduction leaves the state unchanged. In TGD state function reduction can occur at both boundaries of causal diamond (CD) and in this case the state remains invariant only at the boundary at which the repetition takes place. This allows to understand how the arrow of time and its flow correspond essentially the increase of the average temporal distance between the tips present in the superposition of CDs with second end localized at fixed light-cone boundary. Self can be identified as a sequence of state function reductions occurring at given boundary of CD. The act of free will corresponds to the occurrence of quantum jump to the opposite boundary of CD and changes the arrow of geometric time at the level of the hierarchy of CDs corresponding to self. Qualia must characterize to the experiences of self assignable to the repeated state function reductions.

The original model of qualia was based on the idea that all quantum jumps involve change of quantum numbers so that increments of quantum numbers would characterize qualia. This assumption does not make sense for the quantum jumps at the fixed boundary of CD but at the opposite boundary of CD flow of quantum numbers between two subsystems is possible. Hence the increments of quantum numbers or rather the rates for their change would characterize qualia. The capacitor model for sensory receptor, which emerged before the correct view about self, actually assumed this.

One ends up with the following model of qualia.

1. Only the increments of zero modes and quantum numbers are experienced consciously. In the original model these increments were associated with quantum jumps: in the updated model their are associated with a flow of quantum numbers between two sub-systems at the non-fixed boundary of CD.

2. There are geometric qualia corresponding to zero modes expressing the result of quantum measurement in each quantum jump. All geometric information about space-time surface should reduce to geometric qualia. For instance, geometric data given by visual, auditory, and tactile senses should reduce to conscious information about zero modes or about increments of zero modes in quantum jump.

3. A further working hypothesis analogous to functionalism is universality: kinesthetic qualia depending on the quantum number increments are universal. Thus the increments of Poincare and color and electro-weak quantum numbers define what might be called universal kinesthetic qualia.

One can of course consider also the possibility that sensory qualia do not require any quantum number flow to the system corresponding to sub-self and it would be interesting to see whether this idea leads anywhere.

The vision about metabolism as transfer of negentropic entanglement (or rather stealing it from other conscious entities) suggests that the quantum numbers assignable to metabolites correspond to fundamental qualia. At least in the case of biomolecules serving as nutrients this could make sense. Also for olfaction metabolic qualia could be important.

9.1.2 Qualia And Thermodynamics

Thermodynamical approach to qualia suggested itself.

1. The sequence of the states assignable to the changing boundary of CD can be modelled as a statistical ensemble of Fock states, which suggests that thermodynamics is basically part of theory of consciousness. The ensemble of prepared states gives rise to a large number of

statistical qualia. The relationship $dE = TdS - PdV + \mu dN + B \cdot dM...$ generalizes to TGD context: note however that in case of ME selves energy is replaced with the Super Virasoro generator L_0 associated with the light cone boundary of ME. Each intensive-extensive variable pair in the differential should correspond to a non-geometric quale, which results only when there is a gradient (flow) of the extensive variable in the direction of the subjective time. Super-canonical thermodynamics should obviously map ordinary thermodynamics to the level of conscious experience.

2. Statistical interpretation also suggests that an averaging over the increments occurs. The possibility of sub-selves makes possible to have sequences of sub-selves (mental images) of finite subjective time duration and this makes possible structured subjective memories (for instance, it becomes possible to remember the digits of a phone number).

The thermodynanical expression for dE suggests a general classification of qualia consistent with the "holy trinity" of existences implied by TGD. Emotions - such as pain and pleasure - can be identified as order-disorder qualia with the sign of the gradient of negentropy associated with negentropic entanglement defining the coloring of emotion. Kinesthetic qualia are associated with generalized forces: senses of force and torque, hearing, and intensity of color sensation would serve as examples. Generalized chemical qualia correspond to flows between two sub-systems for various quantum numbers such as those associated with charged particles, ions, molecules, Cooper pairs, etc. Chemical qualia and color vision would serve as examples. The fermionic generators of super-conformal algebras and states created by them are labeled by binary digits labeling spin like quantum numbers, whose increments could give rise to Boolean consciousness with intrinsic meaning ("This is true"). The flows associated with these binary digits could define Boolean qualia.

The recent formulation of NMP - weak form of NMP - suggests strongly an optimistic analogy of thermodynamical world view. Strong NMP would demand maximum entanglement negentropy gain, and would be in case of dark matter almost deterministic principle. The weak form of NMP allows also reductions in which negentropy gain is not maximal and the negentropy of the final state can also vanish meaning vanishing entanglement entropy [K73]. At first glance TGD Universe looks like a diametrical opposite of the standard Universe. Negentropic entanglement is generated continually and entanglement negentropy increases in statistical sense and life evolves spontaneously and unavoidably. Only the analogs of thermodynamical fluctuations can perturb this trend and imply that TGD Universe is not the best possible one but on the other hand make possible even larger negentropy gains as possible for the strong form of NMP. On the other hand, in standard Universe second law says that ensemble entropy (to be distinguished from entanglement entropy) increases and life is a thermodynamical fluctuation doomed to disappear eventually. Note that second law holds in TGD Universe for processes in which visible matter is not permanently transformed to dark matter.

One can consider the possibility that the thermodynamical relationships could be written by replacing entropy in thermodynamical formulas by entanglement negentropy. The formal structure would remain the same but interpretation would be completely different. Quantum critical systems would be those in which dark matter with large h_{eff} is generated and gives rise to long range quantum fluctuations. An interesting question is whether also thermodynamical criticality could involved generation of large h_{eff} phases [**?**].

9.1.3 Spectroscopy Of Consciousness

The quantum correlates of sensory qualia suggest what might be called spectroscopy of consciousness. The original working hypothesis was that EEG frequencies correspond directly to various qualia but it seems that this assumption must be replaced with a less restrictive one.

The idea is that EEG (or ZEG, WEG, or GEG) MEs can be assigned with entanglement of a sub-self of magnetic body with sub-self of biological representing various mental images. That sub-selves can entangle with selves remaining themselves unentangled is one aspect of the generalized notion of sub-system and inspired by the hierarchy of space-time sheets allowing to identify the space-time correlate for this kind of entanglement as join along boundaries bonds connecting space-time sheets representing the sub-systems of disjoint space-time sheets. The entanglement in question could be in cyclotron degrees of freedom, charge entanglement, or color entanglement. An

open question is whether this kind of entanglement is possible only for sub-selves characterized by a smaller value of $\hbar$ than self, or always when topologically condensed sub-system is characterized by a smaller value of p-adic prime and separated by a light-like causal horizon from the larger system.

Although EEG and its generalizations seem to serve communication and control purposes rather than representing qualia directly, the notion of spectroscopy of consciousness makes still sense. Furthermore, the identification of the fractal hierarchy of EWEGs and GEGs means a dramatic generalization of this notion making precise quantitative predictions in a huge range of frequency scales resulting by simple scaling from [J70] [K37] . The model allows to assign the frequencies $nf_c \pm f_J$ (f_c is cyclotron frequency and f_J Josephson frequency) with the communications of sensory data to magnetic body and frequencies nf_c with the quantum control performed by the magnetic body. For ordinary EEG the harmonics of cyclotron frequencies of bosonic ions correspond to alpha band and its harmonics assignable to quantum control. Beta and theta bands and their analogs for the harmonics of alpha band correspond to the communication of sensory and cognitive data to the magnetic body. The rough correlations of EEG with the state of consciousness can be understood. The challenge would be to identify detailed EWEG and GEG correlates of sensory experience, emotion, cognition and memory and only the first partially misguided attempts in this direction have been made.

One of the first ideas was a possible connection of the theory of the various magnetic qualia with place and time coding with atomic and nuclear spectroscopy. The correspondence with nuclear spectroscopy is not promising since spin remains invariant in the phase transition to dark matter and if dark matter is at the same temperature as the ordinary matter, spin is thermalized and only cyclotron degrees of freedom are relevant. Spontaneous magnetization could of course change the situation.

Second idea was that the structure of the periodic table could reflect directly itself in the spectroscopy of consciousness. This would mean that various full electronic shells (He, Ne, Ar, Kr, Xe) would correspond to a hierarchy of magnetic qualia relating directly with the band structure of EEG. The periods also seemed to correlate with the five-layered structure of sensory cortex (primary, secondary, etc... areas). The objection against this vision is that biologically important ions must be bosons since only they can form Bose-Eistein condensates. Most of the biologically relevant bosonic ions have cyclotron frequencies in alpha band and this leads to a successful prediction of the band structure and of the narrow resonance bands. The correspondence with the periodic table must be given up unless exotic ions of bosonic atoms (also bosons) are allowed. Exotically ionized bosonic ions (say dark $Ca^{++,\pm}$) are necessary in the model of nerve pulse and result in the charge entanglement by W MEs, which suggests that they are indeed present.

Apart from scaling the spectrum of super-symplectic transition frequencies is constant of Nature if MEs have preferred length scales given by p-adic length scale hypothesis. This leads to powerful predictions and theory is immediately testable. One can indeed identify the basic resonance frequencies associated with EEG as lowest frequencies of this kind. Furthermore, the lower bounds of EEG bands correspond to the fundamental frequencies of super-symplectic transitions assuming p-adic length scale hypothesis. Dark matter hierarchy predicts scaled up variants of these frequencies.

A fascinating possibility is that super-symplectic generators generating the algebra are labelled by zeros of Riemann zeta so that their number is infinite. The generic state would have conformal weight which is linear combination of zeros of zeta. Conformal confinement would hold true and there are two alternatives: the real part of total conformal weight equals to 1/2 or its imaginary part vanishes. The first case could correspond to energy and second case to mass squared as observable. In the first case the number of "energy" qualia would be infinite. Energy metabolism is fundamental and the qualia associated with it could be "energy" qualia.

Also now the representations associated with various p-adic length scales seem to correlate with the hierarchy formed by the areas of the sensory cortex. Recall that p-adic length scale hypothesis and its generalization stating that p-adic primes, which are near but below powers of any prime are favored follows now from NMP and strong form of holography. Strong form of holography allows to realize number theoretical universality in terms of string world sheets and partonic 2-surfaces (briefly 2-surfaces) by continuing them to 4-D preferred extremals and assuming that the parameters characterizing the 2-surfaces belong to an algebraic extension of rationals.

Without exaggeration, spectroscopy of consciousness could be for brain science what atomic

spectroscopy has been for physics and chemistry. It is somewhat astonishing that this possibility has not been noticed before. After all, spectral lines provide extremely effective, reliable and universal way to code information and brain is the most refined information processing system we know. Ironically, brain modellers busily mimicking EEG numerically know that EEG correlates strongly with mental state but do not still notice the enormous information storage potential of EEG spectrum. This is perhaps the most dramatic example of the power of the scientific prejudices ("there is no evidence for the importance of quantum effects in brain length scale") to hinder seeing the truth staring directly at our face in its full simplicity and beauty. It is also ironic that so many quantum consciousness theorists spend their time by speculating about quantum gravitational Planck length scale basis of consciousness without realizing that spectroscopy is the most important practical outcome of quantum theory and EEG is the most obvious place to search for this kind of spectroscopy.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

9.2 General Vision About The Quantum Correlates Of Qualia

In this section a general theory providing overall view about the identification of the quantum correlates of qualia is developed. Hard trial and error experimentation with concrete models for the identification of qualia has gradually led to a vision about fundamental physics and general principles behind qualia. Several questions remain still unanswered but it seems that following general vision deserves testing and further development.

1. Qualia can be divided into two classes: discrete, non-geometric, quantal qualia on one hand, and "classical", geometric or what might be called zero mode qualia on the other hand and measured in the quantum jump. Discrete qualia correspond to quantum jumps defined by the non-diagonal generators of two super algebras. Super Kac-Moody algebra is responsible for the standard elementary particle quantum numbers and the super-symplectic algebra defining the group of isometries for the WCW . Thus quantum measurement theory dealing with the diagonal generators fuses with the theory of non-geometric qualia dealing with the non-diagonal generators.

2. Zero modes can represent various types of geometric information, say position, orientation or more general information about size or shape. Certain subspace of zero modes defines as a coset space a flag-manifold whose points characterize the possible choices of the quantization axes. Flag-manifold coordinates are naturally mapped into magnetic field configurations which in turn determine magnetic transition frequencies. Averages of the increment of the zero modes are experienced but sub-selves make possible to have temporally structured experiences especially important for hearing.

3. Place and time coding is important part of the theory. When EEG frequency (note that there is hierarchy of EEGs and its weak and colored generalizations involved) corresponds to a particular magnetic transition frequency, magnetic transitions in corresponding part of the linear cortical structure occur and induce quantum phase transition waking up mental image giving rise to a sensation that something exist in that particular spatio-temporal position. The sensation about movement of an object of perceptive field and perhaps even the sensation about the rate of time flow result automatically when the mental image moves along the linear spatiotemporal structure.

4. Each quale corresponds to some quantum jump serving as a seed of quantum phase transition for macroscopic quantum phases in quantum critical spin glass state. The assumption that primary sensory organs are the seats of the sensory qualia has turned out to provide the simplest view about sensory experience, imagination, and dreams. Assuming quantum entanglement between sensory organs, brain, and magnetic bodies one can avoid various objections against this scenario. This leaves a lot of room for more detailed identifications. The magnetic transitions for ions in Earth's magnetic magnetic fields are good candidates

for quantum transitions associated with the sensory qualia. Visual colors could correspond to increments of color quantum numbers.

5. Music metaphor in its recent form states that primary sensory organs contain the music (also neurons are probably sensory experiencers but these experiences would not be ours) and nerve pulse patterns and membrane oscillations are the notes. Thus brain would construct symbolic and cognitive representations rather than direct sensory experiences.

   EEG MEs would entangle the mental images at magnetic body and in brain and sensory organs. EEG patterns could be also seen as providing a representations for the notes of the music produced by sensory instrument. The function of nerve pulse patterns is to resonantly excite EEG frequencies entangling brain with the magnetic body and to induce magnetic transitions amplified into quantum phase transitions. The frequencies of many of these transitions can be predicted. Essential prerequisite is quantum criticality of the quantum spin glass phases associated with supra phases.

6. The observation that quantum TGD implies quantum measurement theory meant also a breakthrough in the theory of qualia. The localization in so called zero modes is equivalent with the quantum measurement. The cascade of self measurements whose non-deterministic dynamics is governed by Negentropy Maximization Principle [K73] gives rise to the state preparation process leading to a completely unentangled state serving as the initial state of the next quantum jump. Self defines a statistical ensemble as the set of unentangled prepared states resulting in quantum jumps. The statistical description of this ensemble is assumed to provide the description of qualia. It seems that statistical description applies also to the geometric qualia determined by the increments of zero modes. The quantum correlates of the qualia are assumed to correspond very closely to the primary causes of the qualia (for instance, the sensation of force corresponds to the gradient of momentum of some sub-self with respect to subjective time).

Conscious experience is assumed to depend on the increments of zero modes and quantum numbers are assumed to be experienced consciously but to not contain information about the transition to which these increments are associated. One could argue that this is too strong an idealization since quantum jump has complex anatomy and there is also an infinite variety of quantum jump anatomies with no change in quantum numbers.

Qualia can be divided into three basic types: the kinesthetic qualia (determined by increments of Poincare, color and other basic quantum numbers) in quantum jumps; the qualia corresponding to the increments of various kinds of particle numbers (say chemical qualia) and topological quantum numbers; and the entropic qualia relating to information flows associated with the sequence of quantum jumps. The connection with the statistical physics suggests that the average over the increments of the quantum numbers for the sequence of quantum jumps defining the self is experienced consciously. Sequences of sub-selves (mental images) however are experienced separately and this makes possible a temporally structured experience, so that the words of a sentence are experienced separately rather than as an average.

9.2.1 What Qualia Are?

Before going to a detailed model it is useful to pose the question what qualia are. The final answer (as it seems at this moment) to this question provided by the statistical physics analogy has emerged only gradually and in the following this development of ideas is summarized.

Qualia as quantum phase transitions and as discharges of quantum capacitor

In TGD framework the meaning of the primary quale is associated with the mental images created by the self-organization process. If the quale corresponds to an average increment of quantum numbers or zero modes in a long quantum jump sequence, the quantum jump with same increment must occur repeatedly. This picture makes for sub-selves and was inspired by the standard view about state function reduction.

A more recent view inspired by ZEO is that qualia correspond to flows of quantum numbers between two subsystems at the boundaries opposite to the fixed boundary of CD at which state

function reduction does not affect the state. Zero energy stat involves actually quantum superposition of these boundaries or equivalently, of CDs with fixed light-cone boundary containing the second boundary. This picture was actually deduced before the realization that self corresponds to sequence of state function reductions at same boundary of CD.

One can imagine at least two mechanism inducing qualia.

1. Quantum phase transition producee qualia

Quantum phase transition in which single particle transition occurs coherently for some macroscopic quantum phase produces qualia defined by the increments of quantum numbers in the transition. Quantum phase transition could be induced by the transition frequency: quantum phase transition leading to the generation of new kind of macroscopic quantum phase is in question. Transition frequencies themselves as such serve as symbols initiating this process, much like subprogram call initiates subprogram. They act like the name of dog: when dog hears its own name, dramatic self-organization process is initiated. In ZEO this self-organization process is 4-dimensional. Entire temporal patterns for fields are replaced by new ones in the size scale of CD in the process.

Music metaphor suggests that only the ratios of transition frequency to, say, cyclotron frequency can code for qualia. Only the ratios of Larmor and cyclotron frequencies and Super Virasoro frequencies and the intensities of the Fourier components for various harmonics can affect self-organization process. Furthermore, quale together with its emotional aspects depend on a simultaneous occurrence of several quantum phase transitions induced by the EEG pattern containing several magnetic transition frequencies. For instance, sensation of pain probably involves both the fundamental Super Virasoro transition frequency inducing primary quale and harmonics of this frequency at least partially responsible for the emotional aspects of pain.

2. Discharge of quantum capacitor produces qualia

The flow of particles with fixed quantum numbers between "electrodes" of what might be called a quantum capacitor induces qualia defined by the quantum numbers of the particles involved. The "electrodes" carry opposite net quantum numbers. Second electrode corresponds to the sub-self defining the quale mental image. Obviously cell interior and exterior are excellent candidates for the electrodes of the quantum capacitor. Also neuron and postsynaptic neuron. In fact, living matter is full of electrets defining capacitor like structures. The model of sensory receptor as a quantum capacitor will be discussed later. The model applies to various chemical qualia and also to color vision and predicts that also cells should have senses. Ordinary cells would sense only the nearby chemical environment whereas neurons would experience via synapses also representations of external world chemically: at our level of conscious experience these representations could give rise to emotions. The strange behavior of ionic currents leads to the view that even ionic channels and pumps are actually ionic and voltage receptors.

3. "Final" solution to the problem of qualia

The TGD inspired theory of qualia [K50] has evolved gradually.

1. The original vision was that qualiaandother aspects of consciousness experience are determined by the change of quantum state in the reduction: the increments of quantum numbers would determine qualia. I had not yet realized that repeated state function reduction (Zeno effect) realized in ZEO is central for consciousness. The objection was that qualia change randomly from reduction to reduction.

2. Later I ended up with the vision that the rates for the changes of quantum numbers would determine qualia: this idea was realized in terms of sensory capacitor model in which qualia would correspond to kind of generalized di-electric breakdown feeding to subsystem responsible for quale quantum numbers characterizing the quale. The Occamistic objection is that the model brings in an additional element not present in quantum measurement theory.

3. The view that emerged while writing the critics of IIT of Tononi [K123] is that qualia correspond to the quantum numbers measured in the state function reduction. That in ZEO the qualia remain the same for the entire sequence of repeated state function reductions is not a problem since qualia are associated with sub-self (sub-CD), which can have lifetime

of say about .1 seconds! Only the generalization of standard quantum measurement theory is needed to reduce the qualia to fundamental physics. This for instance supports the conjecture that visual colors correspond to QCD color quantum numbers. This makes sense in TGD framework predicting a scaled variants of QCD type physics even in cellular length scales.

This view implies that the model of sensory receptor based on the generalization of dielectric breakdown is wrong as such since the rate for the transfer of the quantum numbers would not define the quale. A possible modification of the model simple: the analog of dielectric breakdown generates Bose-Einstein condensate and the quantum numbers for the BE condensate give rise to qualia assignable to sub-self.

Non-geometric and geometric qualia

Various types of quantum phase transitions are natural candidates for qualia. In accordance with *"Where-What"* decomposition of brain information processing, one can decompose qualia into geometric ("Where" and "When": position, orientation, ...) and non-geometric ("What": colors, tastes, ..) qualia.

Geometric qualia correspond to the zero modes of WCW in which a localization takes place in each quantum jump. An objection against the notion of geometric qualia is that the choice of the quantization axes changes in each quantum jump and it is not therefore sensible to speak about the change of quantum numbers. For a given change of quantization axes one can however assign to the final state of the quantum jump unique color and spin quantum numbers so that the increment is also unique although the "coordinate frame" can change. Perhaps one should interpret the change of the quantization axes as a discrete quantum version of parallel translation. For the asymptotic states of self-organization the values of the zero modes are expected to approach to the values associated with a maximum of Kähler function so that the choice of the quantization axes becomes stationary.

Non-geometric qualia correspond to non-zero modes and hence to quantum jumps between states of super-symplectic and Super Kac-Moody representations. This suggests that non-geometric sensory qualia can be classified at brain level into super-symplectic qualia and Super-Kac Moody qualia.

1. Super-symplectic qualia are higher level qualia in the sense that quantum jump occurs at the level of the entire WCW rather than at the level of space-time only. The quantum number increments (spin and color quantum numbers) associated with BE-condensing super-symplectic boson characterize the quale. BE-condensation occurs for " WCW photons" rather than ordinary photons whose WCW dependence is characterize by color $SU(3)$ and spin quantum numbers.

2. Magnetic qualia could be much more primitive (perhaps kinesthetic qualia). Endogenous NMR or its generalizations could give rise to entire spectrum of magnetic qualia. Geometric data from external can be coded to zero modes of MEs, in particular the position and other geometric characteristics of sub-self (ME) representing an object of the perceptive field. Most naturally the portion of a magnetic flux tube at which ME is glued to the magnetic flux tube codes the information classically to the properties of ME, especially the light-like vacuum current and classical gauge fields associated with it. Note that this picture leaves open the identification of emotional qualia which seem to something different from sensory qualia.

The entire isometry algebra consists the function algebra of $E^2 \times CP_2$ associated with ME localized with respect to the light-like coordinate of the light-like M^4_+ projection X^3 of the light-like boundary of ME and having well defined conformal weights. This algebra is essentially the function algebra of boundary $X^3 \times CP_2$. Each element of this algebra defines Hamiltonian depending parametrically on the radial coordinate. This algebra must extended by the CP_2-localized radial Virasoro algebra of the light-cone boundary to achieve Lorentz invariance. Hamiltonians have conformal weight which is integer valued. Odd integer valued Hamiltonians correspond to non-zero modes whereas even-integer valued Hamiltonians correspond to zero modes. In particular, the Hamiltonians which do not depend on the radial coordinate of the light-cone boundary and have thus vanishing conformal weight correspond to zero modes [K30].

These canonical transformations specify a very general set of choices of quantization axes.

The most general choices of the quantization axes for the canonical $E^2 \times CP_2$ sub-algebra of zero modes are parameterized by the infinite-dimensional flag-manifold defined as the coset space of the canonical group of zero modes and Cartan group of $O(2) \times SU(3)$. Thus the localization in zero modes means also a choice of the quantization axes. Since zero modes characterize macroscopic geometry of the space-time surface, this localization makes the world of the conscious experience classical.

The monomials in the enveloping algebras of the super-symplectic and Super Kac-Moody algebras defined by WCW isometries is the most general candidate for the algebra defining the possible increments of quantum numbers. Primary discrete qualia would correspond to non-diagonal generators of this algebra. Super algebras have decomposition into bosonic and fermionic parts and the first thing coming into mind is that bosonic generators correspond to generalized sensory qualia and fermionic generators to Boolean qualia. This algebra decomposes into zero mode and non-zero mode parts and one should decide which parts give rise to which qualia.

1. The algebra of non-zero modes is obtained by localizing zero mode super-symplectic algebra with respect to the light-like coordinate coordinate of the light-like boundary of ME so that the generators are labelled by super-symplectic conformal weight n which does not contribute to mass squared. This supports super-symmetric option: ordinary Lie-algebra generators which act like creation and annihilation operators correspond to complementary pairs of sensory qualia. The pairs of the fermionic generators correspond naturally to Boolean qualia with opposite truth values. The meaning and content of the Boolean statement should be determined by the non-geometric sensory quale associated with the corresponding bosonic generator.

2. Fermionic counterparts of the canonical zero norm generators in zero mode degrees of freedom have zero norm since gamma matrices have vanishing anti-commutators in these degrees of freedom. One might think that also the bosonic generators generate zero norm states. This is however not the case: infinitesimal isometries of the embedding space do not correspond to pure gauge degrees of freedom. This is in fact the property that distinguishes zero mode symmetries from pure gauge transformations.

3. The interaction of super-symplectic algebra states with the classical gauge fields associated with ME induces quantum jumps. In the lowest order of perturbation theory the interaction must be linear in the generators of SCA. As higher order terms of perturbation theory become significant, also transitions generated by the higher powers of Lie-algebra generators occur with a considerable rate and enhance the experienced intensity of the quale and give rise to transitions not possible in the lowest order.

Comparison with ideas of Noe and Regan

Quite generally, discrete non-geometric sensory qualia (such as colors) must correspond to the changes of the quantum numbers in quantum jumps serving as seeds of quantum phase transitions of the quantum critical macroscopic quantum phases combining to form quantum spin glass phase. This allows to interpret the sequence of quantum jumps giving rise to a quale as a process analogous to what we do when we explore room in total darkness or what physicist does when she studies an unknown system by perturbing it slightly again and again and finding the reaction. The "world of classical worlds" character of super-symplectic states corresponds to this idea at the level of physical states.

Lie-algebras mathematize the notion of infinitesimal change (small perturbation) induced by symmetry transformation and thus they are expected to characterize fundamental qualia. The reduction of non-geometric qualia to the representations of Super Kac-Moody and super-symplectic algebras [1], the latter being related to the isometries of WCW of 3-surfaces and acting at the light-like boundaries of MEs, seems indeed possible. What is nice that super generators of the algebra could correspond to Boolean "this is true" qualia in one-one correspondence with sensory qualia.

[1] Super-conformal and related super algebras are generalized Lie-algebras introduced in seventies and are encountered in both super string models and TGD.

Poincare algebra is closely related to the Super Kac-Moody algebra. A natural expectation is that the increment of momentum should basically characterize the qualia induced by forces and torques (pressure sense, and sensations caused by ordinary and angular acceleration).

This interpretation is extremely general and implies that quantum TGD and also super Lie-algebra theory at basic level is theory of the fundamental discrete qualia. The unexpected feature is the assignment of qualia to non-diagonal generators rather than diagonal ones as quantum measurement theory would suggest. The notion of quantum jump between quantum histories however provides full support for this interpretation. The realization of the importance of the non-diagonal creation and annihilation operator like generators of Lie-algebra took surprisingly long time although the moment of consciousness is basically nothing but creation of something new and annihilation of something pre-existing. The possibility to understand the special features of color vision, such as the phenomenon of complementary colors and color contrast supports the general idea.

This view is in some aspects consistent with the view represented in the article of Regan and Noe [J144]. The authors do not believe in qualia as properties of the external world and speak about sensory modalities only. To avoid confusions, it is important to make clear that in TGD qualia and sensory modalities are used interchangeably: qualia are not properties of single quantum history but are identified as mental images generated by self-organization processes involving huge number of quantum jumps between quantum histories.

The approach adopted in [J144] relies on experimental data about vision and states that sensory modalities can be characterized, not as properties of the world, but as modes of exploration of the world that is mediated by knowledge of what the authors call sensorimotor contingencies. More concretely, sensory experience can be identified as exploratory activity, much like feeling by fingers what the object of the tactile field is like. The structure of this exploratory activity determines the quale. What happens is that object of external world, or rather, the system consisting of observer and object of the external world, is perturbed slightly in very manner ways and this gives rise to the sensation about shape of object. The study of the responses generated by small perturbations is very much what physicist does when studying unknown physical system. The fact, that is possible to "see" external world by signals by hearing or as vibratory stimulation of skin, supports this view.

For tactile senses and for macro-geometric aspects of all modalities this picture seems to make sense. It is however not at all obvious whether one can realize this vision at macroscopic level in the case of, say, color vision. In TGD framework entire physics reduces to WCW geometry and classically the system representing perceiver and external world corresponds to 3-surface X^3 which can be regarded as a point like object moving in infinite-dimensional WCW . The metaphor for active tactile sensing process could make sense at more abstract level as deduction of the position of system + perceiver 3-surface X^3 in configuration space. This process is deducing the shape of a stone by giving it small kicks. X^3 corresponds in good approximation minimum for the negative of Kähler function and sensory experience is determined by the depth and shape of the bottom of the valley of the spin glass energy landscape. In this self-organization process consisting typically of $N \sim 10^{39}$ kicks per second, the experiences created by kicks would be summed up to average experience giving a conscious view what the surroundings of object look like. This metaphor applies to the sensing of the internal state of observer itself and could involve active perturbation of parts of CNS and receiving of the response.

It is interesting to see how this picture relates to the capacitor model of sensory receptor and to the model of nerve pulse [K97] .

1. The capacitor model for sensory receptor assumes that a generalized discharge results as the charge of the other "capacitor plate" changes and crosses the threshold for the occurrence of discharge.

2. In the case of cell membrane a reduction of the magnitude of membrane voltage below criticality would be in question. W ME induces charge entanglement between magnetic body and neuron interior (second plate of the capacitor) and a quantum superposition of states "no nerve pulses" and "nerve pulse".

3. Magnetic body shares the mental images created in brain via entanglement of sub-selves. From the point of view of magnetic bod the sub-self represented by the entangled state

experience is superposition of "no nerve pulses" and "nerve pulses" states so that conscious experience could in principle involve also the comparison aspect. This comparison aspect could explain why rational entanglement can carry positive information (recall that the p-adic variants of Shannon entropy can be negative). It must be emphasized that the comparison aspect would be due to the sharing of mental images.

4. Multiverse state would be the quantum counterpart of the small perturbation created by the magnetic body curious to get information about the state of biological body by perturbing and comparing. The remote modification of the charge density inside neuron at the "nerve pulse" branch of multiverse could be seen as a (remote) motor action in an abstract sense. Whether qualia quite generally involve generalized motor action creating multiverse making possible comparison remains an open question.

What about emotions?

What seems essential is that qualia involve meaning. In some cases this meaning is emotionally stronger (pain, pleasure), in some cases it is emotionally weaker (colors): in fact, it would seem that one could permute colors without changing much of the overall emotional meaning (actually colors can be distinguished by the behavior they induce [J169]). It seems that emotions give this meaning.

The previous ideas do not however give a slightest hint about how emotional content of the quale emerges. As a matter fact, the first guess was that emotions are generalized sensory qualia about the state of body and averaging over sub-selves of sub-selves could explain their single pixel nature and low information content but not the emotional quale itself. This might be part of the story since the neuronal sensory experiences created by nerve pulses at synapses at level of neuronal bodies could determine the emotions. Also cellular qualia about nearby chemical environment could contribute to emotions. The realization of the connection with statistical physics led to more concrete ideas about how emotional content of conscious experience might emerge.

Second guess is that emotions and also cognitions correspond to sensory qualia of magnetic body and perhaps correspond to higher level of dark matter hierarchy than ordinary sensory qualia. This leads to a rather concrete view about emotions and cognitions as patterns of cyclotron phase transitions induced at the magnetic body by EEG radiation consisting of dark photons. Entire fractal hierarchy of EEGs, ZEGs, WEGs, and GEGs corresponding to photons, Z^0 bosons, W bosons, and gluons and labelled by p-adic length scales and values of the Planck constant is predicted. Charged bosons could correspond in this framework to sensory qualia in the standard sense of the word whereas neutral bosons could correspond to cognitive and emotional qualia.

General classification of qualia inspired by the connection with quantum measurement theory and statistical physics

The connection between qualia and quantum measurement theory and statistical physics was the real breakthrough in the development of ideas. In some sense this finding is not a news: the close connection between pressure sense and temperature sense and thermodynamics is basic facts of psychophysics and quantum measurement theory involves in essential manner consciousness. First of all, millenium had to change before I realized that quantum TGD predicts standard quantum measurement theory. Each quantum jump can be regarded as an ordinary quantum measurement involving a localization in zero modes representing geometric information following by a state preparation procedure realized as a sequence of self measurements whose dynamics is dictated by Negentropy Maximization Principle (NMP). This suggests strongly the division of qualia to geometric qualia associated with quantum measurement part of quantum jump and non-geometric qualia associated with the state preparation stage.

In TGD framework the contents of consciousness is determined as some kind of average over the sequence of a very large number of quantum jumps defining self. This suggests that qualia allow a statistical description generalizing ordinary thermodynamical ensemble to the ensemble formed by the prepared states in the sequence of quantum jumps after the last "wake-up" of self. This ensemble is dynamical since each quantum jump generates a new member in the ensemble. In standard statistical physics the notion of ensemble is only a fictive concept but in the ensemble defined by self would be the fundamental statistical ensemble realized at the level of subjective

existence. Therefore consciousness theory would provide foundations of both quantum measurement theory and of statistical physics. Before continuing, notice that this picture allows to see the aging of self with respect to subjective time as a universal phenomenon resulting from an approach to thermal equilibrium. Getting tired would be only one aspect of the same phenomenon. Also mental images should age and this would correspond to gradual loss of the sharpness of the mental image.

Quite generally, one can divide qualia to the geometric qualia characterized by the increments of the zero modes, to the generalized kinesthetic qualia characterized by the increments of Poincare, color and electro-weak quantum numbers, to the generalized chemical qualia labelled by the increments of various particle numbers, such as the numbers of ions or Cooper pairs in various magnetic states and the topological quantum numbers characterizing the topology of the many-sheeted space-time surface, and to the information theoretic qualia characterized by entropy gradients. Besides the gradients of the state variables with respect to subjective time for the statistical ensemble determined by the quantum jumps, also the values of the state variables themselves contribute to the contents of conscious experience. It would thus seem that the theory of qualia reduces to statistical physics and one can expect rather concrete correspondences between sensory inputs and their quantum correlates. In particular various physical metaphors for conscious experience might find a justification in this approach.

9.2.2 Classification Of Qualia In Thermodynamical Framework

Consider now the general classification of qualia in this conceptual framework.

Do qualia depend on the averages of quantum number increments only?

Functionalism, which has been one of the dominating views in neuroscience, states roughly that the contents of consciousness of system is determined solely by its functional structure. The analog of this hypothesis in TGD framework states that the contents of consciousness are determined completely by the increments of zero modes, quantum numbers and particle numbers in various quantum jumps in context independent manner. This hypothesis has very strong implications and internal consistency requirements make possible to test it. For instance, kinesthetic qualia characterized by the increments of Poincare, color and electro-weak quantum numbers would be universal and would not depend on the system to which they are associated.

1. All quantum phase transitions involve frequency increments. Therefore, if hearing is frequency quale and if energy and frequency increments are equivalent, some kind of auditory sensation should be involved with all sensory experiences. The fact that EEG frequencies cover only a small part of the range of audible frequencies, the weakness for the intensity of this sensation could explain why visual and other experiences do not involve sensation of hearing something. One could also argue that the background noise always present in auditory experience actually corresponds to the contribution from other senses.

   Also deaf persons should experience some kind of auditory sensation, kind of background noise, if this view is correct. Interesting question is whether this sensation is present if person is made cortically deaf in an artificial manner. One must of course be very cautious here: it might be that this sensation relates only to the dynamical nature of hearing: several qualia, such as pain, have similar time-like nature.

2. The increments of various quantum numbers in magnetic quantum phase transitions would yield similar sensory experiences, generally kinesthetic experiences.

The connection of the theory of qualia with the statistical physics suggests that self experiences some kind of average over the experiences associated with the quantum jumps of sub-self but self itself at highest dark matter level corresponds to single moment of consciousness. Thus averages of the increments of zero modes and various quantum numbers would dictate the contents of mental images. This would in general mean that the approach to a thermal equilibrium would make conscious experience increasingly diffuse when sub-self (mental image) ages unless sub-self is able to fight against second law. Macro-temporal quantum coherence allows to circumvent the

pessimistic conclusion that every mental images in the human time scale of order.1 second consists of about 10^{38} quantum jumps and should be completely fuzzy as a statistical average. Note also that dark matter hierarchy implies hierarchy of average geometric durations of moments of consciousness.

If averages over the increments of zero modes are experienced this implies that kind of a zigzag curve defined by the averages of the increments of the zero modes formed by sub-selves is experienced consciously but not the initial point of this curve. Kind of a principle of relativity at the level of conscious experience would be in question. In fact, it is very difficult to imagine, how zero modes as such could be experienced. For instance, the huge symmetries involved would make it impossible to experience differently symmetry related points. Note that also in physics one can measure only changes of the observables, rather than observables themselves. The fact that conscious observation of visual textures (say lines) is not possible without saccadic motion is consistent with the assumption that only the increments of the zero modes are experienced consciously. The assumption that intersections of the line sight with lines of figure are time coded is consistent with the assumption that short time averages of zero mode increments are coded to sub-selves.

The fact that position and momentum are quantum incompatible qualia seems to be incompatible with the belief that we experience these geometric qualia simultaneously. One could think that it could be possible to circumvent Uncertainty Principle at the level of conscious experience by using the fact that the velocities that we observe are not velocities with respect to geometric time but with respect to subjective time. This is not the case if we experience only the increments of the zero modes which are analogous to momentum variables. The presence of sub-selves each representing some average value of a zero mode increment make it possible to have an idea about continuous path in zero modes which, in accordance with Uncertainty Principle, is however determined apart from a shift in the space of zero modes.

Various types of non-geometric qualia

As found, one can classify qualia into geometric and non-geometric qualia. Geometric qualia correspond to the increments of zero modes expressing the result of quantum measurement in each quantum jump. All geometric information about space-time surface should reduce to geometric qualia. For instance, geometric data given by visual, auditory, and tactile senses should reduce to conscious information increments of zero modes in the quantum jump. Non-geometric qualia correspond to the preparation of state stage of the quantum jump during which zero modes remain constant.

The sequence of the prepared states can be modelled as a statistical ensemble of Fock states, which suggests that thermodynamics, which like quantum measurement theory is a black sheet of fundamental physics, forms basically a part of the theory of consciousness. The ensemble of prepared states gives rise to a large number of statistical qualia. The relationship $dE = TdS - PdV + \mu dN + B \cdot dM...$ generalizes to TGD context: note however that in the case of ME selves energy is replaced with the Super Virasoro generator L_0 associated with the light-cone boundary of ME, which for super-symplectic representations need not annihilate the physical states. Each intensive-extensive variable pair in the differential should correspond to a non-geometric quale, which results only when there is gradient (flow) of the extensive variable in the direction of the subjective time. Super-symplectic thermodynamics should obviously map ordinary thermodynamics to the level of conscious experience.

The thermodynamical expression for dE suggests a general classification of qualia consistent with the "holy trinity" of existences implied by TGD.

1. Emotions as order-disorder qualia

$T - S$ pair correspond subjective existence and generalizes to disorder-order type, information theoretic qualia qualia about the state of self: hot-cold and pain-pleasure type sensations and also more abstract experiences associated with various sub-selves of self. These qualia are strongly emotional single-pixel holistic qualia measuring whether some kind of an entropy variable is increasing or decreasing. Also zero modes define a statistical ensemble and these geometric emotional qualia might be about external world: perhaps aesthetic experiences and other "non-self-centered" emotions could be in question. The total entropy for the statistical ensemble defined by self de-

termines how sharp the mental image is. Low entropy content means alertness and attentiveness. High entropy content means fuzzy mental image. Getting tired means inability to keep mental images in low entropy state. Fighting against the second law is an essential part in the martial art of having sharp conscious experiences.

2. Kinesthetic qualia defined by generalized forces

p-V pair corresponds to the geometric existence and is replaced with generalized force-generalized coordinate pairs in quantum fluctuating degrees of freedom. The increments of maximum number of mutually commuting Poincare, color and electro-weak quantum numbers define this kind of qualia. The increments of four-momentum code for the sensation of force whereas the increments of orbital angular momentum code for the sensation of torque.

Tactile senses such as pressure sense and their generalizations involve kinesthetic qualia. The increment of energy or equivalently, increment of frequency, can be identified as a correlate for hearing in generalized sense responsible for the essentially dynamical nature of the auditory experience (hearing is time-like version of force sense). Whether spin flip codes something different from torque, and what this something different might be, is not obvious. I

The rate for the increase of the two diagonal color quantum numbers should code intensity type variables associated with color sensation. At least the intensity of color is this kind of variable. The rate for the increase of electric charge of sub-self should code for electric sense possessed by, say, fishes. Also $B-M$, $\phi\rho$ and $E-P$ pairs correspond to generalized forces since electromagnetic fields are reduced to space-time geometry in TGD framework.

3. Generalized chemical qualia

$\mu - N$ pair corresponds to "objective existence" defined by quantum histories with N being generalized to a number of particle like excitations in the Fock state resulting in the state preparation. In this case there must be a flow of particle number in the direction of the subjective time, that is Bose-Einstein condensation type process for, say Cooper pairs. That is the particle number of sub-self increases or decreases. Quite generally, super-symplectic and Super Kac-Moody algebras should define these qualia and the number of these qualia is very large.

1. One can assign particle numbers to super-conducting phases with various magnetic quantum numbers and these could define generalized chemical qualia. They could perhaps be regarded as qualia and subqualia of chemical qualia defined by a particular ion and chemical qualia could actually reduce to magnetic qualia. Since the changes of the magnetic field induce these quantum phase transition, it would seem that magnetic magnetic quantum phase transitions at super-conducting magnetic flux tubes could induce this kind of qualia besides kinesthetic qualia. In principle, endogenous NMR and its generalizations induced by the interaction of magnetic fields of MEs with magnetic magnetic flux tube structures are possible.

   Our chemical qualia could correspond to the Bose-Einstein condensation of ions to the super-conducting magnetic flux tubes. The paradigm of four-dimensional brain allows even the possibility that these ions are ions of the tastant or odorant. Also secondary representations at the level of cortex in terms of super-conducting light ions are possible and would give rise to a classification of primary tastes and odors. Magnetic qualia are characterized by definite transition frequencies and this makes possible place (time) coding by magnetic transition frequencies if magnetic field varies along magnetic flux tube (is a function of time). The activation of a point of the living sensory map would generate some quale at that point.

2. For super-symplectic qualia the number of Bose-Einstein condensed possibly colored " WCW photons" having nontrivial dependence on WCW degrees of freedom replaces number of molecules. The condensation rates for the numbers of the configuration space photons with non-vanishing color quantum numbers could be interpreted as correlates of color qualia, whereas the condensation rates for color singlet WCW photons could relate to the intensity of color sensation. If the rates for the transfer of color quantum numbers define intensity type variables associated with the color sensation, then BE condensation to color singlet states does not give rise to experienced quale so that only non-diagonal color generators correspond to visual colors. Also the BE condensation of the ordinary coherent light should give rise to some kind of quale: perhaps vibratory sense which can be developed to effective vision,

could correspond to non-colored vision. Configuration space Hamiltonians are also labelled by 2-dimensional orbital spin quantum number and longitudinal momentum. Polarization sense and sensation about motion of the object of visual field would naturally relate to spin and longitudinal momentum.

3. Tactile senses involve topological phase transitions involving the creation of flux tubes between object and skin whose number would thus be the relevant variable. The purely sensory aspect of physical pain could correspond to a topological phase transition involving the splitting of join-along boundaries bonds between space-time sheets (MEs could even define these bonds) so that N would be now the number of flux tubes. The simplest picture requires that the MEs associated with sensory organs are connected to the MEs responsible for our experience. Of course, splitting and generation of flux tubes could occur also at the level of sensory representations.

4. Boolean qualia

Boolean qualia would be naturally associated with fermion number or fermionic spin degrees of freedom. There are super-symplectic and super-Kac Moody type Boolean qualia. The spin flipping transitions associated with the fermionic generators of super-symplectic algebra might give rise to Boolean consciousness with intrinsic meaning ("This is true/false").

Fermion number 1/0 can also represent truth value when wormhole contacts with fermion and anti-fermion at causal horizons of the wormhole contact (having interpretation as partons) are used. The assumption that only fermions/anti-fermions are associated with the "upper" space-time sheet would select automatically a maximal set of independent statements. Boolean statements could be seen as particle-antiparticle pairs living simultaneously at two space-time sheets and one might speak about "Boolean matter".

In zero energy ontology quantum states are pairs of positive and negative energy states with opposite net quantum numbers. Therefore it is possible to represent Boolean statements in such a way that fermion number represents bit. This also gives rise to a representation of Boolean rule $A \to B$ as quantum superposition of pairs of Fock states of fermions with individual instances of A and B represented by the states in the Fock basis for fermions. The basic "laws" for this system of rules would be consistent with the conservation laws.

One can argue that the experience of true/false involves always comparison. As proposed, during sharing of mental images the entanglement of two states could also involve comparison which would explain the positive information content of the rational (algebraic) entanglement in p-adic sense. If indeed so, one might think that the conscious experience that statement is true involves a comparison of the statement with a collection of the true reference statements, one half of all possible statements for a given Boolean algebra constructed from N elementary statements and having 2^{N-1} mutually consistent true statements. If true statements are represented as their negation in comparison process based on entanglement, "false" would mean that for one comparison the statement and reference statement area identical and entanglement is not possible and no shared mental image is formed. For "true" the entanglement is possible for all comparisons.

A general model for abstraction process not only explains the basic numbers of the genetic code but also suggests an entire hierarchy of codes [K52] in accordance with fractality of TGD Universe. The next code in the hierarchy is very attractive candidate for "memetic code". The hypothesis predicts correctly the .1 second time scale for the duration of "our" self (immediate short term memory, duration of psychological moment). Codewords corresponds to sequences of 126 bits with duration of one millisecond: this is indeed the time scale of nerve pulse. The most plausible realization of the codon of the memetic code is in terms of electron's CD of duration.1 s containing d quark sub-CDs of duration 1/1.28 ms representing the bits. The frequency of about 10 Hz is in EEG frequency range and also corresponds to ELF topological field quanta with size of Earth representing our cognitive sub-self. Dark matter hierarchy represents a hierarchy of durations of memetic codon coming as $T = rT_0$, $T_0 = .1$ seconds and r is integer valued.

About quantum correlates of alertness and attention

It is a matter of definition whether one can regard alertness, attention, the level of arousal, and other similar attributes of conscious experience as qualia. What is clear that they are not geometric,

sensory or emotional qualia. A possible identification for the quantum correlates of this kind of aspects of conscious experience might be based on the entropy type variables associated with the statistical ensemble defined by self. Thus also entropy rather than only its gradient with subjective time would characterize the conscious experience. Very high/low entropy would obviously mean correlate with diffuse/sharp conscious experience. Obviously macro-temporal quantum coherence would be absolutely essential for having sharp mental images. In this picture alertness would correspond to low entropy state, possibly very few mental images which would have very low entropy. Directing attention to some object of perceptive field could also be regarded as purposeful reduction of the entropy of the sub-self representing the attended mental image. For instance, the diffuse background of my computer screen would correspond to high entropy sub-self and the icon to which I am concentrating my attention corresponds to the low entropy sub-self.

Directing attention to an object of the perceptive field involves amplification type phenomenon and is seen directly as neural activity. This activity would make possible to fight successfully against second law so that the entropy of the attended sub-self would be reduced rather than increase. 7 ± 2 rule might be interpreted as stating that 7 ± 2 is the maximum number of mental images (sub-selves) which can be kept in a low-entropy state simultaneously. Meditative practices often involve concentration of the attention to some object of perceptive field: the number of mental images would be thus minimized to achieve low entropy state of pure alertness. It is interesting to compare the notions of attention and arousal. Arousal wakes-up several mental images. Highly alert state can be even empty of mental images (sub-selves). High level of arousal necessarily involves entropy growth of the mental images by 7 ± 2 rule. One form of attention deficit disorder would involve generation of too many mental images so that mental images necessary become entropic.

Getting tired and fatigue would mean the inability to keep mental images in a low entropy state. The connection with the level of metabolism is thus obvious. One function of sleep might be to "kill" mental images with long wake-up period so that they can reincarnate in a low entropy state. Without this these mental images would become more and more entropic. Sleep would be a fractal phenomenon having counterpart at all time scales: for instance, the wake-up time for sensory mental images would be of order .1 seconds.

9.2.3 Critical Questions And Open Problems

The identification of qualia involves several open questions and the best manner to proceed is to make the unclear aspects of the model as explicit as possible.

Does the brain construct meta-stable sensory maps?

Several highly interesting questions relate to sensory maps. For instance, does brain construct quasi-static sensory maps for the visual world updated continually? The view represented in [J144] is that this need not be the case, and is motivated by several empirical facts, in particular by the observations that there seems to be no visual memory besides the memory of duration of order .1 seconds. It is further argued in [J144] that external world provides the fundamental representation.

Also TGD framework suggests the possibility that the MEs connecting retinas to the object of the perceptive field might be essential for our ability to experience the object of perceptive field as a part of external world. TGD predicts that objects of perceptive field are represented as mind like space-time sheets. Where these mental images are located is a difficult question to answer but the most elegant option is that they reside at the level of sensory organs [K62]. Sensory organs have also magnetic bodies, which can serve as seats for the fundamental sensory representations. Brain would in turn construct symbolic and cognitive representations entangled with these fundamental sensory representations. These representations would entangle with mental images at magnetic bodies associated with various parts of brain so that the resulting structure would have astrophysical size.

If this is the case then the experienced position of the object of perceptive field corresponds to the position of this mind like sheet at the sensory magnetic canvas associated with eyes. Brain would somehow deduce the distances and sizes of the objective of the perceptive field and by back-projection mechanism construct the sensory representation at the level of sensory organs. Remote tactile sensing and the ability to "see" external world by vibratory sense [J144] support

the view that it is orientation-position quale which determines whether an object of perceptive field is experienced as belonging to external world or to body. Also the illusions associated with tactile senses, such as the experienced location of sensation to even dead material object of perceptive field, suggest the same. Perhaps one must make here a careful distinction between sensations about external world on one hand, and about body and body-external world boundary on the other hand.

In TGD view our eyes can be visualized as tubes connecting brain to external world and changing their orientation all the time. Through these tubes light enters to a screen representing visual cortex in a room representing head. Also head is moving and changing its orientation with respect to the external world all the time. The mind like space-time sheets representing objects of perceptive field are certainly present, but they are not static but short-lived objects, having lifetimes not longer than .1 seconds and are recreated all the time and in general in new position of the visual cortex. There is no homunculus inside this room; the experience is not computed nor do 40 Hz EEG waves in some mysterious manner give rise to experience. It is self-organization processes generated by nerve pulse patterns coming from sensory organs and generated by brain itself which give rise to qualia and magnetic transition frequencies serve as names for these processes.

Are super-symplectic qualia associated with vision only?

Super-symplectic qualia are labelled by the increments of color and 2-dimensional spin quantum numbers which for 8-dimensional basic representation correspond naturally to 3+3 basic colors and to polarization sense.

The idea that qualia should correspond very closely to the physical phenomena what qualia suggests that super-symplectic qualia are associated with vision. Light-like 3-surfaces associated with MEs provide indeed classical model for a light front and MEs themselves model geometrical optics in a well-defined sense. MEs inside MEs represent naturally light rays. Also the two-dimensionality of light-like coordinate constant section of the light-like boundary conforms with the two-dimensional nature of the visual experience. In the case of other qualia (except perhaps tactile senses) the two-dimensionality of the objects of the perceptive field is not obvious.

One cannot exclude the possibility that color Lie-algebra, as opposed to higher representations of color group, could correspond to colors, tastes and basic tactile qualia (warm, cold, pain, ..). In the case of odors, and perhaps also in the case of tactile qualia, CP_2 Hamiltonians in higher-dimensional representations of the color group would be needed to account for the large number of these qualia. One could even ask whether some emotional qualia could involve super-symplectic BE condensation type phase transitions or possible phase transition changing the direction of spin polarization of the BE condensate of WCW photons. Although the connection with thermodynamics excludes this possibility, pros and cons of this kind of identification are still worth of a detailed consideration.

1. MEs seem to correspond to the most abstract level in the control hierarchy formed by MEs, super-conducting magnetic flux tubes and ordinary matter. More precisely, super-symplectic states are state functionals in the space of 3-surfaces, "world of classical worlds" and thus correspond to a higher level of abstraction. This would suggest that our qualia should correspond to what happens on the light-like boundaries of MEs. One could however identify super-symplectic-magnetic dichotomy with spirit-flesh dichotomy so that visual experience would represent higher level sense in comparison to other senses.

2. Colors, tastes, odors and tactile qualia like cold, warm and pain allow dichotomic pairs supports the identification as discrete qualia. These good-bad dichotomies are analogous to color-complementary, which supports the view that they could correspond super-symplectic qualia. On the other hand, all sensory qualia can be accompanied by strong entropy gradients explaining positive/negative emotional aspects for qualia such as odors. For reasons of survival organism might even amplify these entropic gradients.

3. One could argue that also emotions could regarded as generalized sensory qualia and the interpretation of pure emotions coming as dichotomic pairs of complementary emotional colors does not exclude the identification in terms of SCA. Emotions involve however often also comparison aspect and this could be reduced to the geometric aspect of the generalized sensory experience represented as a flag-manifold quale representing information about

the space-time surface describing the state of body and CNS geometrically. Therefore, if emotions are accompanied by super-symplectic qualia, they represent pure emotion without any comparison aspect. Does it make sense to speak about, say, pure rage, is difficult philosophical problem.

4. Zero modes involve infinite hierarchy of CP_2 Hamiltonians grouped into representations of color group and odors should correspond to Lie-algebra generators belonging to higher representations of color group instead of octet representation. The simplest vision is that the only difference between colors and, say, odors and tastes is that the Hamiltonians belong to different representations of the color group. The prediction would be that the phenomenon of color contrast and perhaps even color constancy should have counterparts at the level of other qualia. One can argue that this kind of close structural relationship should have been observed if it is really there and tables organizing various sensory qualia neatly to the representations of color group could be found in the text books of neuroscience.

5. One can also wonder why higher representations of color algebra should be experienced so differently from the 8-dimensional representations assumed to be responsible for visual colors. This picture also requires that WCW photons belonging to only single color representation are produced in sensory pathway. It is difficult to imagine a mechanism producing WCW photons belonging to only single color representation unless it is octet representation. One could also argue that only WCW photons in octet representation are produced abundantly and that this is due to the classical color gauge fields accompanying classical electromagnetic fields: if so then higher colors would be rarely realized as conscious qualia.

The assumption that only color octets qualia are possible, allows in principle the identification of colors, tastes and tactile qualia as generalized colors cannot be excluded. Thus a more detailed analysis of this option is motivated.

1. The simplest hypothesis is that 6 basic colors, tastes and basic tactile qualia could all correspond to color flips. This hypothesis is very strong since it suggests that the basic phenomena of color perception such as complementary colors, color contrast, color constancy and possibly even color summation (this phenomenon involves also neural circuitry in essential manner) could have tactile and gustatory counterparts.

2. In the case of tactile senses the very fact that cool resp. warm serves as metaphor for black, blue and green resp. white, yellow and red, encourages the view that tactile qualia correspond to color algebra. In this spirit one could identify the dichotomic pairs cold-warm, pain-pleasant touch and touch-sensation of numbness as counterparts of 3 pairs of color generators of with opposite quantum numbers. Numbness is indeed quale in itself and analogous to sensation of black since it is experienced in absence of sensory input from skin. Proprioception could perhaps be understood as a mixture of sensations of touch and pain-pleasure sensation with geometric qualia. If this view is correct, then superficial touch and pressure sensation are analogous to sensation of color white at different values of brightness.

3. Model predicts six basic tastes. There is evidence for five basic tastes [J119] but situation has not been resolved. Dichotomies suggest that the triplet of bitter, sour and salty corresponds to the triplet of cool colors whereas the sweet, the fifth taste and some sixth taste. One possibility is that different variants of sweet are in question: for instance, sugar and salt and sweet-sour could correspond to different variants of sweet. The sixth taste complementary to bitter could be analogous to color black or sensation of numbness. Very strongly flavored food or bitter food could perhaps induce experience of sixth taste in the same manner as very bright light dazzles.

The basic objection against this kind of assignments is that the tactile and gustatory counterparts of color complementarity and color contrast need not make sense: to my best unprofessional knowledge these phenomena are not observed. One must be however very cautious: these phenomena might be masked by the emotional reactions accompanying these sensations, by the complexity of the phenomena involved and by the non-topographical character of odor and taste perception.

For instance, color contrast phenomenon requires precise object-background separation not possible in the case of odors and tastes. Summation of colors red and green to yellow involves also neural circuitry and does not generalized to the case of tactile senses, tastes and odors.

How qualia are compared?

An interesting question is how geometric qualia are compared consciously. Velocities might be regarded as basic types of qualia for which this kind of comparison occurs. It however seems that velocity type qualia reduce to experience of self about genuine motion of sub-selves inside it if geometric coordinates are mapped to spatial arrays of neurons such that given neuron (or large structure) is sensitive to particular EEG frequency and represents point of map which becomes "alive" when it is activated. Self could also automatically compare the sub-selves representing qualia of same type so that not specific mechanism would be needed. Concerning the comparison of qualia, an interesting idea is that the simultaneous experience of these slightly different qualia gives rise to the simultaneous wake-up of nearby points of the sensory map. This mechanism might be the same as involved with the binaural beat [J56]. This beat mechanism makes it possible, not only to discriminate between slightly different frequencies but also to "hear" very low frequencies not otherwise audible to us. For instance, when one feeds slightly different audible frequencies to ears, difference frequency is heard consciously. Of course, one can argue that this anomalous hearing has nothing to do with comparison in the fundamental sense.

Association problem

How different type qualia are associated with each other? Is spatial and temporal association in the geometric sense always necessary or could it be enough to associate the qualia in subjective time so that they would be associated with same quantum jump and same sub-self always? It would seem that geometric association with same sub-self is the most natural option. Topographical association by the topology of neural circuits is the simplest manner to achieve this and should be involved with vision. The coding of qualia by EEG frequencies is second option. In the case of magnetic transition frequencies continuous spectrum of positions can be coded. Of p-adic lengths define preferred lengths for MEs then the frequency spectrum would be discrete given by integer multiples of basic length: discretization of positional qualia would result if the fundamental frequencies of MEs code for position.

9.3 About The Identification Of The Non-Geometric Qualia

Non-geometric qualia by definition correspond to the quale associated with the state preparation part of quantum jump whereas geometric qualia are understood as characterized by the increments of the zero modes fixed in quantum measurement part of quantum jump. This terminology is somewhat clumsy since one could argue that qualia like pressure and force sense are in a very general sense geometrical.

9.3.1 Color Vision And Super-Symplectic Algebra

Super-symplectic algebra contains infinite number of Hamiltonians in representations of color group and possessing definite two-dimensional spin. For color octet representations, which is the lowest one, there are 3+3 non-diagonal oscillator operator like color generators with opposite quantum numbers. Perhaps the discovers of color symmetry had some precognition about the possible role of this symmetry when they jokingly choose to call it color symmetry. The 3+3 color generators carrying opposite quantum numbers indeed can be related to the six primary colors forming complementary pairs (with black and white included). This identification, originally stimulated by the observations of mathematician Barbara Shipman [A10] about the dance of honeybee, makes sense.

TGD predicts that classical em field are accompanied by classical long range color fields and super-symplectic representation can give rise to colored states. Of course, quantum jumps of any color system could give rise to color qualia and one cannot even exclude copies of QCD in the length scales of living matter in TGD framework: if this is the case then even the generation of color charged gluons quantum coherently could give rise to color quale. A very strong support for

the correctness of the prediction is that it nicely explains the basic characteristics of color vision (color contrast, color opponency, color constancy) besides reducing the existence of six primary colors to the symmetries of the 8-dimensional embedding space (the structure of which can thus be deduced from the basic properties of color vision!). Perhaps the most realistic interpretation of the higher color representations is as higher level colors. One cannot however exclude the possibility that these representations could act as correlates for other qualia, such as odors and tastes.

Basic facts about color vision

Color space provides a multidimensional representation for different color experiences and satisfying the requirement that colors producing nearly same experience are represented by nearby points of color space. Color circle deviced by Newton is the simplest example of color space and provides very economical manner to represent huge amount of information about experience of color (say the fact that blue is more similar to purple than it is to yellow). One can classify colors into spectral colors present in rainbow and non-spectral colors, including many reds, all magentas and most purples and also brown. The famous "inverted spectrum argument" of Locke states that other people might have the same overall set of color experiences as you but differently connected to objects in the external world. For instance, you might experience the colors of rainbow as inverted: your "red" might be my "blue". This is clearly about possible symmetries of the color space and the very emergence of symmetries is consistent with the idea that qualia correspond at the fundamental level to Lie-algebra generators.

Colors can be represented as composites of primary colors defined as colors which have no other "colorishness" in them: for instance, orange has some yellowishness and redness in it. Red, green, blue and yellow are the primary colors and correspond to diametrically opposite points along the two orthogonal axes of color plane. Complete model of color experience must explain the existence of the primary colors and why some colors are experienced as composite of them. It is clear that the existence of fundamental colors breaks complete color symmetry and leaves only discrete set of symmetries consisting of rotations by multiples of $\pi/2$ and reflections with respect to two color axes and two axes forming angle $\pi/4$ with respect to them. Also these symmetries are broken as detailed study of behavior correlates of color experience has demonstrated [J169]. Color circle is not a complete model of color experience since it leaves out the vast majority of color experiences, including white and black, all their mixtures with each other (grays) and their mixtures with chromatic colors.

One can however generalize color circle to 3-dimensional color space by introducing white-black axis orthogonal to green-red and yellow-blue axis. The three cylindrical coordinates of color space are called hue, saturation and lightness (or brightness). Hue is the azimuthal angle along color circle and corresponds to the basic "color" of surface. Saturation represents the vividness of color experience and corresponds to the perpendicular distance from the central axis for the position of the color experience in color space. For instance, the vivid colors of rainbow lie along the outside edge. All the grays lie along the central axis because they have zero saturation. The "muted", "muddy" and "pastel" in between have intermediate levels of saturation. The third dimension of surface color is lightness and refers to the height of color's position. The color circle corresponds to the perimeter of an oblique section through this color solid. This section is oblique because the most saturated yellows are quite light and therefore higher in color spaces whereas the most saturated blues and purples are quite dark and therefore lower in color space.

The phenomena of color constancy, color summation and color contrast are further phenomena related to color vision. Color constancy means that completely homogenous lighting of the visual field by monochromatic light gives rise to no color experiences. This is as it should be since in natural conditions the lighting conditions change all the time. Color summation says that basic colors red, green and blue in suitable proportions sum up to white color. Color contrast means that the region around objects having primary color inherit slight complementary colorishness. For instance, grey object in a red background looks somewhat greenish. The phenomena of color constancy, color contrast and color summation can be satisfactorily understood in terms of experimentally established neural mechanisms [J119]. This does not of course eliminate the need for deeper explanation: the neural mechanisms involved might only reflect the more fundamental facts about color vision.

Can one understand colors Lie-algebraically?

Could one understand these basic facts about color vision in terms of color Lie-algebra? The first question is whether to assign to visual colors the color quantum numbers of states or the color numbers characterizing the changes of states. One could indeed consider the association of three primary chromatic colors and their complementary colors with quark triplet and antiquark triplet, with antitriplet perhaps resulting in tensor product of operation for two triplets. The however implies that color rotation changing the quantization axes should change also the color experience and replace primary colors with new ones: it is however an experimental fact that primary colors are something unique. If they correspond to changes of color quantum numbers induced by specific Lie-algebra generators this is true independently of the particular quantization axes used.

Taking seriously the idea that color Lie-algebra might represent basic facts about color experience, the next question concerns the detailed identification of colors with Lie-algebra generators of color algebra.

1. What seems obvious is that complementary colors must correspond to Lie-algebra generators with opposite sign of quantum numbers. With this assumption 3-dimensional color space could be understood as a space spanned by three diagonal color generators for which there are no linear dependences between color quantum numbers.

2. Primary colors correspond to the six non-diagonal Lie-algebra generators consisting of 3 creation operator like and 3 annihilation operator like generators. There are six primary colors red-green, yellow-blue and white-black.

   This leaves only one possibility: the six non-diagonal generators of color algebra correspond to all the primary colors with white and black included. This conclusion came as a little surprise since the identification of white-black pair as associated with spin flips was competing hypothesis.

3. All color pairs are dichotomic pairs providing metaphorical representation for cool-warm dichotomy such that red, yellow and white correspond to warm colors and green, blue and black correspond to cool colors. What could distinguish between white-black pair and non-chromatic colors is color hypercharge: white and black would have vanishing hyper charge. Thus the following identification of quantum number increments (hypercharge and isospin represented as column vector) associated with various colors suggests itself:

$$\begin{array}{ll} \begin{pmatrix} 0 \\ 1 \end{pmatrix} \leftrightarrow white & \begin{pmatrix} 0 \\ -1 \end{pmatrix} \leftrightarrow black \\ \begin{pmatrix} 1 \\ 1/2 \end{pmatrix} \leftrightarrow red & \begin{pmatrix} -1 \\ -1/2 \end{pmatrix} \leftrightarrow green \\ \begin{pmatrix} 1 \\ -1/2 \end{pmatrix} \leftrightarrow blue & \begin{pmatrix} -1 \\ +1/2 \end{pmatrix} \leftrightarrow yellow \end{array} \tag{9.3.1}$$

It seems that one can indeed reduce color opponency, color contrast and color constancy to deeper level in this framework.

1. Opponent process theory of Ewald Hering [J119] explains basic facts about color summation (for example, summation of red and green to yellow which cannot be understood as summation of color quantum numbers). Color opponent processing means that the members of each pair of complementary colors (red, green), (blue, yellow) and (white, black) tend to compete in the sense that receptors give excitatory response for color and inhibitory response for complementary color, or vice versa.

   Therefore no sensory experience results for suitably balanced intensities of light for complementary colors. For instance, in the case of red and green the sensation of yellow which represents a wavelength between these two remains as a result of this competition. Color

opponency can be understood as reflecting the competition between quantum jump and its reversal induced by two Lie-algebra generators acting like creation and annihilation operators with same color quantum numbers. Note that the sensation of darkness after closing eyes could correlate with quantum jumps in which the ions or Cooper pairs of macroscopic quantum phase generated by quantum jumps "white" gradually decays back to ground state by quantum jumps "black". This suggest that same phenomenon should be associated also with other colors. This would mean that immediate after images should tend to have complementary color. Dazzling phenomenon could result from the depletion of the macroscopic quantum phase from which quantum jumps "white" occur.

2. Color contrast is apparently just the opposite of color opponency: region of given color creates the illusion that background has tinge of complementary color. Thus the complementary colors seem to facilitate each other across boundaries whereas inside the boundaries they tend to cancel each. The called double-opponent cells located in the visual cortex can explain at least partially color contrast phenomenon [J119].

   A more fundamental explanation is based on the properties of color-charged macroscopic quantum phase and on the properties of the classical color field accompanying ELF em field associated with EEG and inducing the color quantum jumps. Color confinement requires that color charge density of the macroscopic quantum phase formed by exotic super-symplectic representations is such that net color vanishes. Thus a region containing exotic particles with given color quantum numbers would be surrounded by a region of opposite color quantum numbers. Only the second sign for the increment of color quantum numbers is possible for a given colored state of lowest-dimensional representations of color group as one finds easily by studying color triplet and octet representations. Color contrast would thus result from the fact that classical color gauge field does not approach zero sufficiently fast at the boundary of colored region and as a real field necessarily contains with the same intensity the Lie-algebra components stimulating color and its complementary color.

3. Color constancy can be reduced to the phenomenon of color contrast. If the net color charge of a color charged Super Virasoro quantum phase vanishes, there must be also a region of complementary color charge. Since this is not possible for a constant illumination by monochromatic light, no sensory experience results. Color constancy is not absolute law: the exceptional cases could correspond to situations in which the entire perceptive field is not actually perceived and this effectively leads to the situation in which constant illumination covers only part of the visual field. In this case complementary colors should be seen on the boundaries.

   The neurology-inspired manner to understand color constancy is that color vision involves comparison in an essential manner. One might say that conscious experience is generated as an integral of the derivative of the intensity of the sensory input such that the initial values at the boundaries of the perceptive field vanishes (this corresponds to the vanishing of the net color charge). If entire perceptive field is illuminated by monochromatic light of constant intensity, there is no sensory experience. A concrete realization of this would be in terms of a saccadic motion. Saccadic motion would translate spatial gradients of the illumination with a given wavelength to increments of color quantum numbers in quantum jump.

9.3.2 Chemical Qualia

Chemical qualia (tastes and odors) are in a well defined sense more primitive than visual qualia. Unless one takes statistical physics connection as an axiom, there are several options concerning the identification of the quantum correlates of chemical qualia.

1. Thermodynamical analogy suggests that basic chemical qualia can be assigned with the Bose-Einstein condensation of super-conducting ions (possibly tastant or odorant), or, less plausibly, to various magnetic transitions of super-conducting ions amplified to macroscopic quantum phase transitions.

2. An alternative identification is in terms of super-symplectic qualia labelled by color and spin quantum numbers. The general objections against assigning other than visual colors and polarization sense to super-symplectic representations have been already discussed.

3. The third option is motivated by the observation that entire hierarchy of experiencers is involved. Thus chemical stimuli, such as odors, could be literally seen at some levels of the self hierarchy. There is indeed empirical evidence for infrared vision based on odor molecules which is however not conscious-to-us.

Quantum correlates of "our" chemical qualia

The naïvest identification of chemical qualia is as correlates of BE condensation of tastants and odorants to the super-conducting space-time magnetic flux tubes. This would predict that the primary chemical sensory experience occurs at the level of sensory organ. The paradigm of four-dimensional brain allows to explain also chemical sensory hallucinations as olfactory memories. The fact that olfactory organs can be regarded as part of brain also supports the view that our primary odor sensation can be localized to primary sensory organ. Quite generally, if super-conducting magnetic flux tube circuits run along sensory pathways to cortex, the events at the level of primary sensory organ can correspond to "our" qualia. This is however not the only option as the following considerations demonstrate.

The energy involved with the BE condensation of single molecule should be extremely small if EEG frequencies are assumed to be able to induce or amplify this process, of order $E - 14$ eV for 10 Hz frequency. If BE condensation occurs by the transfer along flux tubes carrying electric field, this is indeed the case since the BE-condensation energy of BE condensation per molecule is just the change of potential energy when molecule traverses through the join along boundaries bond. It must be emphasized that this kind of mechanism allows also the generation of the BE condensate of ions giving rise to emotion at cortical level. In this case the BE condensation by this mechanism would occur for ions representing large classes of odorants and it would make sense to speak about finite number of chemical qualia. It would not be too surprising if cortex would have developed this kind of classification chemical senses.

Some facts about odors

There are hundreds of receptors for different odorants and this forces to question the idea about primitivity of olfaction. Olfaction is often regarded as the most primitive modality being the only sense involving projections from sensory organs to paleobrain: all other sensory organs project directly via thalamus to cortex. There are two olfactory pathways. The first leads directly to amygdala whereas second leads via the thalamus to cortex as also other sensory pathways. Also entorhinal cortex receives direct projections from olfactory bulb.

Olfactory memories are most emotional and most stable, which is perhaps related with the fact that amygdala which is often regarded as emotional brain, receives direct projections from olfactory bulb but not from other primary sensory organs. The fact that strong odorants are bio-chemically active and induce strong entropy gradients would explain why odors are so emotional. Evolution might have even developed mechanisms amplifying the entropic gradients and thus also emotional responses to odors. The large number of odors is consistent with the idea that each molecule generates its own odor quale in BE condensation on super-conducting magnetic flux tubes. The finite number of odor receptors would not imply that the number of basic odors is finite, but only that there is classification of odors at the cognitive level determining the accuracy of the odor discrimination.

Evidence for infrared vision based on odor molecules?

Callahan has studied the sense of smell of insects [I61]. Many insects, such as moths and ants, are known to be attracted by light, say candles and electric lamps and Callahan took as his challenge to understand what is involved. Callahan discovered that insect's olfaction is not based on chemistry but to a maser like emission of infrared light generated by various molecules such as pheromones, scent molecules and many other bio-molecules. Insects would see rather than sense chemically the sources of the infrared light. The sensillae of the insects serve as receiving antennas and amplify

the incoming maser like infrared emissions. Callahan also observed that the oscillation of insect antennae induce maser like emission from scent/etc. molecules by creating an oscillating emf. Thus sensory experiencing seems to involve active participation from the part of insect. The work of Callahan demonstrates that ELF modulation of IR light is an essential element of the perception mechanism [I61].

In the case of insects infrared light emissions from pheromones mediate sexual messages. Pheromones are known to mediate sexual and social signals also in the case of many mammals. For instance, certain chemical messages from female mouse can make male mouse to mate immediately while certain chemical messages from other males make him agressive. Many mammals, for instance rodents, are known to possess vomeronasal organs, small cigar like sacks containing neurons and having length of order few millimeters [J3], giving rise to an accessory olfactory system, which is known to have much more primitive structure and to work in different way than the ordinary olfactory system. It is also known that this systems bypasses cerebral cortex in rodents. There is evidence that even humans have the ability to sniff certain chemicals mediating social and sexual signals without being aware of it and there is already now flourishing perfume industry based on this evidence. The chemicals responsible for sexual attraction are probably pheromones. The fact that pheromones mediate sexual signals in the case of both insects and mammals, is hardly an accident and suggests that the sensory mechanism must be the same and be based on the infrared emissions by pheromones. If the response is at neuronal level and if the cortex is not involved, one could understand why these messages are not experienced consciously. One could test this hypothesis by finding whether coherent infrared radiation at frequencies emitted by pheromones can affect the behavior of higher mammals including humans.

There is a further peculiar coincidence: the cascade of the transduction events occurring in the absorption of photon in retina is repeated in a remarkably similar way in olfactory receptor cells, which respond to odors whereas the receptor cells that respond to sound use a very different system [J3].

Odor perception as IR vision at the level of odor receptors?

The facts described above suggest that also in the case of mammals the experience of odor involves the, possibly un-conscious, detection of infrared light so that humans would not basically differ from insects and that olfactory system has evolved from the receptor neurons sensing infrared light. The proposed identification means that IR odors are like colors and large number of odors means high acuity with respect to the IR wavelength: this is natural if large number of odorants must be distinguished from each other. Furthermore, odor perception at the level of primary sensory organs could involve exotic super-symplectic representations associated p-adic length scales $L(173) = .02$ mm, $L_3(59) = .08$ mm, $L_2(89) = .11$ mm, $L(179) = .16$ mm, $L(181) = .32$ mm and perhaps even shorter length scales corresponding to $k = 167$ and 169.

If incoming IR photons indeed induce super-symplectic transitions, integer multiples of the fundamental frequency generate maximum response. Good sensory acuity requires that fundamental frequency of the super-symplectic representation is small enough and that the resonant frequencies coded to our conscious experience correspond to relatively high multiples of the fundamental frequency (this conclusion depends crucially on assumption that super-symplectic transition frequencies are multiples of the fundamental frequency). This would suggest that olfactory receptors can perceive consciously very low IR frequencies not conscious-to-us. Similar argument in the case of color vision would suggest that photoreceptors perceive consciously IR frequencies not conscious-to-us. The structures responsible for primary color vision could be cilia containing micro-tubuli with length distribution covering besides visible wavelengths also UV and IR wavelengths. Also in the case of odor perception micro-tubuli are good candidate for the primary detectors of odors: the longest axonal micro-tubuli have length of order .1 mm.

Frequency coding of odors

It is known that odor discrimination relies on spatiotemporal patterns of nerve pulse patterns [J117]. This spike pattern could be however interpreted as coding information about EEG and/or ZEG frequencies which must be excited in order to generate quantum phase transitions generating the sensation of a particular odor which in general involves several primary components. Also

geometric information about, say, the direction of source of odor must be coded into magnetic transition frequencies. A good metaphor is provided by color vision but which much larger number of basic colors and therefore counterparts of cones. The higher harmonics of the transition frequencies might also code emotional reaction to odor discrimination. The importance of ELF modulation in the case of odor perception of insects [I61] suggests that this modulation basically codes for the odor experienced by the insect and is thus in the same role as EEG rhythm coding for odor in human brain. The testing of whether infrared light can affect the behavior of mammals would be also a test of TGD based theory of consciousness.

9.3.3 Magnetic Qualia As Generalized Chemical Qualia

Magnetic quantum phase transitions are characterized not only by the increments of the Poincare quantum numbers perhaps giving rise to kinesthetic qualia but also by increments of the particle numbers in various macroscopic quantum phase labelled by magnetic quantum numbers. This would suggest the interpretation as generalized chemical qualia. The BE condensation of particle numbers to given magnetic phase could give rise to a sub-quale of a chemical quale.

The model for the interaction between sensory organ and its magnetic body [K100] leads to the conclusion that the spatio-temporal patterns of cyclotron phase transitions at the magnetic bodies must be fundamental from the point of view of our consciousness. Varying cyclotron frequencies are ideal for the coding of various perceived geometric variables like frequencies and distances as positions at the magnetic body, and cyclotron frequency patterns generated by biological body would define kind of somatosensory sensations at the level of magnetic body. The representations of the sensory input constructed as temporal sequences of phoneme and note type basic units modulating cyclotron frequencies could be interpreted as cognitive and emotional representations (left brain talks, right brain sings). The chemical qualia of the magnetic body would be cognitive and emotional qualia of ours and correspond to higher level of dark matter hierarchy that our sensory qualia.

Spin flips are problematic since spin does not change in the scaling of $\hbar$. If magnetic field strength remains invariant and the area of flux quantum scales up as r in the scaling of $\hbar$, magnetic interaction energy $-\mu \cdot B$ remains invariant whereas cyclotron energy scales up. If dark space-time sheets are at same temperature as ordinary ones, spin would be thermalized and only cyclotron transitions would contribute to qualia. Spontaneous magnetization and spin flips of spontaneously magnetized regions of spin glass having very large magnetic moment might change the situation. One must also remember that the assignment of same temperature to all space-time sheets of the dark matter hierarchy is the most pessimistic working hypothesis.

For instance, magnetic spin flip phase transitions changing the direction of spontaneous magnetization inside figure could induce conscious figure-background splitting. The repeated occurrence of this phase transition and its reversal induced by an oscillating ELF em field would make figure analogous to a twinkling star. This is like superposing to a harmonic background a tone shifted by constant amount so that dissonance distinguishes the superposed tone from background. The Fourier dual of this representation is by phase shift and there is evidence that hippocampal neurons of rat apply this method to represent the position of rat with respect to surroundings as a temporal phase shift of spike patterns with respect to EEG rhythm with hippocampal theta frequency [J58]. Figure-background separation involves decomposition of the perceptive field to objects which means that higher level representation is indeed in question.

Endogenous NMR spectroscopy?

MEs could induce the rotating part of the magnetic field associated with flux tube inducing magnetic transitions. This could make possible an endogenous NMR spectroscopy in which purely magnetic qualia besides force and torque accompanying magnetic transitions would code the points of a living chemical map. Conscious NMR spectroscopy need not however correspond to *our* experiences directly. Rather, it could contribute to proprioception after several averagings implied by the lower position of the cell-sized selves in the self hierarchy. Note however that the BE condensation of coherent photons generated in the magnetic phase transitions on MEs could induce experiences of force and torque at super-symplectic level.

If p-adic length scales define preferred lengths for MEs, then there is a difference between magnetic and super-symplectic transitions. The tunability of the magnetic transition frequencies makes possible the mapping of the geometric information to flag-manifold coordinates mapped to the magnetic transition frequencies mapped to an excitation of certain neuron or neuron group of 4-dimensional brain and thus waking-up the point of cognitive map of the external world or of body.

9.3.4 Kinesthetic Qualia

The connection with statistical physics allows very nice understanding of kinesthetic qualia and tight connections with basic physics.

Are kinesthetic qualia universal?

TGD version of functionalism would state that kinesthetic qualia are completely universal in the sense that the quale is determined completely by the increments of the Poincare, color, and electroweak quantum numbers in the quantum jumps. Thus both magnetic quantum phase transitions as well as super-symplectic transitions could give rise to similar kinesthetic qualia. Since super-symplectic qualia seem to correspond to higher level qualia in a well-defined sense, there are good motivations to consider the possibility that our kinesthetic qualia correspond to magnetic quantum phase transitions.

The quantum numbers which change in the magnetic quantum phase transitions are spin, orbital angular momentum, momentum in the direction of the magnetic flux tube, and the energy of the single particle state. The kinesthetic qualia associated with the magnetic quantum phase transitions could basically correspond to the experiences of torque in the case of angular momentum increment and force in the case of increment of longitudinal momentum. Also the increment of the integer n characterizing the radial dependence of the harmonic oscillator wave function could give rise to some kind of quale. Kinesthetic interpretation would encourage to assign a sensation of radial force to this kind of transition. Since the eigenvalues of the harmonic oscillator Hamiltonian are integers, one could consider also the possibility that elementary arithmetic quale could be in question. Generalized hearing as time-like force sense seems however to provide the most convincing identification.

Momenta correspond to spatial translations whereas energy corresponds to time translations and in spirit of special relativity one expects that sensation of energy flow is the counterpart of sensation of force. Sense of force involves always some spatial direction and sense of torque direction of rotation besides the intensity of the force of torque. Auditory experience involves duration and direction of time in an essential manner and the increment of energy, or equivalently of frequency, relates closely with hearing which is basically frequency sense. Thus the unification of hearing and force senses to generalized four-force sense suggests itself.

An objection against this identification is that energy increments are involved with all quantum transitions so that also vision would involve some kind of auditory aspect. Most audible frequencies are however above EEG range makes hearing especially makes possible to store a lot of information to auditory sensation whereas for other senses the content of dynamical information is so small that the auditory information of these senses remains un-noticed. Alternatively, the net energy flow in the direction of subjective time in turn could correspond to the intensity of the quale for all qualia. This would be in nice accordance with the universality of the kinesthetic qualia. The intensity of quale could however have other identifications: for instance, very entropic mental images should give rise to dim qualia.

One can wonder what the interpretation of Lorentz boosts, do they correspond to independent qualia or not? Very probably not: what is needed to characterize the basic qualia is quantum number increments for a maximum number of mutually commuting observables. Boosts induce increments of four-momentum and thus force and energy qualia.

Linear and angular acceleration

Magnetic states have well defined momentum and angular momentum component in the direction of the magnetic field and the sensation of acceleration or force in the direction of the magnetic field

and angular acceleration around this direction naturally correspond to a quantum phase transition changing the momentum and angular momentum of charged particles of the macroscopic quantum phase. For instance, sensations of falling in gravitational field and sensation of dizziness when the world rotates around could be related correspond to primitive angular acceleration quale.

Note that it is also possible to have state basis for which two momentum components are well defined quantum numbers with suitable choice of gauge. In TGD framework the choice of gauge is not however completely free since classical fields are induced from CP_2 spinor connection. For instance, canonical transformations of CP_2 acting formally as $U(1)$ gauge symmetries of the Kähler potential do not act as ordinary gauge symmetries but isometries of WCW and deform space-time surface and affect classical gravitational fields.

Identification as linear and angular acceleration probably makes sense when the experience is about body. If spin flip and increment of momentum are associated with an object of perceptive field they might give rise to figure-background separation in magnetic case. Object of perceptive field effectively "pops up" from the background or makes small twists with respect to the background. In this case the net changes of these quantum numbers vanish in the long run and kind of "twinkling" results. A classical example about the flipping of the figure-background identification between two alternatives is the figure in which Freud's head and naked woman is seen alternately but never simultaneously.

Increment of orbital angular momentum and color flip are in general associated with the same Hamiltonian which can be chosen to be a product of functions in E^2 *resp.* CP_2. Hamiltonians associated with E^2 can be chosen to be eigen states of the angular momentum in the direction determined by the point of flag-manifold. Functions are most naturally localized around point of E^2 and thus only angular momentum component J_z is good quantum number. The transitions are thus characterized by the increment $\Delta M = J_z$ of angular momentum and by the increments of color quantum numbers and for given color representation D infinite series of qualia or variants of same quale labelled by ΔM are possible. The identification of spin increment as related to polarization sense is very natural if color corresponds to the visual color. Polarization would be experienced as some kind of a torque of universality holds true.

Hearing as time-like counterpart of force sense?

As already found, a natural identification for the energy increment is as being related to hearing which would be thus time component of sense of four-force. This identification is elegant but perhaps formal and one must compare it with alternative possibilities.

The quantum model of hearing [K96] has evolved through painful steps. At this moment it however seems that basic auditory quale could correspond to an increment of electroweak spin at the level of cell membrane (see the discussion towards the end of the chapter). The increment of electroweak spin can be assigned to either quark pair assignable to a lipid of receptor membrane or a pair of quark pairs assignable to separate receptor membranes and joined by flux tube during sensory reception. The experienced pitch in turn seems to correspond to a quale of magnetic body and correspond to a frequency modulation of Josephson frequency by the frequency of the sound [K37] .

The modulation of Josephson frequencies would provide a completely general representation of sensory and other information at the magnetic body. Music metaphor allows to see this representation as analogous to that produced by a choir of of whales. Both neurons and astrocytes are expected to sing and the value of Planck constant for a given neuron or astrocyte characterizes the octave associated with this particular singer. Speech and song would be direct motor expressions of this representation. Also ordinary speech involves frequency modulation as becomes clear by playing a recorded speech with abnormally slow rate.

Increments of spin and momentum and figure-background separation

In M^4_+ degrees of freedom there are two quantum numbers corresponding to the $SO(2) \times R$ Cartan algebra of $SO(3,1)$. These quantum numbers can be chosen to be spin and momentum in direction of the quantization axis. It is probably of significance that just these quantum numbers are also associated with the magnetic states besides magnetic quantum number which is analogous to the conformal weight in the case of Virasoro algebra. This suggests that discrete magnetic qualia and

Super Virasoro qualia in Lorentz degrees of freedom might have a close relationship. Universality of the kinesthetic qualia indeed implies this kind of a relationship.

There is no change in orbital degrees of freedom involved with spin flip, which suggests that sensation of torque is not involved. A possible identification is in terms of figure background separation. In the case of magnetic qualia spin flips associated with the representations of objects of the external world could correspond to figure-background separation since transition frequencies for spin flip transitions are shifted with respect to the frequencies of transitions without spin flip.Indeed, by music metaphor the addition of the spin-flip frequency to the cyclotron frequency implies that figure is separated from background like dissonance from harmony.

There is also a second metaphor for what figure-background separation means. In order to separate figure from background one can to give it a small push upwards or perform a tiny twist for the figure with respect to background. This is what increments of spin and momentum in the direction of quantization axes could represent. This kind of tiny pushes and rotations would give vanishing net effect in the sequence of quantum jumps but take care that the object of the perceptive field gains attention. Perhaps this has something to do with the fact that primitive organisms like insects are unable to see objects which are not moving with respect to the surrounding world. Saccadic motion might be essential in generating artificially the motions separating figure from background: if saccadic motion is made impossible, visual field gradually falls in total darkness [J144].

"Push-or-twist" metaphor would allow to assign figure-background separation also to super-symplectic spin flips. For super-symplectic algebra transition frequencies of the transitions induced by classical gauge fields associated wit MEs are however harmonics of the fundamental frequency and the generation of figure-background separation by the shift of the EEG frequency is not possible. This implies that there is infinite number of qualia or variants of the same quale associated with given increments of color quantum numbers.

9.3.5 Tactile Qualia

Concerning the identification of the tactile qualia (sense of touch, pressure sense, temperature sense, physical pain and pleasure), the first hint comes from the observation that a topological phase transition involving the formation of flux tubes with the object is involved. Thus the number of the join along boundaries contacts could play the number of particles in this case.

In the case of purely physical pain/pleasure (different from the emotional aspect of pain and pleasure) the splitting/formation of the flux tubes associated with the tissue occurs and the number of these contacts could define the relevant particle number. The purely emotional aspect of pain and pleasure in turn would correspond to the presence of entropy gradient with respect to the subjective time implied by this process. The most naïve interpretation is that primary sensory experience is located with skin since the replication of this kind of activity at brain level would seem somewhat artificial.

flux tubes are natural space-time correlates for quantum entanglement and their splitting means a loss of entanglement. Rational (algebraic) entanglement corresponds to positive information and also information is lost in the splitting process. At higher levels of dark matter hierarchy physical pain is replaced with more abstract psychic pain but the space-time correlate for it would remain same.

This is however not the only possible option. Also tactile qualia could be induced by EEG frequencies as our qualia at the level of cortex. This would mean a rather concrete representation of the topological aspects of tactile qualia. The fact that various objects of perceptive field are represented as recognizable patterns of neural activity supports the view that also tactile experiences are regenerated at the level of the virtual world of cortex. EEG waves should induce the generation and splitting of internal and internal-external flux tubes inside cortex and this requires that the energy for the generation of flux tube is extremely small, of order of 10^{-14} eV for 10 Hz frequency for ordinary value of $\hbar$: for $k_d = 40$ level of dark matter hierarchy energy is above thermal threshold. Note that the hypothesis is $h_{eff} = nh$, where n is product of distinct Fermat primes and power 2^{k_d}.

The flux tubes in question must be electric (magnetic flux conservation does not allow splitting of the bond). By assuming that the electric flux through the bond is given by elementary charge, one obtains that the electric energy associated with the bond is given by the potential

energy difference over the bond for electron. Josephson junctions with potential differences of this order of magnitude should be indeed present in bio-matter and the number of the Josephson junctions would become the basic variable. The Josephson junctions acting as join along boundaries bonds/flux tubes could be also MEs, which indeed can have very small thickness and can carry also constant component of electric and magnetic fields in the case that they appear as pairs (the throats of wormhole contacts connecting the members of ME pair would serve as sources of these fields).

The purely physical aspect of the temperature sense (as opposed to the emotional aspect) most naturally corresponds to energy flow in the direction of subjective time. Temperature sense would be energy sense basically. Sensors for cold and hot would detect consciously the flow of energy from body/into body and code this into increment of energy for magnetic or super-symplectic states. The average increment of transition frequency using p-adic frequency scale as unit would measure the intensity of sensation.

9.3.6 Emotions

The thermodynamical approach by replacing second law with NMP suggests that emotions correspond to the gradients with respect to subjective time for various entropy like variables associated with sub-systems of self. Thus positive/negative emotions should reflect the increase/decrease of order. This identification is supported by the general characteristics of emotions.

Emotions contain only few bits of information but this information is very important for survival. Emotions are holistic, "single-pixel" qualia and about the state of the entire body or relatively large part of body. Emotions are very much like conscious representations for time rates for the deviations from homeostasis realized as many-sheeted ionic flow equilibrium and tend to appear in complementary pairs. Emotions correlate very strongly which the chemical state of the body. In particular, peptides are often regarded as both the molecules of emotion as well as of information. Since peptides perform bio-control as information molecules they must induce especially intense entropy gradients with respect to subjective time and thus strong emotions if TGD view is correct.

In the sequel TGD view about emotions are compared with the ideas of Damasio described in his book [J35]. To avoid confusions it is good to emphasize that in TGD approach emotions are defined as sensations rather than as motor responses to sensory input about state of body as Damasio defines them [J35]. In the following various classifications of emotions and various aspects of the concept of emotion are discussed. After that the general identification of emotions as generalized sensory qualia about state of body and CNS containing both geometric and non-geometric component is described.

About classification of emotions

In order to even try to say something sensible about the identification of correlates of emotions, one must try first to try to develop general view about different kinds of emotions.

1. One classification of emotions [J63] is based on the notions of cognitive world model and goal structure. The simplest emotion is excitement which does not involve any recognizable goal or cognitive model. Surprise and relief involve conflict or resolved conflict between prediction of model world and real world experience. "Amygdalar emotions" fear, anger, craving, protection and disgust are directed and involve goals and external threats to goals. Also cortico-striatal emotions like sadness, hate, embarrassment, contentment and joy involve goal structures and failure or success to achieve the goal in essential manner. A general representation for goal should be in terms of generalized geometric qualia representing the desired state of body or some other system and represented as mind like space-time sheets.

2. Damasio classifies emotions to six universal "big" emotions: happiness, sadness, fear, anger, surprise and disgust; to background emotions or moods (feeling good/bad, tired, excited, depressed, strong, ..) and to social emotions (feeling embarrassed, ashamed, guilty, ..). One can also classify emotions to bipolar pairs (fear/anger, craving/disgust, pain/pleasure, ...) according to whether they involve approach or withdrawal from some situation (fight or flight) or ambivalent rest and digest emotions (surprise, excitement) or emotions related to

seeking of pleasure. Drives induce emotions like hunger or thirst and satiation follows the achievement of the related goal. The dichotomic nature of these emotions conforms nicely with the fact that Super algebra generators appear as complementary pairs.

3. If simple emotions are just generalized sensory qualia, it is natural to interpret emotional expression as a generalized motor action so that motor action, imagination and emotional expression would be very much analogous to each other. It is known that the expression of emotions is indeed very brain area specific and hence very much analogous to motor expression [J35]. The ideas about e-motor expression and emotional imagination sounds perhaps strange since emotions are often regarded as something which just come from heaven and do not involve volition. This is not the case always: for instance, actors have specialized in practicing e-motor activities. Damasio tells in his book about pianist who told about emotional currents going through her body and about her ability to control them at her will: it turned out that this ability had direct neurophysiological signatures. One can also distinguish between active and passive emotions. For instance, pleasure and craving, anger and hate, and fear and anxiety (not a direct reaction) differ in that they are passive/active emotions.

4. Some metaphorical representations of emotions as qualia like tastes and basic tactile senses [(warm, cold, pain) at least] appear very naturally. This could be understood if also emotions are accompanied by super-symplectic qualia. As already found, there are however strong objections against this identification.

5. The fact that emotions are holistic "single-pixel" experiences suggests that emotions represent experiences about average state of body or body part. This averaging is natural if emotions correspond to $k = 67_3, 101_2$ and/or $k = 103_2$ level sensory qualia at length scales $32, 45$ and 180 cm and are determined as reactions to what happens in shorter length scales. Of course, also shorter length scales $L(k)$, $k = 191, 193, 97_2, 197, 199$ could be involved.

6. There are also very refined emotions like those accompanying music experience. It is not at all clear whether these emotions can be regarded as representing "average pixels" of lower level sensory experience about body and might be primary emotions experience directly and correlating with the patterns of ELF em waves. One can indeed assign to the Fourier decomposition of EEG wave entropy in terms of the probabilities defined by the Fourier coefficients of EEG wave and the gradient of this kind of entropy with respect to subjective could correlate with the emotional aspects of music. White noise and monochromatic sound (and more generally EEG wave) would represent the two extremes. Interestingly, $1/f$ noise for the distribution of frequencies and durations of notes is a characteristic of musical sounds. The assignment of entropy gradients with respect to subjective time (this is important!) as correlates of aesthetic experiences is indeed natural.

7. There are also emotions which indeed seem to "come from heaven". It is difficult to believe that religious and spiritual experiences could be mere representations of the state of body and CNS. More feasible assumption is that these emotions are communications from the higher levels of self hierarchy to our level. Communication mechanism would be semitrance mechanism transforming the communications to emotions and e-emotor actions. Probably a loop in which selves below us in self hierarchy are affected and yield e-emotor expression which is perceived by us and in turn stimulates emotion at our level.

How emotions differ from ordinary sensory experiences?

Emotions differ from ordinary senses in that they seem to be relatively simple in some respects. Instead of providing a detailed picture with each pixel having several possible colors they seem to provide a single big pixel. Thus a plausible view about emotions is as "single pixel qualia" associated with the levels $k = 67_3, 101_2$ and $k = 103_2$ levels of the self hierarchy (at least). There are also alternative explanations for the diffuse character of emotions. These explanations are however consistent with this first principle explanation.

1. The sensory information about internal milieu is about pH, ionic concentrations, hormone levels, .. and thus not topographical bit map type information. If this information dominates emotional input, it is easy to understand why emotions tend to have single pixel character: the color of the pixel simply various very slowly. Also the control of moods by mono-aminergic and catecholaminergic and other neuromodulator systems is based on diffuse projections. On the other hand, the somatosensory information from muscles (in insular cortex and some regions of parietal lobe), known to be important for emotions, has bitmap character. One could also see the correlation of emotions with peptides and other important bio-molecules whose presence induces large entropy gradients as a direct support for the view that emotions are associated with entropy gradients.

2. Our emotions are determined to a high degree by experiences which are averages....over averages over all sub-selves of the lower level self. These averages replace a picture containing very many colored pixels with single pixel picture having the average color. The generalized sensory experiences of the lower level selves are in turn determined by the input from muscles, smooth muscles and inner environment and by hormonal communications.

3. It could be also that at least some emotions (for instance, those involving comparison of what happened with long term goals) are communicated to us from the higher levels of self hierarchy. The primary communication could be to some lower level self and we would experience these emotions both as averaged experiences and by reading our body language (also the body language spoken by the inner organs) language. Unconscious-to-us sensory qualia also induce e-motor reactions realized as bodily expression of emotion. We perceive this bodily expression and it affects strongly our emotional state. Thus there is close relationship between pure emotional coloring and the generalized geometric qualia inducing it. This option is consistent with the ideas of Damasio about self hierarchy [J35].

According to Damasio [J35], the ability to experience and express mood like emotions is preserved even when neocortex suffers lesions destroying practically all cognitive abilities and the ability to process sensory information and respond to it. On basis of this fact Damasio suggests that mood like emotions are associated with "pre-self". Pre-self is prerequisite of nuclear consciousness and extended consciousness involving cognition and long term goals [J35]. The regions assigned by Damasio to "pre-self" correspond to the nuclei of brainstem, hypothalamus, basal forebrain, insular cortex and somatosensory regions (S1 and S2) in the medial parietal cortex. Perhaps these regions represent sub-selves which receive the sensory input determining our emotions. The hypothesis that primary and secondary regions of the cortex correspond to the first and second period of the periodic table and do not correspond to sensory input directly conscious-to-us is consistent with this picture.

Can one identify emotion with its expression?

There are empirical data supporting Damasio's view that our emotions can be identified with their expressions. For instance, if the motor pathways in the reticular formation are destroyed, person is unable to perform volitional movement and the bodily expression of emotions becomes impossible. Contrary to what one might expect, the patients are calm and peaceful although they can feel frustration and sorrow at intellectual level. Damasio interprets this as support for the correctness of the identification of emotions with their bodily expressions.

The sharp distinction between emotional and purely sensory aspects of pain can be understood if emotions accompany generalized sensory experiences. The purely sensory aspect of pain would correspond to non-geometric and geometric qualia giving information about the state of body and CNS whereas emotional coloring would be due to the entropic gradients necessarily involved with the sequence of the quantum jumps. The reason why sensory input from our body induces much stronger entropic gradients than that from the everyday external world would be dictated by the relatively higher importance of this input and positive feedback loops exaggerating the entropic gradients from body might quite well be involved. That also the sensory input from external world can induce emotional reactions is in accordance with this view.

A more detailed TGD based model of emotions consistent with the observations of Damasio is following. Emotions are based on sensory perceptions about the state of body directly by some

lower level self, perhaps the "pre-self" of Damasio. We experience these qualia as averaged qualia which is much like objective sensory perception: emotions provide summaries rather than bitmaps. The more levels there are between the primary experiencer the slower is the dynamics of emotions and moods correspond therefore to the lowest level self, perhaps the level of "pre-self" of Damasio. The lower level self reacts to its emotional percepts by e-motor activity generating emotional expression affecting the state of body and of internal organs, which higher level selves in hierarchy and also we in turn perceive. The entropic gradients characterizing this perception determined the emotion and in turn the reaction and it is easy to imagine a positive feedback generating a response which contains increasingly stronger entropic gradients. It seems to be the perception of the e-motor responses of pre-self to which cause mostly the suffering at our level.

If lower level self of the patient is not able to react e-motorially to its emotional percepts, the patient do not get in a state of horror. Of course, an open question is what "pre-self" experiences, when it cannot express its experiences: not necessarily anything dramatic and not necessarily anything emotional. It might be that the holistic nature of emotional content is essentially due to single pixel character of emotional experience. Note that this feedback loop resembles the loop created by typing text or talking loudly one's own thoughts. Lower level self communicates directly to us via our body using body language and via lower level selves below us via nervous system. This model explains also why many bodily expressions of emotions occur before we become conscious about them.

Peptides as molecules of emotion and information molecules

It is known that peptides correlate strongly with emotions and moods [J55] and they are even called molecules of emotions. Peptides are also regarded as information molecules. This connection between information and emotions fits nicely with the fact that peptides and other important biomolecules certainly induce strong entropy gradients with respect to subjective time. We do not taste or smell the presence of peptides or other information molecules in our body. A possible explanation is that Bose-Einstein condensation of peptides on super-conducting space-time sheets does not occur. This could quite well be the case for the simple reason that peptides are macromolecules. Of course, one could also argue that the color of emotion is nothing but a generalized taste or odor.

Although it looks more plausible that peptides are only one step in a control sequence leading to quantum phase transition giving rise to quale, one cannot rule out the possibility is that also magnetic transition frequencies of peptides (short proteins acting as hormones) correspond to geometric aspects of emotional qualia. The cyclotron frequencies of singly charged amino-acids are in the range of $1 - 4$ Hz and it is known that proteins carry constant charge density per unit length. If this density is same as for DNA, the charge per protein would be about 6 elementary charges. For unit charge per single protein $n = 1$ cyclotron transition is in delta band whereas for 6 elementary charge per unit $n = 1$ cyclotron transition frequency is in alpha band and would be conscious-to-us.

Since proteins and DNA are spin glass type system allowing huge number of ground states and angular momenta, explosion in complexity is expected to occur and make possible extremely rich spectrum of geometric aspects of emotions.

What emotions could be in TGD framework?

TGD suggests several visions about emotions and it is not yet completely clear whether these views are really mutually consistent.

1. The statistical physics approach to qualia leads to the hypothesis that emotions correspond to rates for the generation of various type of entropies for sub-systems of self. The sign of rate tells whether emotion is positive or negative and thus negative emotions would thus be conscious control variables warning self when some sub-system is generating entropy. The holistic nature of emotions can be understood easily in this picture and also the fact that they are not directly related to sensory input. One could perhaps also understand higher level emotions like sorrow as reflecting the growing disorder of the virtual world of brain resulting from the primary cause of sorrow. The connection of peptides and other information molecules with emotions provides a strong support for this view.

2. Many emotions are comparison type emotions. These emotions tend to be negative (say envy).
   i) At fundamental level one could perhaps regard comparison type emotions as resulting from the comparison of geometric and subjective memories occurring automatically in any quantum jump and thus to some degree with any quale. Unfortunately, it is very difficult to imagine how to concretely test this kind of hypothesis and it is also difficult to see how the connection with entropy gradient could emerge.
   ii) One must also seriously consider the possibility that emotions result from the comparison of remembered/anticipated quale and real quale rather than the fundamental comparison involved with anticipation and memory: kind of quasi-computerized version of geometric memory would be in question. The result of comparison would be coded to the sign of the growth rate of some entropy variable. The comparison could perhaps be realized in such a way that subsequent quantum jumps for comparing sub-system could represent either the anticipated or real quale. If this were the case, the difference between anticipated and real would automatically induce growth of entropy and negative emotion would result. This would be the basic mechanism of disappointment.

3. One could also regard emotion as or induced by generalized sensory qualia giving information about CNS itself rather than external world or the boundary between external world and body. Regulation involved with the homeostasis involves comparison in an essential manner so that one could perhaps regard emotions as analogous to control variables representing consciously the result of comparison of expected and desired forcing the organism to behave in a way to reduce this difference and end up to a rest and digest state. This aspect is consistent with the statistical interpretation since the entropy gradients associated with the organism are stronger than those associated with surrounding world. Also amplification mechanisms exaggerating the entropy gradients might have developed. For instance, our reactions to some odors or tastes could involve this kind of amplification.

4. A hypothesis consistent with these views is that emotional component is involved with all sensory experiences and that we are used to call generalized sensory experiences emotions when they are about body. The emotionality of qualia indeed increases in the sequence of perceptive fields external world – CNS-world boundary – body. The degree of emotionality of experience should be characterized by the deviation of real from expected or desired and this suggests that the emotional component is much stronger for sensory experiences about CNS itself, since the system in question is much less predictable than the external world consisting of dead objects. Interpretation of emotion as measure for entropy gradient explains also this hierarchy.

5. A further point of view is provided by music metaphor. Music is language of emotions which suggests that emotions are at least partially coded into the EEG pattern. Perhaps pure emotions which seem to involve no obvious comparison (love, joy, excitement, ..). At least the emotions produced by music might represent this kind of emotions. The view about emotions as entropy gradients allows to understand also emotions of this kind. In state of deep love, self enters into very low-entropy state and mental images (not necessarily even present in "enlightened states") become very pure. Comparison type emotions could be seen as a system of rewards and punishments used to control the self (the controller could be higher level self (conscience) or higher levels selves which also want to survive (the emotions generated by hunger, first, and physical pain).

6. Sensory qualia can be divided to geometric and non-geometric ones. One can classify also emotions in this manner. Emotions corresponding to the localization in zero modes would perhaps correspond to "higher level emotions" about external world (say, aesthetic qualia) whereas the non-geometric emotions associated with the state preparation would correspond to "self-centered" emotions about the state of body (pain, physical pleasure, ...).

Some examples of concrete identification of emotions

In the following some examples about the identification of emotions are discussed to see what problems are encountered in attempts to concretize the general theory.

1. Simple emotions

Pleasure and pain are the most important emotions (pain as emotion must be distinguished from physiological pain which is ordinary sensory experience). The identification as conscious entropy type variables works very nicely in this case. Relief and disappointment are examples of simple emotions induced by some unexpected event and involving comparison and goal structures. Emotions as entropy gradients vision allows to understand these emotions along the lines already described. Surprise is an ambivalent emotion which is associated with the deviation between expected and real. The lack of comparison aspect could be understand if surprise involves a generation of totally new mental image. Getting bored is more or less a complementary emotion to surprise. It probably involves the growth of the entropy content of the mental images. There are six basic emotions involving goal structures arrangeable into two triplets (happiness, sadness, craving) and (fear, hatred, disgust) or three doublets (happiness, sadness), (fear, rage), (craving, disgust). These emotions are comparison type emotions allowing description in terms of entropy gradients.

2. About geometric aspect of emotions

Simplest comparison type emotions involve comparison of the model of reality with reality. More complicated emotions involve goals and their comparison with what was achieved. This suggest that world model and abstract goals can be mapped the generalized geometric qualia. The metaphorical correspondence of emotions and motions suggests that flag-manifold qualia indeed could represent abstract goals and cognitive structures. The infinite-dimensional flag-manifold associated with the group of zero mode canonical symmetries of WCW must describe the geometric aspect of emotional experience. This gives huge flexibility and good hopes of coding various goals to the geometry of the space-time sheet (and thus also to cyclotron frequency) by applying appropriate canonical transformation to it.

The most concrete goals are expressible as desired position and posture of body. Consciousness builds geometric metaphors for abstract concepts and goals and metaphorizes also abstract evolution in terms of simple dynamical concept. For instance, goals are often metaphorized using expressions like achieving certain position in society. This suggest that various metaphorization might have developed from these concrete "geometrodynamical" goals. Therefore one must take seriously the possibility that flag-manifold qualia associated with Lorentz and color group can code also geometric aspects of emotional experience. This reduction could be also due to the fact that flag-manifold coordinates must be eventually mapped to concrete standard configurations of the magnetic flux tubes characterized by position, orientation and internal states achieved by applying Lorentz boosts in the longitudinal direction of tube.

3. Higher level emotions

TGD suggests that higher level emotions are communicated to us by higher level selves by semitrance mechanism in which some part of brain, presumably belonging to right temporal lobe and including hippocampus and amygdala, entangles with higher level self and serve as a medium allowing higher level self to communicate its message as emotions, sensory "hallucinations" or internal speech as nerve pulse patterns to the audience consisting of those parts of brain which are in wake-up state. The physical correlate for this process would be standing EEG waves which in turn correspond to spatially constant "space-like" soliton sequences associated with the region of brain serving as medium whereas propagating EEG waves are associated with soliton sequences propagating in linear circuits of brain. The standing wave part of EEG would clearly correspond to "free part" of EEG wave not induced by sensory experience alone and identifiable as active aspect of collective consciousness represented by ELF MEs.

The assumption of Damasio that emotion accompanies a generalized sensory experience about the state of body seems to be in conflict with the idea that higher level emotions are communicated to us by higher level selves. Entropic interpretation of emotions does not require that emotions are always about state of body. One the hand, body could serve as an instrument making possible to represent higher level emotions. Higher level self could use semitrance mechanism to induce nerve pulse patterns giving rise to characteristic temporal patterns of EEG in turn giving rise to communicated emotions. Higher level selves could also induce neural activity at some lower level of self hierarchy which would in turn be experienced by us as average emotions like moods.

For instance, higher level selves above us could be responsible for the higher level social emotions like shame and experience of having done something wrong. The experiences of higher level self could be communicated to us, or rather to our lower level sub-selves, as kind of artificially generated virtual world emotions which correspond to EEG frequencies which are higher octaves of the magnetic transition frequencies associated with the fundamental experience. p-Adic length scale hypothesis implies that this communication optimal. The spectrum of super-symplectic frequency scales indeed comes as powers of 2 for primary p-adic length scales: if secondary and higher p-adic length scales are included, frequency scales come as powers of $\sqrt{2}$.

9.3.7 Dark Matter Hierarchy And Emotions

The ideas related to dark matter hierarchy led to a progress in the attempts to understand what emotions and cognition might correspond physically. The new views discussed in more detail in [K100] challenge the assumption that emotions reduce to negentropy gradients and suggest that the sensory qualia of the magnetic body assignable to cyclotron phase transitions correspond to emotions and cognitions. Only the negative-positive coloring of emotions would reduce to the sign of the negentropy gradient in this framework. In the following earlier view and the dark matter inspired vision about emotions are confronted.

Emotions as higher level qualia?

Emotions have metaphorical resemblance to qualia (white/black, cold-warm, ...) but intuitively correspond somehow to a higher level than sensory qualia. For instance, insects presumably possess sensory qualia but do not look emotional. Pain-pleasure dichotomy is especially interesting since physical pain can be regarded as a sensory quale and psychological pain as an emotion. This suggests that emotions might be qualia of some kind, perhaps sensory qualia of the magnetic bodies at higher levels of the dark matter hierarchy. This correspondence might however be illusory: the association of certain kind of emotions with certain kind of qualia could explain these metaphors.

It is not at all clear whether this identification is consistent with the assignment of emotions to the negentropy change. One can of course ask whether the "sign" of the emotion as a higher level sensory quale is determined by the sign of the negentropy change. One could also argue that the sign of the negentropy change for sub-self defines one particular higher level sensory quale.

Emotions are whole body feelings

Emotions are holistic and not localizable in any part of the biological body. The time scale for the change of emotions is long as compared to that for the sensory qualia. Emotions possess time scale hierarchy and vary from temporary irritation as you find that you email box is full of junk mail to moods and emotional states like love and hatred lasting for decades. To love some-one for decades one must be able to remember this person. If one assumes that the time scale associated with the level of dark matter hierarchy fixes the geometric duration of the moment of conscious and the characteristic time span of long term memories at that particular level of hierarchy, the conclusion would be that emotions are associated with the higher levels of dark matter hierarchy and are indeed assignable to the magnetic bodies.

Could Josephson radiation to the magnetic body generate emotions?

The simplest hypothesis is that magnetic bodies share the sensory mental images localizable at the sensory organs. The same would hold true for the mental images generated by brain as symbolic representations of the sensory input. The sharing of mental images would correspond to quantum entanglement between sub-selves of the magnetic body and biological body. Charge entanglement induced by W MEs is a good candidate in this respect and would be also in a key role in the motor control. The selection involved in the state function reduction process would correspond to a selection of percepts known to occur (binocular rivalry provides a standard example).

This leaves open the interpretation of the communications to the magnetic body based on Josephson radiation at frequencies $nf_c \pm f_J$, where f_c is ionic cyclotron frequency and f_J Josephson frequency determined by membrane resting voltage. Also more general frequencies are possible.

In particular, communications based on slow (in cyclotron time scale) modulations of Josephson frequency induced by modulation of membrane voltage are of special interest.

The Josephson radiation consisting of dark photons induces cyclotron transitions at the magnetic body and in the absence of any other identification, the natural interpretation would be that these transitions define emotions as somatosensory experiences of the magnetic body. The intentionally generated generalized motor actions involving charge entanglement by W MEs would induce the emotional expression just like other motor interactions.

If magnetic body experiences emotions as somatosensory input, it is difficult to avoid the question whether magnetic body is also able to move and change its shape. The model for various kind of OBE experiences [K121] indeed relies on the assumption motor control is induced by motor actions deforming the magnetic body: biological body would be like a puppet hanging from strings.

There is quite recent finding that the sensation of movement is generated by the intention to move rather than by the real motion of body part itself [J33]. The explanation would be that the sensation of movement is a somatosensory of magnetic body about its own motion (the interference patterns for Josephson radiation from the body are changed and therefore also cyclotron transition patterns). The communication-control loop between magnetic body and biological body would guarantee that the two movements correspond to each other. This interpretation would provide also a new view about dreams and hallucinations.

9.3.8 Dark Matter Hierarchy, Hierarchical Structure Of Nervous System, And Hierarchy Of Emotions

One can ask how the structural and functional hierarchy of CNS and the hierarchy of emotions relates to the dark matter hierarchy. The basic picture wherefrom one can start is following.

1. The emergence of nervous system corresponds to the emergence of $k_{eff} < 205$ levels of dark matter hierarchy above $k_{eff} < 167$. For instance, worms and insects would correspond to this level.

2. Vertebrates have EEG and thus the most primitive vertebrates (reptiles) should correspond to $k_{eff} \geq 205$.

3. The emergence of new structures need not mean the emergence of new levels of dark matter hierarchy. Rather, the most reasonable criterion for the presence of these levels is the emergence of behaviors involving long term goals and the magnetic bodies of the parts of brain assignable to the control of this kind of behaviors would correspond to higher values of k_{eff}. Also the maximum span of memories at given level should be characterized by the value of k_{eff} associated with the brain structures involved (hippocampus, mammillary bodies). This picture conforms with the fact that already insects possess neurons, ganglia, and head containing the precedessor of cerebrum but correspond to $k_{eff} \leq 205$ most naturally.

For goal related emotions the maximal time scale assignable to the achievement of the goal might allow to identify the time scale characterizing corresponding level of dark matter hierarchy. The lowest level emotions would be "primitive" emotions not related to any goal and one can as whether they could be assigned to organs consisting of ordinary cells and correspond to $k_{eff} \leq 205$.

1. The time scale of planned behavior and of long term memories makes possible to estimate upper bounds for the values of k_{eff} assuming Josephson frequency hypothesis. $k_{eff} \leq 205$ would give the upper bound of 6 ms which corresponds to cerebellar resonance frequency 160 Hz. This time scale looks too short even for the simplest vertebrates and one must be very cautious here.

2. An alternative interpretation is as the shortest possible span for short term memory whose time scale is known to vary.

3. Cerebellar rhythm could be analogous to hippocampal theta rhythm and involved with the cebellar memory storage and therefore would not tell anything about the span of the memory but would characterize the time resolution of memories and planned actions. The role of cerebellum in the fine coordination of motor actions indeed requires high time resolution.

Brain has anatomic division into midbrain, hindbrain, and forebrain [J6]. Midbrain and hindbrain (sometimes both are included in brain stem) is possessed by even the most primitive vertebrates and its emergence could therefore correspond to the emergence of $k_{eff} \geq 205$ levels and EEG. The emergence of these levels relates naturally to the emergence of long term planning of motor actions in motor areas. The emergence of limbic brain, which defines the most primitive forebrain, could mean the emergence of the Gaussian Mersenne defined by $k_{eff} = 239$ containing dark electron condensates level and goal related emotions. This conforms with the fact that for mammals forebrain and cerebral hemispheres dominate whereas for other vertebrates hindbrain and cerebellum are in the dominant role.

Reptilian brain as $k_{eff} \leq 205$ system?

Reptilian brain contains only the structures corresponding to brain stem (midbrain and hind brain, in particular cerebellum) and as far structures are considered would correspond to $k_{eff} \leq 205$ levels of the hierarchy. Cerebellum is not believed to contribute directly to our consciousness. The absence of higher looks however an unrealistic assumption since reptiles certainly have long term memories.

Simplest emotions correspond to emotions involving no goal. Moods like excitement, feeling good/bad/tired/strong, etc.. could represent examples of such emotions and could be experienced already by reptilians. Of course, the scaled up variants of these emotions could appear at higher levels of hierarchy and would relate to the states of magnetic bodies (degree of the quantum coherence of Bose-Einstein condensates!).

Limbic system

Limbic system is not possessed by reptiles [J17]. It is responsible for emotions, control of emotions, and also emotional intelligence. Limbic system corresponds to the brain of the most mammals. The limbic brain includes the amygdala, anterior thalamic nucleus, cingulate gyrus, fornix, hippocampus, hypothalamus, mammillary bodies, medial forebrain bundle, prefrontal lobes, septal nuclei, and other areas and pathways of the brain.

1. The sub-cortical part of the limbic system involves amygdalar and septal divisions. According to [J17] amygdalar division promotes feeding, food-search, angry, and defensive behaviors related to obtaining food. Septal division promotes sexual pleasure, genital swelling, grooming, courtship, and maternal behavior. These divisions are emotional mirror images of each other hand could correspond to $205 < k_{eff} < 239$.

2. The cortical part of the limbic system contains cingulate gyrus which is the newest part of the limbic system and belongs to thalamo-cingulate division which promotes play, vocalization (e.g., the separation cry), and maternal behavior. The time scale of memories would be shorter than 3.4 at this level.

3. Frontal lobes [J12] are often regarded as the organ of volition. The frontal lobes are involved in motor function, problem solving, spontaneity, memory, language, initiation, judgement, impulse control, and social and sexual behavior. Prefrontal lobes representing the extreme front part of frontal lobes belong also to the limbic system and are responsible for motivation and ability to pose long term goals. This ability distinguishes humans from other primates. For these reasons frontal lobes, in particular prefrontal lobes, could involve the highest levels of dark matter hierarchy in the case of humans. The Gaussian Mersenne levels $k_{eff} = (239, 241)$ could be assigned as lowest level in this hierarchy. The time scale of long term memories would be longer than 3.4 years at these levels.

Cortico-striatal emotions like sadness, hate, fear anger, surprise, embarrassment, happiness, contentment, and joy involve goal structures and failure or success to achieve the goal in essential manner and would involve prefrontal lobes.

These levels would naturally relate to collective levels of consciousness coded by hyper genes. Hence these emotions could also relate to goals not directly related to the fate of biological body. Mirror neurons are a crucial prerequisite of a social behavior (autistic children seem to lack them), which suggests that hyper genes are involved at least with them.

Social emotions (feeling embarrassed, ashamed, guilty, loved, accepted, ...) could be induced by the collective levels of dark matter hierarchy as punishments or rewards for social behavior very much like neurotransmitters are believed to provide rewards and punishments at neuronal level.

Neocortex and two kinds of intelligences

Neocortex is often assumed to be superior ("neomammalian") part of the brain and makes the majority of brain hemispheres. The species which are considered to be highly intelligent, such as humans and dolphins, tend to have large amounts of neocortex. The amount of neocortex is roughly proportional to the brain size for primates.

Neocortex cannot correspond to $k_{eff} \geq 239$ (defining Gaussian Mersenne) as a whole. The decomposition of sensory areas to layers is consistent with the presence of lower levels since it is time resolution which matters in the case of sensory representations. Same conclusion applies to sensory association areas. The fine tuning of the motor control performed by cerebellum is consistent with $k_{eff} \leq 205$. Intelligence understood in the conventional sense of the word is accurate, works fast, and is computer like. The part of neocortex responsible for ordinary intelligence would be a rapid and accurate processor of sensory and cognitive representations. Hence $k_{eff} < 239$ would naturally characterize sensory areas, secondary and primary motor areas, to hippocampal representation of declarative memories, and all association areas except dorsolateral prefrontal sensory-motor association cortex where short term memories are represented.

Emotional intelligence works slowly and is responsible for visions and holistic views and would thus correspond to higher levels of dark matter hierarchy. Limbic system is involved with emotions, motivation and long term planning and would thus be responsible for emotional intelligence. Indeed, the damage to frontal lobes [J12] need not affect ordinary intelligence but affects emotional intelligence.

The levels of dark matter hierarchy associated with short and long term memory

The first thing to ask is of course whether the notions of short and long term memory make sense in TGD framework. Indeed, it would seem that it is more natural to speak about hierarchy of memories with characteristic time scales coming as selected powers of two.

1. According to [J25], the span of other than visual short term memories is 30-45 seconds. This requires $k_{eff} \in \{217, 218\}$.

2. Visual short term memories [J2] representing selected features of visual field are reported to have time span of few seconds. This suggests $k_{eff} \in \{213, 214, 215\}$.

3. Iconic visual memories representing entire visual field have much shorter time span of order 1 s: $k_{eff} \in \{211, 212\}$ would be appropriate for them,

4. Long term memories would correspond to $k_{eff} > 218$.

Hippocampus and mammillary bodies involved with long term memory recall are part of the limbic system. The hippocampal theta rhythm 4-12 Hz, which could corresponds roughly to $k_{eff} \in \{163, 162, 161\}$ has nothing to do with the span of long term memories but would define the time resolution of the memories: the moment of sensory experience indeed corresponds to 10 Hz frequency. The frequencies responsible for memory storage need not have anything to do with the ultralow frequencies characterizing the temporal distance of the past event associated with the memory recall and hippocampus could just build a kind of bit sequence which during memory recall is communicated from the geometric past to some part of the future brain or magnetic body.

Anterograde amnesia means an inability to restore long term memories. The damage of hippocampus or of mammillary bodies can induce anterograde amnesia. In the usual conceptual framework the explanation would be the inability to store new long memories. In TGD framework this would be inability to construct those cognitive representations which are communicated to the geometric future in long term memory recall. Retrograde amnesia seems to involve almost always anterograde amnesia and means loss of memories for some time span before the injury. A possible explanation is that injury can propagate also to the geometric past of the brain quantum jump by quantum jump.

During aging memories tend to be lost but the memories of childhood are the most stable ones. A possible interpretation is that faster rhythms of the generalized EEG tend to disappear: kind of scaled up variant for the process of falling into sleep accompanied by silencing of higher EEG bands could be in question.

What about transpersonal levels of consciousness?

$k_{eff} > 245$ levels of dark matter hierarchy correspond to time span longer than 109 years and cannot relate to the biological body alone. They could relate to higher collective levels of the dark matter hierarchy and evolution of social structures. The memories extending over personal life span claimed by meditators could have interpretation in terms of $k_{eff} > 245$ transpersonal levels of consciousness. Also the "god module" located to temporal lobes could correspond to this kind of levels of dark matter hierarchy. If it corresponds to Gaussian Mersenne with $k_{eff} = 283$ the time scale of memories becomes huge: about 10^{14} years so that the notion of "god module" is indeed appropriate.

Boolean qualia, fermions, and memetic code

The original proposal for the realization of Boolean mind was in terms of sequences cognitive neutrino pairs. These can be interpreted as wormhole contacts carrying neutrino and antineutrino at the light-like wormhole throats and would thus represent boson like entities. In the framework of the standard model the proposal looks of course completely non-sensical. TGD however predicts the existence of long range classical electro-weak fields, and one might imagine that inside neutrino- whose Compton length corresponds to length scale of cell- intermediate gauge bosons behave like massless fields. Although neutrinos could be important, the time scale of corresponding CD - about 10^4 years - suggests that cognitive neutrinos might be important in much longer time scale than the.1 second time scale assignable to the memetic code.

The recent view about TGD allows a much more general view. Zero energy ontology allows to interpret the fermionic parts of zero energy states as quantum superpositions of Boolean statements of form $a \to b$ with a and b represented in terms of positive and negative energy parts of the zero energy state. If one has negentropic entanglement this kind of state has interpretation as an abstraction - a "law of physics" - representing as a quantum superposition various instances of a more general law.

The simplest situation corresponds to a CD having only single positive energy fermion and negative energy fermion at its light-like boundaries. The fermion number or spin or isospin of the fermion could represent qubit. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy, when combined with p-adic length scale hypothesis, led to a prediction of order .1 seconds for the duration of the "wake-up" period of sub-self corresponding to the codeword of the memetic code. Since the CD assignable to electron has time scale.1 seconds and the CD assignable to u and d quarks has time scale 1/1.28 milliseconds there is a temptation to proposed that the quark-like sub-CDs of electronic CD give to a realization of memetic code word as a sequence of 126 quark like sub-CDs. u and d quarks would be assigned to the magnetic flux tubes connecting DNA and the lipids of the cell membrane in the model of DNA as topological quantum computer. Clearly, beautiful connection between new elementary particle physics, genetic code, nerve pulse activity, DNA as topological quantum computer, logical thought, and the basic time scales of speech are suggestive.

This codeword consists of 126 bits represented by quarks such that the two possible magnetization directions correspond to the two values of Boolean statement. This implies that the duration of single bit should 1/1260 seconds. The duration of the nerve pulse is slightly longer than this which might mean that the full memetic code is realized as membrane oscillations rather than nerve pulse patterns. Both hearing and vision have .1 second time scale as a fundamental time scale and sounds are indeed coded to membrane oscillations in ear.

One can consider also the realization of genetic code with six bits of the codon represented by various scaled up versions of quark CD coming as size powers of 2. In this case the ordering of the bits would come from the size of sub-CD whereas in previous example temporal ordering would define the ordering. It is not however clear whether the powers of two can be realized physically.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20.000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-, 5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is.1 seconds. This could be seen as a support for the realization of some degenerate version of the memetic code as nerve pulse patterns.

The model for the memetic code encourages the following conclusions.

1. Membrane oscillation/nerve pulse patterns correspond to temporal sequences of magnetization directions for quarks representing yes/no Boolean statements.

2. The spin polarization of quarks is changed from the standard direction fixed by the spontaneous magnetization in the direction of axon by a ME moving parallel to axon, and inducing membrane oscillation or even a nerve pulse. Nerve pulses could correspond to a degenerate memetic code resulting by frequency coding for which the number of distinguishable code words is 64, and would thus naturally correspond to the reduction of the memetic code to the genetic code.

A very precise correspondence with the basic structures of the genetic code results. mRNA $\rightarrow$ protein translation corresponds to the translation of temporal sequences o magnetization directions to conscious cognitive experiences. Under very natural constraints the mapping to cognitive experiences is not one-to-one and the predicted degeneracy (2^{126} sequences correspond to $(2^{126} - 1)/63$ cognitive experiences) can be understood.

One might think that the full memetic code is an evolutionary newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. The full memetic code could be realized for certain regions of brain only. These regions certainly include auditory pathways responsible for the comprehension of speech.

9.4 Constraints On The Fermionic Realization Of Genetic Code From The Model For Color Qualia

The original model for DNA as topological quantum computer assigns to DNA nucleotides quarks at ends of flux tubes or quark pairs at the ends of wormhole flux tubes. This is only the realization that came first to my mind in TGD Universe where dark variants of quarks can define QCD like physics even in cellular length scales. One can actually imagine several realizations of the genetic code and the first realization is far from being the simplest one. It is enough to have four different particles or many-particle quantum states to build at least formally a map from A, T, C, G to four states. It is obvious that the number of possible formal realizations is limited only by the imagination of the theoretician. Additional conditions are required to fix the model.

9.4.1 Fermionic Representation

Consider first the fermionic representations in the general case without specifying what fermions are.

1. The original proposal was that DNA nucleotides correspond to flux tubes with quark q and antiquark $\overline{q}$ at the ends of the parallel flux sheets extremely near to each other. Second options relies on wormhole magnetic flux tubes in which case quark pair $q\overline{q}$ is at both ends. Quarks u, d and their antiquarks would code for A, T, C, G. The spin of quarks is not taken into account at all in this coding: why not restrict the consideration to single quark. The total quark charge at given end of flux tube pair vanishes and flux tube ends carry opposite quark charges.

   The nice feature of this option is that one could understand the generation of color qualia in the model of sensory receptor in simple manner to be discussed below. Even if one accepts the arguments supporting the view that dark quarks in cell scale are natural outcome of

the hierarchy of Planck constants, one could argue that the presence of both quarks and antiquarks does not conform with matter antimatter asymmetry (not that one can however identify the analog of matter antimatter asymmetry at DNA level).

2. Spin states for fermion pairs assigned with two parallel magnetic flux tubes with the magnetic field generated by spin provide much simpler representation for nucleotides. Similar fermion pair would reside at the second end of flux tube pair.

   (a) It is is essential that rotational symmetry is broken and reduces to rotational symmetry around the direction of flux tubes so that spin singlet and spin 0 state of triplet mix to form states for which each fermion is in spin eigenstate. The states must be antisymmetric under exchange of the protons and spin 1/0 states are antisymmetric/symmetric in spatial degrees of freedom (wave functions located to the ends of flux tubes). The states with definite spin for given flux tube are mixtures of s=1 states with vanishing spin projection and s=0 state.

   (b) It is not quite clear whether one should treat fermion pairs as identical bosons with 3+1 spin states since in TGD framework one considers disjoint partonic 2-surfaces and the situation is not that of QFT in M^4. This interpretation would require totally symmetry of the states under permutations of bosonic states defined by the 3+1 spin states. Coding by spin requires that each nucleotide corresponds to a state with a well defined spin. In field theory language the state would be obtained by applying bosonic oscillator operators generating states of given spin localized to a given nucleotide position.

   (c) The classical correlate for the permutations of coordinates of fermions has interpretation as braiding for the flux tubes of the flux tube pair. In the similar manner the permutation of the flux tube pairs associated with nucleotides has interpretation as braiding of the 3-braids formed form from flux tube pairs. Braiding therefore gives a representation of spin analogous to the well-known orientation entanglement relation invented by Dirac and providing geometric representation of spin 1/2 property.

9.4.2 Various Options For The Fermionic Representation Of A, T, C, G

Fermionic representations allows several options since fermion can be electron, u or d quark, or proton. Wormhole magnetic fields would not be needed in this case.

1. The problem of electron and proton options is that it does not allow realization of color qualia. There is also the well-known problem related to the stability of DNA caused by the phosphate charge of -2 units per nucleotide. Somehow this charge should be screened. In any case, the charge -2 should correspond to the electron pair at the DNA end of the flux tube for electron option. For proton option the charge would be screened completely. One could of course consider also the large $\hbar$ color excitations of ordinary protons instead of quark at its nucleotide ends. This option would however require the modification of quark wave functions inside proton and this option will not be discussed here.

2. Quark option would give rise to both color and allow also to reduce the electronic charge of -2 units by 4/3 units to -2/3 units in the case of u quark pair. This would help to stabilize DNA. In the case of d quarks the charge would increase to -10/3 units and is not favored by stability argument. Flux tube pairs assigned to single nucleotide define diquarks with spin 1 or spin 0.

   (a) Diquarks behave ass identical bosons with 3+1 spin states and 3×3 color states. They form formally super-multiplet of $\mathcal{N} = 2$ SUSY. The states with well defined symmetry properties in spin degrees of freedom have such properties in spatial degrees of freedom. This means that one obtains a superposition of flux tube pairs with are either braided or unbraided. Triplet/singlet state is symmetric/antisymmetric and total asymmetry could be guaranteed by assuming symmetry/antisymmetry in spatial degrees of freedom and antisymmetry/symmetry in color degrees of freedom. This

would give anti-triplet/6-plet in color degrees of freedom. Spatial symmetry would favor antitriplet and diquark would behave like antiquark with respect to color. Let us assume antitriplet state for definiteness.

(b) DNA codon corresponds to three-di-quark state. This state must be totally symmetric under the exchange of bosons. One can have total symmetry in both spatial and color degrees of freedom or total antisymmetry/symmetry in spatial and total antisymmetry/symmetry in color degrees of freedom.The first option gives 10-dimensional color multiplet and the second one color singlet. Braiding is maximal and symmetric/antisymmetric in these case. One can consider also mixed symmetries. In this case one has color octet which is antisymmetric with respect to the first nucleotide pair and symmetric with respect to first nucleotide pair and third nucleotide. The braiding of the first two nucleotides must be antisymmetric and the braiding of this pair with third nucleotide. The conclusion would be that color multiplets correspond to well defined braidings and one would therefore have directed connection with topological quantum computation. Color octet is especially interesting concerning the representation of color qualia.

The challenge of all these options (note that the representability of color selects quark option) is to find a good justification for why the assignment of A, T, C, G to quark states or spin states is unique dynamically. Stability argument is expected to help here.

9.4.3 Realization Of Color Qualia For Quark Option

Consider now how one could understand the generation of qualia for quark option.

1. The generation of qualia involves interaction with external world giving rise to a sensory percept. In the case of visual colors it should correspond to a measurement of quark color and should give rise to eigenstages of color at the ends of flux tubes at DNA nucleotides for a nucleus or cell of photoreceptor. A modification of capacitor model is needed. Color polarization is still essential but now polarization in nucleus or cell scale is transformed in the generation of color quale to a polarization in longer length scale by the reconnection of flux tubes so that their ends attach to "external world". The nucleus/cell becomes color and state function reduction selects well defined quantum numbers. It is natural to assume that the entanglement in other degrees of freedom after color measurement is negentropic.

2. Does the "external world" corresponds to another cell or to the inner lipid layers of the cell membrane containing the nucleus. In the first case flux tubes would end to another cell. If the nuclei of receptor cells are integrate to a larger structure by magnetic flux sheets traversing through them one can also consider the possibility that the polarization in the scale of cell nucleus (recall that the nucleus has also double lipid layer) is transformed to a polarization in cell scale so that similar process in cell scale gives rise to qualia.

   The entire receptor unit must have net color charge before the state function reduction. This requires that there are flux tubes connecting the receptor unit to a unit representing "external world" and having vanishing color charge. If second cell is the "external world" these flux tubes must go through the pair of lipid layers of both cell membrane and end up to the nucleus of cell in the environment. If external world correspond to the complement of nucleus inside cell the inner layers of cell membrane represents external world. Cell membrane indeed serves as sensory receptor in cell length scale. One can of course have sensory qualia in various length scales so that both options are probably correct and a kind of fractal hierarchy is very natural giving rise also to our qualia at some higher level. Living matter as conscious hologram metaphor suggests a fractal hierarchy of qualia.

   After state function reduction reducing the entanglement the flux tubes split and the receptor becomes un-entangled with external world and has vanishing color charges. At the level of conscious experience this means that there can be only memory about the quale experience. The sensation of quale lasts with respect to subjective time as long as the negentropic entanglement prevails. There is an obvious analogy with Orch-OR (see

http://tinyurl.com/ylfv6pp) proposal of Hameroff and Penrose in which also conscious experience ends with state function reduction.

3. Consider now how the color qualia are generated.

   (a) There must be two flux tube states. In the first state there are two flux tube beginning from cell nucleus A and ending to the inner lipid layer a_1 and flux tube beginning from the outer lipid layer a_2 and ending cell nucleus B. Both flux tubes have vanishing net color so that cells have vanishing net colors. This could be regarded as the resting state of the receptor. The lipids in layers a_1 and a_2 are connected by another short flux tube. Same for b_1 and b_2.

   (b) The second flux tube state corresponds to long flux tubes connecting the nuclei of cells A and B. The ends carry opposite color charges. In this case the net color of both A and B is non-vanishing. This state would be an outcome of a reconnection process in which the flux tubes from A to a_1 and B to a_2 re-connect with the short flux tube connecting lipid layers a_1 and a_2.

   (c) When these flux tubes carry opposite colors numbers at their ends, the cell possess net color charge and can represent color quale. Or rather, creation of this kind of flux tube connections would give rise to the color charging of the receptor cell with external world carrying opposite color charge.

One can argue that this mechanism is not quite in spirit with color capacitor model. Polarization is still essential but now polarization in receptor scale is transformed to polarization in longer length scale by the reconnection of flux tubes. The analog of di-electric breakdown however still applies in the sense that its analog induces large polarization. Several mechanisms generating larger polarization are of course possible. One can ask how essential the electromagnetic polarization of cell membrane is for the generation of qualia at cell level. Note also that biomolecules are quite generally polar molecules.

The unexpected prediction of the model is that braiding would correlate directly with qualia. This would mean also a connection between quantum computation and qualia. This condition emerges from Fermi/Bose-Einstein statistics correlating braiding with symmetric properties of color states and spin states. Quite generally, the correlation of braiding with the symmetries of wave functions as functions of points of braid end points would allow to have direct geometric correlate between induced entanglement and braiding as naïve intuitive expectations have suggested.

This model is not consistent with the naïve expectation that the quale is generated after state function reduction. Rather, the beginning of sensation of quale means beginning of negentropic entanglement and fusion with external world and state function usually associated with the quantum measurement would mean the end of the sensation and separation from the external world! Maybe one can say that state function reduction means that experience is replaced with a memory "I had the sensation of quale" ! Krishnamurti would certainly agree!

9.5 Flag-Manifold Qualia

Sensory mappings are basic aspect of what brain is doing and therefore one expects that this kind of mappings are performed routinely also at the level of brain. For instance, our tendency to visualize very abstract concepts as geometric objects suggests that they are indeed represented as sub-selves having definite positions inside brain (and as it seems also outside!).

I encountered this kind of mappings in rather early stage, much before the TGD inspired theory of consciousness allowed to even say much about this kind of mappings. The reason was the work of Barbara Shipman about honeybee dance [A10]. The strange findings of Shipman suggest that the color symmetry of hadron physics plays key role in sensory experiencing of the tiny honeybees, and led ultimately to the realization that classical color fields predicted by TGD are crucial for understanding visual qualia in TGD framework. Place and time coding by magnetic frequencies has been already considered in the section describing the general vision about the identification of qualia. In this section the attention will be focused to particular geometric qualia

associated with the flag manifold defined by the possible choices of the quantization axes for the super-symplectic algebra and the findings of the Barbara Shipman will be discussed in TGD framework.

9.5.1 Basic Structure Of WCW

The basic mathematical structure of quantum TGD is the infinite-dimensional space of 3-surfaces. If Kähler action were deterministic, WCW would effectively reduce to the space of 3-surfaces on the light-cone boundary $\delta M_+^4 \times CP_2$ representing the moment of big bang. The classical non-determinism of the Kähler action however forces to consider also the spaces of 3-surfaces belonging to the light-like M_+^4 projections of the light-like boundaries of the massless extremals (MEs), which are thus extremely natural geometric correlates of selves. These selves could perhaps be called light-like selves. The fact that the M_+^4 projections of CP_2 type extremal representing elementary particle is a random light-like curve, suggests strongly that one must also allow space-like 3-surfaces as correlates of selves. In this respect theory does not yet say anything definite but magnetic flux tubes are very attractive candidates (certainly not the only ones) for what might be called space-like selves.

WCW degrees of freedom can be divided into quantum fluctuating degrees of freedom and zero modes which do not quantum fluctuate (being thus "classical")and characterize the size and shape of 3-surface and are excellent candidate for representing information about the state of organism (3-surface itself) geometrically. The zero modes of WCW are special in the sense that in each quantum jump localization occurs in these degrees of freedom.

The hypothesis is that the sequence of events leading to experience geometric qualia involves localization in (measurement of) zero modes parametrizing among other things also the possible choices of quantization axes. One cannot assign geometric qualia to the flag-manifold of the entire isometry group since the localization occurs only in zero modes: rather the sub-group generated by canonical generators labelled by even conformal weights is in question. The flag-manifold in question corresponds to the extension of canonical group of $E^2 \times CP_2$ generated by generators of even conformal weight by CP_2 local conformal transformations of light-cone boundary generated by algebra generators having even conformal weight divided by the Cartan group of $SO(2) \times SU(3)$.

One must consider also the possibility that infinite-dimensional canonical flag-manifold actually reduces (at practical level at least) to finite-dimensional flag-manifold F_3 by the requirement that the choice of the quantization axes for the super-symplectic algebra is induced by the choice of the quantization axes for color. Note that in the case of MEs the quantization axis for spin is completely fixed for $E^2 \times CP_2$ whereas for $S^2 \times CP_2$ the sphere S^2 parametrizes the choices of the quantization. Thus the flag manifold F_3 encountered by Barbara [A10] [A10] emerges naturally for MEs.

9.5.2 Quantum Honeybee

Barbara Shipman [A10] has made rather puzzling observation about the possible connection of the dance of honeybee with the color group $SU(3)$ appearing as the gauge group of strong interactions. The dance of honeybee, providing information of and depending on the distance and direction of the food source, could be regarded as a map of a certain path in the flag manifold $F_3 = SU(3)/U(1) \times U(1)$ mapped to a hexagon like plane region serving as a dance floor.

Barbara Shipman suggests a possible connection between biophysics and quantum physics at quark level. From the point of view of standard physics this suggestion looks inplausible since color confinement should make dynamical effects related to color invisible above the hadronic length scale of order one fermi (10^{-9} times cellular length scale!). In TGD framework it is however possible to understand the observations of Barbara Shipman and these observations are also consistent with the general model for the universal submodalities of sensory qualia. In fact, the work of Barbara Shipman served as an important impetus during the process leading to the general TGD based model of sensory qualia.

Dance of the honeybee

The dance of the honeybee occurs at the vertical face of the honeycomb and codes the information about the distance and direction of the food source. Von Frisch discovered the choreographic syntax and interpretation of the dance and published the results of his work in his 1967 book "Dance language and Orientation of Bees" [J175].

The pattern of the dance is that of figure eight above certain critical distance to the food source and that of a circle below this distance.

1. The angle of the figure eight pattern with respect to the vertical codes the angle between the direction of the food source and the horizontal projection of Sun. For instance, when the food source is in the direction of Sun, figure eight pattern is vertical. The dancer waggles and produces buzzing sound during the first phase of the dance and then walks to the original position along the other circle of the figure eight. After that the dancer waggles again but now along the second circle of the figure eight so that the waggling phases of the dance form the pattern of a figure V in the middle of the figure 8. The buzzing sound produced by the wings of the dancer makes it possible for the audience to locate the dancer (dance occurs in darkness). The opening angle of the figure V codes the distance to the food source for distances above some critical distance.

2. Below the critical distance the pattern changes to a circle. Now the waggling parts of the dance correspond to two disjoint straight line portions located at the opposite sides of the hexagon.

What Barbara Shipman found [A10] was that the images of certain curves of 6-dimensional flag manifold under the so called momentum map reproduce the dancing pattern of the honeybee if the six initial values determining the curve are chosen suitably. Only two of these parameters code the information about the food source. The article about the model of honeybee dance is not published yet but on the basis of short abstract [A10] it is very plausible that the curves in question are solution curves associated with a completely integrable system known as a full Kostant-Toda lattice studied by Barbara Shipman [A11, A12]. The solutions of the $2(n-1)$ equations of motion associated with this model can be mapped to the solutions of certain completely integrable Hamiltonian system in the flag manifold $F_n = SL(n,C)/B$, where $SL(n,C)$ is the space of complex matrices with unit determinant and B is the space of upper triangular matrices with unit determinant. F_n is in turn isomorphic with $SU(n)/U(1)^n$ and this implies a connection with the quantum measurement theory of color charges in $n = 3$ case.

The dance of honeybee should somehow map the some curve of the flag-manifold to a planar curve representing the dancing pattern. $SU(n)$ acts as Hamiltonian transformations of the flag manifold but not as symmetries of Kostant-Toda lattice: in particular, the Cartan algebra generators define Hamiltonians $H_I(x)$ and $H_Y(x)$ in F_3. The so called momentum map associating to the point x of the flag manifold F_3 the point $(H_I(x), H_Y(x))$ characterizing the values of the isospin and hypercharge Hamiltonians at the point x. The image of F_3 under this map is hexagonal region of plane and the image of Kostant-Toda orbit under this map is identified as the dancing pattern of the honeybee. It is obvious that $SU(3)$ cannot act as symmetries of the Kostant-Toda system since in this case Hamiltonians would be constant along the solution curves and momentum map would map every orbit to single point.

To summarize the result concisely:

1. If the orbit of 3-surface in the flag manifold is characterized by Hamiltonian equations related to the so called Kostant-Toda lattice, which is a completely integrable system,

2. if the hexagonal planar region defined by the image of the momentum map corresponds to the "dance floor" and

3. if the orbit of the bee corresponds to the image of the orbit of flag manifold under the momentum momentum map,

one can understand the basic aspects of the waggle dance.

One can indeed understand the dance of honeybee as a representation for the information content of thought of the honeybee. What forces one to take the model seriously is that it reproduces also the dependence of the dancing pattern on bee community and predicts correctly the spectacular change of the V shaped dancing pattern to a union two disjoint lines on the opposite boundaries of the hexagon like region.

TGD based model of the honeybee dance

The concept of self and the TGD based model for sensory experiencing lead directly to the prediction that mental images, also those of tiny honeybee, should correspond to almost continuous curves of infinite-dimensional flag-manifold containing F_3 as sub-flag-manifold. If these orbits are solution curves of dynamical system defined by Kostant-Toda lattice, one can understand the observations of Barbara Shipman.

1. Why curves in flag-manifold?

1. Flag manifold F_3 characterizes especially interesting zero modes. If the contents of the sensory experience is determined by the localization in zero modes occurring in quantum jump, the coordinates of F_3 for mind like space-time sheet generated in sensory perception and representing object of perceptive field, should code some basic data about sensory experience. Since F_3 represents geometric qualia, it is associated with all senses, not only vision and that this role might be similar for all sensory qualia.

2. F_3 is indeed identical with the flag manifold $SL(3,C)/B$ studied by Barbara Shipman. The dimension of $SU(n)/H$, $H = U(1)^{n-1}$, is $D = n(n-1)$ and same as the dimension of the flag-manifold and In $n = 2$ case the two spaces are identical as direct inspection shows. In the general case the isomorphy follows from the observation that arbitrary $SL(n,C)$ matrix s can be expressed as a product $s = b_1 u$, where u is $SU(n)$ matrix and b_1 belongs to the group $B_1 \subset B$ of the upper diagonal matrices with real elements on the diagonal. The elements of B in turn are expressible in the form $b = b_1 h$, where h is diagonal matrix belonging to Cartan group and b_1 belonging to B_1. Therefore the flag manifold can be written as $F = SL(n,C)/B = B_1 SU(n)/B_1 H = SU(n)/H$.

3. Time development by quantum jumps means hopping in zero modes and since the increment of the geometric time in single quantum jump is expected to be very short, of order 10^4 Planck times, the time development should define an almost continuous curve in F_3. In particular, subjective memory of self about quantum jump sequence corresponds to curve in F_3 defined by the averaged increments of zero modes represented by sub-selves.

4. In the ideal case honeybee could code the coordinates and velocities for entire fly path to the food source but this kind of feat is impossible even for us. In practice only the distance and direction of the food source is needed. This information must correspond to sub-self of the honeybee and sub-self in turn corresponds a curve of the flag-manifold F_3. If the projection of this orbit to F_3 is determined by the dynamics of a completely integrable system known as full Kostant-Toda lattice, the physical foundations for the model of Barbara Shipman can be understood in TGD framework.

2. Why the projection of flag-manifold curve to hexagonal plane region

A possible explanation for the reduction of the path to a two-dimensional path is based on the following observations.

1. The simplest extremals of Kähler action have 2-dimensional CP_2 at a geodesic sphere of CP_2, which can be homologically non-trivial or trivial. For the first option classical electromagnetic and W fields are non-vanishing. For the latter option electromagnetic and Z^0 fields are non-vanishing and proportional to each other. Almost vacuum extremals provide a detailed model for both sensory receptor and basic sensory qualia and will tbe discussed at the end of the chapter whereas far from vacuum extremals seem to provide a model for magnetic bodies. Also the simplest MEs can be classified to these two types.

2. The holonomy algebra of color group is Abelian and one can gauge rotate the color gauge algebra to some $U(1) \times U(1)$ subalgebra of $SU(3)$ and two CP_2 coordinates can serve as the coordinates of these space-time surfaces. Also the dance floor of honeybee can be coordinatized by two CP_2 coordinates.

3. Each space-time surface has by topological field quantization a unique Cartan algebra $U(1) \times U(1)$. Since the values of the color Hamiltonians are well defined functions in CP_2, a very natural choice for the two coordinates is as Hamiltonians H_I and H_Y appearing also as the coordinates of the dance floor in Shipman's model. The region defined by H_I and H_Y has the hexagonal shape and since its boundaries naturally correspond to the boundaries of a mind like space-time sheet such as ME, the mapping of the sequence of increments of flag-manifold coordinates to space-time sheet to a curve inside diffeomorph of the hexagon in plane looks natural. It seems that honeybee really experiences these coordinates directly as imagined positions in plane.

3. How flag-manifolds emerge from first principles?

A deeper explanation for flag-manifold emerges in zero energy ontology combined with the hierarchy of Planck constants.

1. Zero energy states correspond to entangled pairs of positive and negative energy states located at the opposite light-like boundaries of a given causal diamond (CD) defined as the intersection of future and past directed light-cones. Strictly speaking a Cartesian product of CD with CP_2 is in question. CDs form a fractal hierarchy. In the ordinary ontology zero energy state corresponds to a physical event. The time-like entanglement between positive and negative energy states defines M-matrix generalizing the notion of S-matrix. Time-like entanglement must be fundamental also from the point of view of consciousness as a reduction of quantum state to a state with well defined values of observables for the initial (positive energy) and final (negative energy) states. The Cartesian product of causal diamond CD defined as the intersection of future and past directed light cones with CP_2. CD is characterized by the positions of its tips so that one has M^4 valued cm coordinate plus relative coordinate between the tips. p-Adic length cale hypothesis follows if the proper time distance is quantized in powers of two. This suggests that also the of the tip at the hyperboloid with constant proper time is discrete and that discrete lattice like structure defined by some discrete subgroup of SL(2, C) acting as boosts on given reference CD.

2. The hierarchy of Planck constants forces a generalization of the embedding space to a book like structure [K44, K38, K36, K21, K22]. The pages of the Big Book are characterized by two numbers x_a and x_b assignable to M^4 and CP_2 degrees of freedom. The values of these numbers are either integers of their inverses depending on whether the page of the book is a singular covering or factor space defined by a discrete subgroup of SU(2). For a given CD the sectors characterized by different integers are glued together along $M^2 \subset M^4$ defining quantization axis of energy and spin. In CP_2 degrees of freedom the gluing is along a homologically trivial geodesic sphere of CP_2 and also now a fixing of the quantization axes is involved. The positions of the tips of CD and preferred points of CP_2 at the two light-like boundaries of CD fix the quantization axis and moduli space for CDs. An attractive hypothesis is that the relative positions of tips and corresponding preferred points of CP_2 form discrete spaces. The quantization of the temporal distance between tips in powers of two implies p-adic length scale hypothesis.

3. The tips of CD define a preferred time coordinate, which together with M^2 defines the quantization axes of energy and spin. In the case of CP_2 has also a choice of color and isospin quantization axes implied by the choice of a pair of CP_2 points and the choice of S^2. This means that one has a flag-manifold defined by the choices of quantization axes for energy and momentum one one hand and for color quantum numbers on the other hand. Therefore the model for the honeybee dance finds a justification from the first principles of quantum TGD.

4. Why solutions of full Kostant-Toda lattice?

The hexagonal shape of the dance floor is very strong qualitative prediction as such involving no dynamical models and the attempt to reduce the dynamics to Kostant-Toda lattice might be more that one can desire. Certainly so, if honeybee represents its memories about entire non-deterministic path to the food source rather than just the minimum data abstracted from what honeybee remembers. Of course, honeybee dance might represent only the minimum information making possible to find the food source and this would be achieved if dance represents a deterministic dynamical system with a very high symmetry. Thus it makes sense to ask why just the solution curves of full Kostant-Toda lattice should approximate the almost continuous orbit of F_3 defined by quantum jump sequence summarizing the memories of honeybee.

1. A possible explanation is that the mental images of the honeybee are result of long evolution and self organization and that mental images with standardized content such as position of the food source, correspond to a solution of some very symmetrical dynamical system.

2. That the full Kostant-Toda lattice is needed can be partially understood. For the full Kostant-Toda lattice time evolution is not unitary transformation but similarity and $SU(3)$ does not in general act as symmetries: if this were the case Cartan group associated with the 3-surface would be a constant of motion. Rather, the eigenvalues of the traceless SL(3, C) Lie-algebra matrix S (see appendix) are the needed two complex constants of motion. For instance, geodesic motion in flag manifold would have $SU(3)$ as symmetries and this would imply that Cartan algebra would define constants of motion and the momentum map would map the orbits to the points of plane. The breaking of $SU(3)$ symmetry is natural since also quantum jump sequence defining the memory of honeybee represents sequence of changes of color quantization axes.

Questions

There are several questions to be answered.

1. The representation curve in F_3 is determined by the initial values of six coordinates. The information coded into the dance fixes only two coordinates and the initial values of the remaining coordinates must be constants specific to hive or subspecies of honey bees. It would not be surprising that these parameters are somehow complementary to the 2 complex constants of motion (eigenvalues of S) associated with the Kostant-Toda dynamics.

2. Somehow the direction of food source and its distance should be coded into the initial values: perhaps the initial values of the flag manifold point develop in time during the flight of the honeybee from the food source to the nest according to a simple rule from initial values corresponding to vanishing distance and ill defined direction angle. The flight occurs along a straight line so that this mechanism looks plausible.

3. For the information to become properly interpreted, the dance should generate the original representation of the information as a flag manifold orbit in the minds of the audience. This requires that the direction with respect to vertical and opening angle are mapped to the initial values of the flag manifold orbit. One can also consider possibility is that the orbit of the flag manifold provides a mental representation for the shortest path to the food source. Magnetic fields are known to be important for the ability of the bee to fly in straight line and the fact that magnetic fields give rise to color magnetic fields suggests that quantum measurement of color charges during the flight might be an important factor in the orienteering of the honeybee. Perhaps the comparison of the measured real color charges with the measured color charges in the mental representation of the orbit is involved.

Some mathematical background

1. Complete Kostant-Toda lattice

Completely integrable systems [B4] allow quite generally a Hamiltonian formulation such that there exist maximal number of constants of motion in involution (having vanishing Poisson brackets). This makes the quantization of the completely integrable systems possible. The so called

Lax pair allows to transform the dynamics of completely integrable systems to a time dependent unitary transformation of some tensorial or spinorial quantity and this leads to the so called inverse scattering method allowing to solve completely integrable models.

An example of a finite-dimensional completely integrable system is provided by the so called Toda lattice consisting of $n-1$ lattice points on line (one can formally add the point at $Q_n = \infty$ to make equations more symmetrical. To each lattice point $a = 1, ..., n$ a coordinate variable Q^a is attached. The interaction potential is non-vanishing for the nearest neighbors only and has exponential dependence on the coordinate difference $Q^a - Q^b$. The Hamiltonian of the system can be written as

$$H = \sum_{a=1}^{n} \left[\frac{1}{2}(P^a)^2 + exp(-Q^{a+1} + Q^a) \right] \quad . \tag{9.5.1}$$

Toda equations allow group theoretical interpretation [B4] . The change of variables $q^a = Q^a - Q^{a-1}$ allows to cast the Lagrangian associated with the action into the form into the form

$$L = \frac{1}{2} \sum_{a,b=1}^{n-1} \frac{dq^a}{dt} K^{-1}_{ab} \frac{dq^b}{dt} - \sum_{a=1}^{n-1} exp(-q_a) \quad . \tag{9.5.2}$$

The equations of motion for S read as

$$\frac{dS}{dt} - [S, U] = \frac{1}{2} \sum_{a,b=1}^{n-1} H_a K^{-1}_{ab} \left[\frac{d^2 q^b}{dt^2} - \sum_{c=1}^{n-1} K_{bc} exp(-q_c) \right] = 0 \quad , \tag{9.5.3}$$

and by the unitarity requirement are equivalent with the original equations of motion for the Toda lattice.

The Lax pair of the so called full Kostant-Toda lattice (presumably relevant to the model of the dance of honeybee) is defined in the following manner (for a detailed and very technical description see the articles [A11, A12]). The dynamical variable S belongs to the space $B_- + \varepsilon$ of matrices belonging to $SL(n, C)$ Lie algebra. ε is a matrix having units only above the diagonal: $\varepsilon_{ij} = \delta_{j,i+1}$. B_- consists of the lower triangular matrices with trace zero. The equations of motion read

$$\begin{aligned} \frac{dS}{dt} &= i[H, S] \quad , \\ S &= b_- + \varepsilon \quad , \\ H &= \Pi_{N_-} S \quad . \end{aligned} \tag{9.5.4}$$

$H = \prod_{N_-} S$ is the strictly lower triangular part of S, which is nilpotent, and acts as a non-hermitian Hamiltonian in the quantum form of the equations of motion. The time development is not unitary but corresponds to a similarity preserving the eigenvalues of S, which in fact define $2(n-1)$ constants of motion.

There exists a natural embedding of the space $B_- + \varepsilon$ to the flag manifold $F_n = SL(n, C)/B$, where B consists of upper diagonal matrices with units in diagonal. The mapping is obtained by first identifying $B_- + \varepsilon$ with B_- and then noticing that the complement of B_- represent the Lie-algebra elements of $Sl(2, C)$ modulo matrices having upper triangular part with vanishing diagonal elements. The standard exponential mapping of Lie-algebra to the group maps B_- to $Sl(n, C)/B$. The equations of motion in F_n reduce to Hamiltonian equations of motion generated by the Hamiltonian $H = \frac{1}{2} Tr(S^2)$ [A12]. The simplest constants of motion are the eigenvalues of the matrix S and give four constants of motion. In the case of $SL(n, C)$ the eigenvalues span the space C^{n-1}.

$SL(n, C)$ Cartan algebra action induces Hamiltonian flow in the flag manifold and one can associate with the $SU(n)$ Cartan algebra Hamiltonian functions $H_i(x)$, $i = 1, ..., n-1$ defined in the

entire flag manifold. Since Konstant-Toda dynamics is not unitary, the Cartan algebra of $SU(n)$ does not act as symmetries and the corresponding Hamiltonians are not constants of motion. The Toda flows associated with the diagonal traceless matrices are trivial so that the points in the image of C^{n-1} are fixed points of the Hamiltonian evolution associated with the Cartan algebra. The level sets of the Kostant-Toda Hamiltonian consist of unions of $(n-1)$-dimensional complex tori.

The values $H_1, H_2, ..., H_{n-1}$ of the compact Cartan algebra Hamiltonians at given point x of the flag manifold F_n define a map of the flag manifold to $(n-1)$-dimensional convex polytope known as momentum map. For $n = 3$ the polytope is hexagon. Since the solutions of the Toda equations correspond to certain curves in flag manifold they are mapped to curves inside this hexagon. If Cartan algebra would act as symmetries, the momentum map would map the flag manifold to a single point.

2. Flag manifold F_3 from topological field quantization

A less general manner to end up with the flag-manifold concept is based on what I call topological field quantization. The first approach is certainly more attractive in its generality and by its close relationship with the basic concepts of TGD inspired theory of consciousness (entanglement has interpretation as attention in TGD inspired theory of consciousness) and topological field quantization could at best provide a concrete realization of the picture based on the quantum measurement theory.

1. Topological field quantization corresponds to the formation of 3-surfaces of a finite spatial size with a choice of a preferred "quantization axes" for rotations (say z-axis) and color hyper charge and color isospin. One can express the angle coordinates Ψ and Φ associated with hyper charge and isospin in terms of the angle coordinate ϕ associated with the rotations around z-axis as

$$\Psi = n_1\phi + k_1 z + \text{Fourier expansion}$$
$$\Phi = n_2\phi + k_2 z + \text{Fourier expansion}$$

   n_1 and n_2 are almost topological quantum numbers expressing the change of angles Ψ and Φ in a rotation around z-axis. In the case of non-vacuum space-time sheets one can say that there are hypercharge and isospin currents rotating in the direction of ϕ. The choice of the hyper charge and isospin quantization axes leads naturally to the possibility to associate to a given 3-surface a point of the flag manifold encountered in the work of Barbara Shipman.

2. The requirement that the Cartan group H fixing the quantization axes corresponds to the subgroup of $SU(3)$ determined by quantum entanglement fixes uniquely topological field quantization and implies the equivalence of the topological field quantization approach with the picture based on quantum measurement theory.

3. The choice of the quantization axes with constant values of n_i over the entire 3-surface is *not* possible for an arbitrary 3-surface globally: rather the 3-surface decomposes into several regions with varying values of n_i. It might however happen that only 3-surfaces consisting of only single region are dynamically stable. On the other hand, the assumption that the choice is global in general fixes the choice uniquely since small change in the direction of the rotational quantization axes implies that a region where the change of angle variable around closed curve around the new z-axes is trivial. Same applies to the change of quantization axes in color degrees of freedom. Note however that for a general closed curve around z-axes, small change in the direction of quantization axes does not change the value of the phase increment. When 3-surface allows global choice of n_i, one can associate to the 3-surface a unique point of the flag manifold. Physical intuition suggests that this point is same as that determined by the quantum entanglement. In the general case one can decompose the 3-surface into several regions, such that each of them has different values of topological quantum numbers for a given choice of quantization axes. It is tempting to interpret the maximal region with fixes values of n_i as a maximal sub-system for which it makes sense to perform the measurement of color charges with given quantization axes.

9.5.3 Quantum Honeybee And DNA As Topological Quantum Computer

The model for the dance of honeybee was an idea before its time and remained in a dormant state for several years. The increased understanding of quantum TGD proper making possible to develop a model for how DNA could act as a topological quantum computer eventually provided a fresh perspective to the problem.

The progress in understanding of quantum TGD

It is appropriate to make a list of new concepts and ideas which are prerequisites for the model of DNA as topological quantum computer.

"The world of classical worlds" can be identified as the space of light-like 3-surfaces identifiable also as partonic orbits with dynamics which is not completely deterministic so that 3-dimensionality in discretized sense and local effective 2-dimensionality are obtained [K29]. A considerable generalization of the conformal symmetries of string models and a formulation of quantum TGD as almost topological quantum field theory emerged.

2. The evidence that planetary orbits are identifiable as Bohr orbits led to a generalization of the notion of embedding space obtained by replacing it with a union of infinite number of sectors labeled by different values of Planck constant [K112, K87, K44]. The generalization explains dark matter as phases in which Planck constant differs from its value for the visible matter (visible to us, the notion of darkness is relative). Phases of matter with arbitrarily large values of Planck constant are predicted and give rise to macroscopic quantum phases even in astrophysical length scales. These phases are especially important in living matter. The value of Planck constant characterizes topological field quanta serving as space-time correlates for the interactions between particles. Dark matter residing at magnetic flux quanta of field body having large value Planck constant would be responsible quantum control of living matter [K12, K37]. Magnetic body would have an onion like structure consisting of layers with increasing value of Planck constant. The highest layer determines the evolutionary level of system and great leaps in evolution would correspond to the emergence of a new layer with larger value of $\hbar$ to the magnetic body.

3. A more precise characterization for the fundamental notion of quantum criticality emerges from the generalization of the notion of embedding space. The sectors intersect along $M^4 \times S^2$ and $M^2 \times CP_2$ and maximal quantum criticality corresponds to $M^2 \times S^2$. The geodesic sphere S^2 of CP_2 with trivial homology plays key role in this picture and vacuum extremals $X^4 \subset M^4 \times S^2$ define one particular example of quantum critical surfaces. The isometries of S^2 correspond to $SO(3) \subset SU(3)$. Notice that the flag manifold $F = SU(3)/U(1) \times U(1)$ reduces naturally to $F_{red} = SO(3)/U(1) = S^2$ for almost vacuum extremals.

4. In TGD positive energy ontology must be replaced with what I have christened zero energy ontology [K29, K28]. In zero energy ontology physical states correspond to zero energy states decomposable to pairs of positive and negative energy states localizable at the future and past directed boundaries of a pair of light cones forming a causal diamond. Zero energy ontology allows to identify time-like entanglement coefficients - M-matrix - as a "complex square root" of the density matrix decomposing to a product of positive square root of density matrix and unitary S-matrix so that thermodynamics becomes part of quantum theory.

5. Von Neumann algebras known as hyper-finite factors of type II_1 [K138, K44] play a fundamental role in the formulation of quantum TGD [K29, K28]. This means a profound deviation from standard quantum field theories and ordinary quantum mechanics. The notion of quantum group whose physical interpretation has remained poorly understood represents a key aspect of this difference. Finite measurement resolution [K28] becomes the key notion of the quantum measurement theory in this framework. It can be represented as an inclusion of von Neumann algebras with included algebra defining the measurement resolution. More concretely, complex rays of state space are replaced with sub-spaces generated by the included algebra and the Hermitian elements of this algebra represent symmetries of the M-matrix.

These enormous symmetries allow to fix the possible M-matrices highly uniquely in terms of Connes tensor product. Thus the mere fact that measurement resolution is finite fixes the quantum dynamics of the theory almost completely and leads to a new kind of description of coupling constant evolution allowing also to understand the origin of p-adic length scale hypothesis.

General model for DNA as topological quantum computer

The progress in the understanding of quantum TGD led to various biological applications. The presence of dark matter with the properties predicted by TGD can be deduced from the strange findings about the behavior of cell membrane [I39]. These properties are not quite the same as they are believed to be: dark matter has classical interactions with ordinary matter - in particular electromagnetic interactions - but only particles with same value of $\hbar$ (belonging to same sector of embedding space) can appear in interaction vertices. This is enough to achieve consistency with what is really known about dark matter. Detailed models for nerve pulse [K97] and EEG [K37] emerge. One of the most fascinating applications is the model of DNA - cell membrane system as a topological quantum computer (TQC) [K3]: this model leads to a further insights about findings of Shipman.

1. The model for DNA as topological quantum computer [K3] assumes that magnetic flux tubes connecting DNA nucleotides to lipids of nuclear/cell membrane define braid strands. To be precise, wormhole magnetic fields consisting of two parallel magnetic flux tubes with opposite fluxes are in question. Wormhole magnetic flux tubes have at their ends wormhole contacts with quark and antiquark at their throats (these defining light-like 3-surfaces) [K142]. Braid strands are "colored" and the four colors correspond to the four nucleotides A, G, T, C. Coloring corresponds physically to a map of nucleotides to quarks u, d and their antiquarks at the upper throat of wormhole contact at the DNA end of wormhole magnetic field (second end contains the conjugate of this state). Kind of 1-1 genetic code is in question and has profound implications for the understanding of the selectivity of bio-catalysis. Quarks have large $\hbar$ and obey a scaled up variant of QCD like dynamics. Note that in this framework the proposal of Barbara Shipman that quarks are involved with honeybee dance begins to make sense.

2. Tqc program is coded by the "dance" of lipids defining a time-like braiding. Since the lipids are connected to nucleotides, their dance defines also space-like braiding coding TQC program to memory: an extremely general mechanism of memory storage is in question which might been present already during pre-biotic era. The braiding is generated by the motion of lipids in liquid crystal phase forced by the motion of cellular water in gel phase because the hydrophobic ends of lipids are anchored to the moving water molecules. Dissipation in the presence of metabolic energy feed means that the liquid flow approaches to an asymptotic self organization pattern depending only weakly on the initial conditions: the interpretation is as a Darwinian selection of TQC programs. There is actually a fractal hierarchy of TQC programs and each sub-program appears as an emsemble of similar copies so that TQC gives automatically probability distributions as an outcome represented as a four-dimensional pattern of classical fields and various rates (chemical rates, firing rates for nerve pulses, ...).

3. The basic braiding operation - a twist permuting the position of lipids- defines the universal 2-gate. Besides this 1-gates are needed and SU(2) rotation is enough. Here one can consider several candidates: since quarks and antiquarks are in crucial role in TQC, one of them corresponds to color SU(3) or its subgroup. This could explain the mysterious looking discovery of Barbara Shipman. This aspect is described in more detail below.

Realization of 1-gates of TQC in terms of color rotations and connection with honeybee dance

The realization of single particle gates as $U(2)$ transformations leads naturally to the extension of the braid group by assigning to the strands sequences of group elements satisfying the group multiplication rules. The group elements associated with a n^{th} strand commute with the generators

of braid group which do not act on n^{th} strand. G would be naturally subgroup of the covering group of rotation group acting in spin degrees of spin 1/2 object. Since $U(1)$ transformations generate only an overall phase to the state, the presence of this factor might not be necessary. A possible candidate for $U(1)$ factor is as a rotation induced by a time-like parallel translation defined by the electromagnetic scalar potential $\Phi = A_t$.

One of the challenges is the realization of single particle gates representing $U(2)$ rotation of the qubit. The first thing to come mind was that $U(2)$ corresponds to $U(2)$ rotation induced by magnetic field and electric fields. A more elegant realization is in terms of $SU(3)$ rotation, where $SU(3)$ is color group associated with strong interactions and this suggests connection with the findings of Shipman.

1. The realization of qubit as ordinary spin

A possible realization for single particle gate $s \subset SU(2)$ would be as $SU(2)$ rotation induced by a magnetic pulse. This transformation is fixed by the rotation axis and rotation angle around this axes. This kind of transformation would result by applying to the strand a magnetic pulse with magnetic field in the direction of rotation axes. The duration of the pulse determines the rotation angle. Pulse could be created by bringing a magnetic flux tube to the system, letting it act for the required time, and moving it away. $U(1)$ phase factor could result from the electromagnetic gauge potential as a non-integrable phase factor $exp(ie \int A_t dt/\hbar)$ coming from the presence of scale potential $\Phi = A_t$ in the Hamiltonian.

One can criticize this model. The introduction of magnetic pulses does not look an attractive idea and seems to require additional structures besides magnetic flux tubes (MEs?). It would be much nicer to assign the magnetic field with the flux tubes defining the braid strands. The rotation of magnetic field would however require changing the direction of braid strands. This does not look natural. Could one do without this rotation by identifying spin like degree of freedom in some other manner? This is indeed possible.

2. The realization of 1-gate in terms of color rotations

TGD predicts a hierarchy of copies of scaled up variants of both weak and color interactions and these play a key role in TGD inspired model of living matter. Both weak isospin and color isospin could be considered as alternatives for the ordinary spin as a realization of qubit in TGD framework. Below color isospin is discussed but one could consider also a realization in terms of nuclei and their exotic counterparts [L3], [L3] differing only by the replacement of neutral color bond between nuclei of nuclear string with a charged one. Charge entanglement between nuclei would guarantee overall charge conservation.

1. Each space-time sheet of braid strands contains quark and antiquark at its ends. Color isospin and hypercharge label their states. Two of the quarks of the color triplet form doublet with respect to color isospin and the third is singlet and has different hyper charge Y. Hence qubit could be realized in terms of color isospin I_3 instead of ordinary spin but third quark would be inert in the Boolean sense. Qubit could be also replaced with qutrit and isospin singlet could be identified as a statement with ill-defined truth value. Trits are used also in ordinary computers. In TGD framework finite measurement resolution implies fuzzy qubits and the third state might relate to this fuzziness. Note that hyper-charge would induce naturally the U(1) factor affecting the over all phase of qubit but affecting differently to the third quark.

2. Magnetic flux tubes are also color magnetic flux tubes carrying non-vanishing classical color gauge field in the case that they are non-vacuum extremals. The holonomy group of classical color field is an Abelian subgroup of the $U(1) \times U(1)$ Cartan subgroup of color group. Classical color magnetic field defines the choice of quantization axes for color quantum numbers. For instance, magnetic moment is replaced with color magnetic moment and this replacement is in key role in simple model for color magnetic spin spin splittings between spin 0 and 1 mesons as well as spin 1/2 and 3/2 baryons.

3. There is a symmetry breaking of color symmetry to subgroup $U(1)_{I_3} \times U(1)_Y$ and color singletness is in TGD framework replaced by a weaker condition stating that physical states have vanishing net color quantum numbers. This makes possible the measurement of color quantum numbers in the manner similar to that for spin. For instance, color singlet formed

by quark and antiquark with opposite color quantum numbers can in the measurement of color quantum numbers of quark reduce to a state in which quark has definite color quantum numbers. This state is a superposition of states with vanishing Y and I_3 in color singlet and color octet representations. Strong form of color confinement would not allow this kind of measurement. The almost vacuum extremal property suggests also the reduction of $SU(3)$ to $SO(3)$ with ensuing reduction of F to S^2.

4. Color rotation in general changes the directions of quantization axis of I_3 and Y and generates a new state basis. Since $U(1) \times U(1)$ leaves the state basis invariant, the space defined by the choices of quantization axes is 6-dimensional flag manifold $F = SU(3)/U(1) \times U(1)$. The original belief was that -in contrast to standard model- color rotations in general do not leave classical electromagnetic field invariant. There are however good arguments based on the Abelian holonomy of the classical gluon fields showing that color rotation only induces an Abelian gauge transformation so that the induced gauge field remains a superposition of gauge transformed em field and W boson field *resp.* em field and Z^0 field corresponding to the two kinds of geodesic spheres. This also conforms with the general vision about electro-weak symmetry breaking taking place already at the level of CP_2 geometry. Hence color rotations are not visible at the level of classical interactions as was the original belief inspiring the idea that color rotation would affect the resting potential of cell membrane and have thus a direct neuronal correlate.

5. If color isospin defines the qubit or qutrit in topological quantum computation, color quantum numbers and the flag manifold F should have direct relevance for cognition. If nearly vacuum extremals are involved one might understand also the reduction of parameters from 6 to two as the effective replacement of F with $S^2 = SO(3)/SO(2)$; this is actually rather natural if the information communicated is the 2-D coordinates of the food source. Color rotations of the lipid ends of the magnetic flux tubes would define 1-gates representing this geometric information. Subsequent state function reduction would provide conscious representations in terms of trits characterizing for instance sensory input symbolically.

To sum up, this picture suggests that 1-gates of DNA topological quantum computation (understood as "dance of lipids") are defined by color rotations of the ends of space-like braid strands and at lipids. The color rotations would be induced by sensory and other inputs to the system. Topological quantum computation would be directly related to conscious experience and sensory and other inputs would fix the directions of the color magnetic fields. The findings of Barbara Shipman give support this picture.

9.6 A General Model For Qualia And Sensory Receptor

Various sensory qualia correspond to the average increments of quantum numbers for a quite long sequence of quantum jumps. Quantum numbers could be spin, momentum, energy, eletromagnetic charge, color quantum numbers (isospin and hypercharge in a constant proportion), various particle numbers, etc... What happens in the sensory receptors is that the gradient of some physical quantity is transformed to average increments of appropriate quantum numbers responsible for the quale representing the gradient of the physical quantity. Spatial gradients are transformed first to temporal gradients by a process, which is essentially scanning (say saccadic motion). Temporal gradients are then transformed to non-vanishing average increments of appropriate charges per quantum jump in a long sequence of quantum jumps. The problem is to understand how this process is realized at the level of sensory receptors.

9.6.1 A General Model Of Qualia

It is good to start by summarizing the general vision about sensory qualia and geometric qualia in TGD Universe.

1. The basic assumption is that sensory qualia correspond to increments of various quantum numbers in quantum jump. Standard model quantum numbers- color quantum numbers,

electromagnetic charge and weak isospin, and spin are the most obvious candidates. Also cyclotron transitions changing the integer characterizing cyclotron state could corresponds to some kind of quale- perhaps "a feeling of existence". This could make sense for the qualia of the magnetic body.

2. Geometric qualia could correspond to the increments of zero modes characterizing the induced CP_2 Käjhler form of the partonic 2-surface and of the moduli characterizing the causal diamonds serving as geometric correlates of selves. This moduli space involves the position of CD and the relative position of tips as well as position in CP_2 and relative position of two CP_2 points assigned to the future and past boundaries of CD. There are good motivations for proposing that the relative positions are quantized. This gives as a special case the quantization of the scale of CD in powers of two. Position and orientation sense could would represent this kind of qualia. Also kinematical qualia like sensation of acceleration could correspond to geometric qualia in generalized 4-D sense. For instance, the sensation about motion could be coded by Lorentz boots of sub-CD representing mental image about the object.

3. One can in principle distinguish between qualia assignable to the biological body (sensory receptors in particular) and magnetic body. The basic question is whether sensory qualia can be assigned only with the sensory receptors or with sensory pathways or with both. Geometric qualia might be assignable to the magnetic body and could provide third person perspective as a geometric and kinematical map of the body and its state of motion represented using the moduli space assignable to causal diamonds (CD). This map could be provided also by the body in which case the magnetic body would only share various mental images. The simplest starting assumption consistent with neuro-science is that sensory qualia are assigned with the cell membrane of sensory receptor and perhaps also with the neurons receiving data from it carried by Josephson radiation coding for the qualia and possibly partially regenerating them if the receiving neuron has same value of membrane potential as the sensory receptor when active. Note that during nerve pulse also this values of membrane potential is achieved for some time.

9.6.2 Detailed Model For The Qualia

The proposed vision about qualia requires a lot of new physics provided by TGD. What leads to a highly unique proposal is the intriguing coincidence of fundamental elementary particle time scales with basic time scales of biology and neuro science and the model of DNA as topological quantum computer [K3].

1. Zero energy ontology brings in the size scale of CD assignable to the field body of the elementary particle. Zero energy states with negentropic time-like entanglement between positive and negative energy parts of the state might provide a key piece of the puzzle. The negentropic entanglement beween positive energy parts of the states associated with the sub-CD assignable to the cell membrane and sub-CD at the magnetic body is expected to be an important factor.

2. For the standard value of $\hbar$ the basic prediction would be 1 ms second time scale of d quark, 6.5 ms time scale of u quark, and.1 second time scale of electron as basic characterizes of sensory experience if one accept the most recent estimates $m(u) = 2$ MeV and $m(d) = 5$ MeV for the quark masses [C1]. These time scales correspond to 10 Hz, 160 Hz, and 1280 Hz frequencies, which all characterize neural activity (for the identification of 160 Hz frequency as cerebellar resonance frequency see [J77]). Hence quarks could be the most interesting particles as far as qualia are considered and the first working hypothesis would be that the fundamental quantum number increments correspond to those for quark-anti-quark pair. The identification in terms of quantum numbers of single quark is inconsistent with the model of color qualia.

3. The model of DNA as topological quantum computer led to the proposal that DNA nucleotides are connected to the lipids of the cell membrane by magnetic flux tubes having quark and antiquark at its ends such that the u and d quarks and their antiquarks code for

the four nucleotides. The outer lipid layer was also assumed to be connected by flux tubes to the nucleotide in some other cell or in cell itself.

4. The model for DNA as topological quantum computer did not completely specify whether the flux tubes are ordinary flux tubes or wormhole flux tubes with possibly opposite signs of energy assigned with the members of the flux tube pair. Although it is not necessary, one could assume that the quantum numbers of the two parallel flux tubes cancel each other so that wormhole flux tube would be characterized by quantum numbers of quark pairs at its ends. It is not even necessary to assume that the net quantum numbers of the flux tubes vanish. Color confinement however suggests that the color quantum at the opposite ends of the flux tube are of opposite sign.

   (a) The absence of a flux tube between lipid layers was interpreted as an isolation from external world during the topological quantum computation. The emergence of the flux tube connection means halting of topological quantum computation. The flux tube connection with the external world corresponds to sensory perception at the level of DNA nucleotide in consistency with the idea that DNA plays the role of the brain of cell [K105]. The total color quantum numbers at the ends of the flux tubes were assumed to sum up to zero. This means that the fusion of the flux tubes ending to the interior and exterior cell membrane to single one creates a flux tube state not localized inside cell and that the interior of cell carries net quantum numbers. The attractive interpretation is that this process represents the generation of quale of single nucleotide.

   (b) The formation of the flux tube connection between lipid layers would involve the transformation of both quark-antiquark pairs to an intermediate state. There would be no kinematic constraints on the process nor to the mass scales of quarks. A possible mechanism for the separation of the two quark-antiquark pairs associated with the lipids from the system is double reconnection of flux tubes which leads to a situation in which the quark-antiquark pairs associated with the lipid layers are connected by short flux loops and separated to a disjoint state and there is a long wormhole flux tube connecting the nucleotides possibly belonging to different cells.

   (c) The state of two quark pairs need not have vanishing quantum numbers and one possibility is that the quantum numbers of this state code for qualia. If the total numbers of flux tubes are vanishing also the net quantum numbers of the resulting long flux tube connecting two different cells provide equivalent coding. A stronger condition is that this state has vanishing net quantum numbers and in this case the ends of the long flux tube would carry opposite quantum numbers. The end of flux tube at DNA nucleotide would characterize the quale.

5. Two identification of primary qualia are therefore possible.

   (a) If the flux tubes have vanishing net quantum numbers, the primary sensory quale can be assigned to single receptor cell and the flow of the quantum numbers corresponds to the extension of the system with vanishing net quantum numbers in two-cell system.

   (b) If the net quantum numbers of the flux tube need not vanish, the resulting two cell system carries non-vanishing quantum numbers as the pair of quark-antiquark pairs removes net quantum numbers out of the system.

6. If the net quantum numbers for the flux tubes vanish always, the specialization of the sensory receptor membrane to produce a specific quale would correspond to an assignment of specific quantum numbers at the DNA ends of the wormhole flux tubes attached to the lipid layers of the cell membrane. The simplest possibility that one can imagine is that the outer lipid layer is connected to the conjugate DNA nucleotide inside same cell nucleus. This option would however assign vanishing net quantum number increments to the cell as whole and is therefore unacceptable.

7. The formation of a temporary flux tube connection with another cell is necessary during the generation of quale and the question is what kind of cell is in question. The connection of the receptor to cells along the sensory pathway are expected to be present along the entire sensory pathway from DNA nucleotide to a nucleotide in the conjugate strand of second neuron to DNA nucleotide of the third neutron.... If Josephson photons are able to regenerate the quale in second neuron this would make it possible to replicate the quale along entire sensory pathway. The problem is that Josephson radiation has polarization orthogonal to axons and must propagate along the axon whereas the flux tube connection must be orthogonal to axon. Hence the temporary flux tube connection is most naturally between receptor cells and would mean horizontal integration of receptor cells to a larger structure. A holistic process in directions parallel and orthogonal to the sensory pathway would be in question. Of course, the flux tube could be also curved and connect the receptor to the next neuron along the sensory pathway.

8. The specialization of the neuron to sensory receptor would require in the framework of positive energy ontology that -as far as qualia assignable to the electro-weak quantum numbers are considered - all DNA nucleotides are identical by the corresponds of nucleotides with quarks and antiquarks. This cannot be the case. In zero energy ontology and for wormhole flux tubes it is however enough to assume that the net electroweak quantum numbers for the quark antiquark pairs assignable to the DNA wormhole contact are same for all nucleotides. This condition is easy to satisfy. It must be however emphasized that there is no reason to require that all nucleotides involved generate same quale and at the level of neurons sensory maps assigning different qualia to different nucleotides and lipids allowing DNA to sensorily perceive the external world are possible.

The model should be consistent with the assignment of the fundamental bio-rhythms with the CDs of electron and quarks.

1. Quark color should be free in long enough scales and cellular length scales are required at least. The QCD in question should therefore have long enough confinement length scales. The first possibility is provided by almost vacuum extremals with a long confinement scale also at the flux tubes. Large $\hbar$ for the cell membrane space-time sheet seems to be unavoidable and suggests that color is free in much longer length scale than cell length scale.

2. Since the length of the flux tubes connecting DNA and cell membrane is roughly 1 micrometer and by a factor of order 10^7 longer than the d quark Compton length, it seems that the value of Planck constant must be of this order for the flux tubes. This however scales up the time scale of d quark CD by a factor of 10^{14} to about 10^4 years! The millisecond and 160 ms time scales are much more attractive. This forces to ask what happens to the quark-anti-quark pairs at the ends of the tubes.

3. The only possibility seems to be that the reconnection process involves a phase transition in which the closed flux tube structure containing the two quark pairs assignable to the wormhole contacts at lipid layers is formed and leaks to the page of the Big Book with pages partially labeled by the values of Planck constant. This page would correspond to the standard value of Planck constant so that the corresponding d quark CDs would have a duration of millisecond. The reconnection leading to the ordinary situation would take place after millisecond time scale. The standard physics interpretation would be as a quantum fluctuation having this duration. This sequence of quark sub-CDs could define what might be called memetic codon representation of the nerve pulse sequence.

4. One can also consider the possibility is that near vacuum extremals give rise to a copy of hadron physics for which the quarks associated with the flux tubes are light. The Gaussian Mersennes corresponding to $k = 151, 157, 163, 167$ define excellent p-adic time scales for quarks and light variants of weak gauge bosons. Quark mass 5 MeV would with $k = 120$ would be replaced with $k = 163$ (167) one would have mass 1.77 eV (.44 eV). Small scaling of both masses gives 2 eV and.5 eV which correspond to basic metabolic quanta in TGD framework. For quark mass of 2 MeV with $k = 123$ $k = 163$ (167) one would give masses.8

eV (.05 eV). The latter scale correspond to Josephson energy assignable with the membrane potential in the ordinary phase.

In this case a phase transition transforming almost vacuum extremal to ordinary one takes place. What this would mean that the vacuum extremal property would hold true below much shorter p-adic length scale. In zero energy ontology the scaling up of quark masses is in principle possible. This option looks however too artificial.

Overall view about qualia

This picture leads to the following overall view about qualia. There are two options depending on whether single quark-antiquark pair or two of them labels the qualia. In the following only the simpler option with single quark-antiquark pair is discussed.

1. All possible pairings of spin and electroweak isospin (or em charge) define 16 basic combinations if one assumes color singletness. If arbitrary color is allowed, there is a nine-fold increase of quantum numbers decomposable to color singlet and octet qualia and further into 3×15 qualia with vanishing increments of color quantum numbers and 6×16 qualia with non-vanishing increments of color quantum numbers. The qualia with vanishing increments for electroweak quantum numbers could correspond to visual colors. If electroweak quantum numbers of the quark-anti-quark pair vanish, one has 3×7 *resp.* 6×8 combinations of colorless *resp.* colored qualia.

2. There is a huge number of various combinations of these fundamental qualia if one assumes that each nucleotide defines its own quale and fundamental qualia would be analogous to constant functions and more general qualia to general functions having values in the space with $9 \times 16 - 1$ points. Only a very small fraction of all possible qualia could be realized in living matter unless the neurons in brain provide representations of body parts or of external world in terms of qualia assignable to lipid-nucleotide pairs. The passive DNA strand would be ideal in this respect.

3. The basic classification of qualia is as color qualia, electro-weak quale, and spin quale and products of these qualia. Also combinations of color qualiaandelectroweak and spin quale are possible and could define exotic sensory qualia perhaps not yet realized in the evolution. Synesthesia is usually explained in terms of sensory leakage between sensory pathways and this explanation makes sense also in TGD framework if there exists a feedback from the brain to the sensory organ. Synesthesia cannot however correspond to the product qualia: for "quantum synesthesia" cross association works in both directions and this distinguishes it from the ordinary synesthesia.

4. The idea about brain and genome as holograms encourages to ask whether neurons or equivalently DNA could correspond to sensory maps with individual lipids representing qualia combinations assignable to the points of the perceptive field. In this framework quantum synesthesia would correspond to the binding of qualia of single nucleotide (or lipid) of neuron cell membrane as a sensory representation of the external world. DNA is indeed a holographic representation of the body (gene expression of course restricts the representation to a part of organism). Perhaps it is this kind of representation also at the level of sensory experience so that all neurons could be little sensory copies of body parts as holographic quantum homunculi. In particular, in the associative areas of the cortex neurons would be quantum synesthetes experiencing the world in terms of composite qualia.

5. The number of flux tube connections generated by sensory input would code for the intensity of the quale. Josephson radiation would do the same at the level of communications to the magnetic body. Also the temporal pattern of the sequence of quale mental images matters. In the case of hearing this would code for the rhythmic aspects and pitch of the sound.

Guesses about detailed identification of the qualia

One can make also guesses about detailed correspondence between qualia and quantum number increments.

1. Visual colors would correspond to the increments of only color quantum numbers. Each biologically important ion would correspond to its own color increment in one-one correspondence with the three pairs of color-charged gluons and these would correspond to blue-yellow, red-green, and black white [K97]. Black-white vision would mean a restriction to the $SU(2)$ subgroup of color group. The model for the cell membrane as a nearly vacuum extremal assigns the peak frequencies corresponding to fundamental colors with biologically important ions. Josephson radiation could induce artificially the same color qualia in other neurons and this might provide an manner to communicate the qualia to the brain where they could be re-experienced at neuronal level. Some organisms are able to perceive also the polarization of light. This requires receptors sensitive to polarization. The spin of quark pair would naturally code for polarization quale.

2. Also tastes and odours define qualia with "colors". Certainly the increments of electroweak numbers are involved but since these qualia do not have any directional flavor, spin is probably not involved. This would give c 3×4 basic combinations are possible and can certainly explain the 5 or 6 basic tastes (counted as the number of different receptors). Whether there is a finite number of odours or not has been a subject of a continual debate and it might be that odours already correspond to a distribution of primary qualia for the receptor cell. That odours are coded by nerve pulse patterns for a group of neurons [J117] would conform with this picture.

3. Hearing seems to represent a rather colorless quale so that electroweak isospin suggests again itself. If we had a need to hear transversely polarized sound also spin would be involved. Cilia are involved also with hair cells acting as sensory receptors in the auditory system and vestibular system. In the case of hearing the receptor itself does not fire but induces a firing of the higher level neuron. The temporal pattern of qualia mental images could define the pitch of the sound whereas the intensity would correspond to the number of flux tube connections generated.

   The modulation of Josephson frequencies -rather than Josephson frequencies as such- would code for the pitch and the total intensity of the Josephson radiation for the intensity of the sound and in fact any quale. Pitch represents non-local information and the qualia sub-selves should be negentropically entangled in time direction. If not, the experience corresponds to a sequence of sound pulses with no well-defined pitch and responsible for the rhythmic aspects of music. Right brain sings-left brain talks metaphor would suggests that right and left brain have different kind of specializations already at the level of sensory receptors.

4. Somato-sensory system gives rise to tactile qualia like pain, touch, temperature, proprioception (body position). There are several kinds of receptors: nocireceptors, mechanoreceptors, thermoreceptors, etc... Many of these qualia have also emotional coloring and it might be that the character of entanglement involved (negentropic/entropic defines the emotional color of the quale. If this is the case, one might consider a pure quale of touch as something analogous to hearing quale. One can argue that directionality is basic aspect of some of these qualia -say sense of touch- so that spin could be involved besides electroweak quantum numbers. The distribution of these qualia for the receptor neuron might distinguish between different tactile qualia.

Could some sensory qualia correspond to the sensory qualia of the magnetic body?

Concerning the understanding of a detailed model for how sensory qualia are generated, the basic guideline comes from the notion of magnetic body and the idea that sensory data are communicated to the magnetic body as Josephson radiation associated with the cell membrane. This leaves two options: either the primary a sensory qualia are generated at the level of sensory receptor and the resulting mental images negentropically entangle with the "feeling of existence" type mental images at the magnetic body or they can be also generated at the level of the magnetic body by Josephson radiation -possibly as cyclotron transitions. The following arguments are to-be-or-not-to-be questions about whether the primary qualia must reside at the level of sensory receptors.

1. Cyclotron transitions for various cyclotron condensates of bosonic ions or Cooper pairs of fermionic ions or elementary particles are assigned with the motor actions of the magnetic

body and Josephson frequencies with the communication of the sensory data. Therefore it would not be natural to assign qualia with cyclotron transitions. One the other hand, in zero energy ontology motor action can be regarded formally as a time reversed sensory perception, which suggests that cyclotron transitions correlated with the "feeling of existence" at magnetic body entangled with the sensory mental images. They could also code for the pitch of sound as will be found but this quale is strictly speaking also a geometric quale in the 4-D framework.

2. If Josephson radiation induces cyclotron transitions, the energy of Josephson radiation must correspond to that of cyclotron transition. This means very strong additional constraint not easy to satisfy except during nerve pulse when frequencies varying from about 10^{14} Hz down to kHz range are emitted the system remains Josephson contact. Cyclotron frequencies are also rather low in general, which requires that the value of $\hbar$ must be large in order to have cyclotron energy above the thermal threshold. This would however conform with the very beautiful dual interpretation of Josephson photons in terms of bio-photons and EEG. One expects that only high level qualia can correspond to a very large values of $\hbar$ needed.

   For the sake of completeness it should be noticed that one might do without large values of $\hbar$ if the carrier wave with frequency defined by the metabolic energy quantum assignable to the kicking and that the small modulation frequency corresponds to the cyclotron frequency. This would require that Josephson frequency corresponds to the frequency defined by the metabolic quantum. This is not consistent with the fact that very primitive organisms possess sensory systems.

3. If all primary qualia are assigned to the magnetic body, Josephson radiation must include also gluons and light counterparts of weak bosons are involved besides photons. This is quite a strong additional assumption and it will be found that the identification of sensory qualia in terms of quantum numbers of quark pair restricts them to the cell membrane. The coding of qualia by Josephson frequencies is however possible and makes it possible to regenerate them in nervous system. The successful model explaining the peak frequencies of photoreceptors in terms of ionic cyclotron frequencies supports this view and provides a realization for an old idea about spectroscopy of consciousness which I had already been ready to give up.

9.6.3 Capacitor model for sensory receptor

The assumption that sensory qualia are realized at the level of sensory receptors, when combined with the requirement that the average increments are non-vanishing, and perhaps even same from quantum jump to quantum jump, poses strong constraints on the model of the sensory receptor.

These constraints suggest what might be called the capacitor model of the sensory receptor.

1. There are two reservoirs of quantum charges having total charges of equal magnitude but of opposite sign. The charges are macroscopic in order to guarantee robustness. These reservoirs are analogous to capacitor plates, and only the second one corresponds to the sensory experienced quale unless both the quale and its conjugate are experienced simultaneously. Capacitors plates can carry several charges.

2. When the sensory quale is generated, there is a flow of charge quanta between the quantum capacitor plates. The charge quanta are more or less constant. This requirement could be relaxed to the condition that only the average increment is constant.

Cell membrane, or rather the pair formed by cell interior and exterior, and synaptic junction are excellent candidates for quantum capacitors.

1. During nerve pulse various ions flow between cell interior and exterior, which suggests that sub-neuronal sensory qualia are generated in a time scale of a millisecond. Also membrane oscillations might give rise to some kind of sensory qualia. In particular, super-conducting Cooper pairs and bosonic ions enter or leave the Bose-Einstein condensates at the magnetic flux tubes and this should give rise to a chemical experience defined by the quantum numbers of the carrier particle. Not only the increment of electric charge but increments of magnetic

quantum numbers characterize the qualia in question. Various information molecules transferred through the cell membrane could also give rise to sensory qualia.

2. In the synaptic contact the vesicles containing neurotransmitter are transmitted, and the net quantum numbers for the vesicles should determine the neuronal chemical qualia associated with the process.

This model does not apply to all qualia. Qualia can be also associated with the quantum phase transitions at magnetic flux quanta. A typical example is a coherently occurring cyclotron transition for a macroscopic phase of Cooper pairs. It would seem that quantum phase transitions at the magnetic flux quanta and particle flows between the quantum electrodes associated with electret type structures could define two basic types of qualia. Note that electret structures are dual to magnetic flux quanta as solutions of field equations. Vision and hearing would be basic examples of these two types of qualia.

9.6.4 Capacitor Model For Color Vision

Capacitor model allows to attack the problem of how color qualia are generated physically.

1. Color sensation results from a spatial gradient of illumination at a given wavelength transformed first to a temporal gradient: presumably by a saccadic motion. This explains color constancy naturally. The temporal gradient of illumination in turn induces a quantum jump sequence for which average increments of color isospin and hypercharge per quantum jump are non-vanishing and characterizes the color in question.

2. What is needed are two color capacitor plates with opposite color charges. Since color confinement implies the vanishing total color charges below certain length scale, the notion of color capacitor is very natural. The fact that a region of a given visual color has at its boundaries a narrow stripe with the complementary color could relate closely to color confinement. Also the after images with varying colors could relate to the back-flow of the color charges establishing the equilibrium situation between the plates of color capacitor. The color black experienced when eyes are closed could be interpreted as being due to a background flow occurring even in the absence of the visual stimulus (this sensation disappears and visual consciousness is lost if saccadic motions is not allowed to occur).

3. The temporal gradient of illumination induces a flow of color charges between the plates of the color capacitor. The coding of photon frequencies to colors results if the quanta transferred between the plates are colored particles with an isospin-hypercharge ratio characterizing the visual receptor in question. The simplest possibility is that color octet particles are in question so that three primary colors and their conjugates define the basic colors. A Bose-Einstein condensate of colored bosons is the most elegant manner to realize the capacitor. This mechanism requires only that the receptor is frequency sensitive, and that the quantum numbers of the colored particles associated with the capacitor plates depend on the receptor. Depending on the direction of the color charge flow a given receptor contributes color or its conjugate color to the experience, which is average over some set of receptors and thus a mixed color.

4. 3+3 primary colors (black and white are counted as conjugate colors) correspond naturally to the charged "gluons" in the octet representation. For higher color representations a more refined color palette results. For white-black vision the increment of the color hypercharge would be vanishing on the average. It could be also vanishing for the quanta involved (charged "gluons" belonging to $SU(2)$ triplet of gluons). If the classical color gauge field associated with the plates of the color capacitor reduces to $SU(2)$ one could indeed expect that black-white vision results.

The role of classical color gauge fields

The classical color gauge fields associated with the receptor plates could favor BE condensate with particular color quantum numbers. Classical color gauge fields in general give rise to vacuum

color currents, and these could generate coherent states of some gluon like particles giving in turn rise to BE condensates. Since classical color fields are proportional to the induced Kähler field, one expects that strong color gauge fields are associated to solutions which are far from vacuum extremals. Other sensory receptors might differ from visual receptors in that they correspond to almost vacuum space-time sheets with very weak classical color gauge fields. A weaker condition is that the classical color gauge fields are so random that only weak coherent state and BE condensate results. MEs are excellent candidates for the carriers of colored BE condensates since their CP_2 projections are 2-dimensional and the classical color gauge field is Abelian and thus corresponds to a fixed $U(1)$ sub-group.

The model leaves a lot of room for the identification of the colored particles. The color could be in color rotational degrees of freedom of the space-time sheets, it could be gluonic color for a QCD realized in cellular length scale, or super-conformal color associated with what might be called WCW photons.

Rigid body color?

The identification of the color as a degree of freedom analogous to rigid body rotational degrees of freedom is rather attractive because of its simplicity.

1. Every space-time sheet has color-rotational rigid body degrees of freedom. Since the space-time sheet is topologically condensed at a larger space-time sheet and connected by join along boundaries bonds to other space-time sheets, these degrees of freedom are partially frozen. This means breaking of color symmetry to a subgroup of color group. $U(2)$, $U(1) \times U(1)$, and $U(1)$ are the options besides complete breaking of color symmetry. This could explain why color capacitor mechanism is not involved with all cell membranes but requires special receptors.

2. The gluing operation for two space-time sheets occurs along 3-dimensional surface for both wormhole contacts and join along boundaries bonds. The requirement that gluing is possible implies that this portion of surface is a fixed point with respect to the subgroup of color group, which remains unbroken. If the region in question corresponds to a single point of CP_2, the isotropy group is maximal and equal to $U(2)$. This means that quantum states correspond to a rigid body motion in $U(2)$. For $U(1) \times U(1)$ the states are also characterized by isospin and hypercharge. For $U(1)$ only isospin labels the states and this would correspond to black-white vision.

3. The simplest states correspond to the restriction of color representations in $SU(3)$ realized as matrix elements of color representations to $U(2)$. The restriction means that certain states drop off. To get some grasp on the situation, consider a simple example first. In the case of $SO(3)$ CP_2 is replaced by the sphere S^2 and the restriction to the group $U(1)$ drops away all matrix elements which vanish at the equator. For $J = 1$ triplet only the states having spin $J_z = \pm 1$ remain. Probably also in the case of $SU(3)$ only charged gluons survive in the octet representation restricted to $U(2)$. Since also color neutral states must be possible, the restrictions of higher representations must contain also color neutral states.

4. The freezing of color degrees of freedom means that the remaining degrees of freedom for the space-time sheet are zero mode like degrees of freedom. These degrees of freedom define what is known as a flag manifold. For $U(2)$ these degrees of freedom correspond to $CP_2 = SU(3)/U(2)$, for $U(1) \times U(1)$ the flag manifold is six-dimensional $SU(3)/U(1) \times U(1)$. Flag manifold qualia would correspond to sequences of constant changes for flag manifold coordinates. In the simplest case, sequences of steps along one parameter subgroup of $SU(3)$. The connection between the dance of the honeybee and color group made by Barbara Shipman supports the view that flag manifold coordinates define fundamental geometric qualia and are responsible, not only for the geometric aspects of vision, but of also other sensory modalities.

Gluons of scaled down versions of QCD and dark matter hierarchy

It become years ago clear that TGD allows a hierarchy of QCDs. The assumption that these QCDs are not asymptotically free allowed to circumvent the experimental bounds on the number of elementary particles. Given QCD would exist only in a certain range of p-adic length scales and thus in a certain range of energy and momentum transfers.

After the discovery of dark matter hierarchy with levels labelled by the values of Planck constant [K36, K37] it became clear that TGD not only allows but predicts hierarchies of electroweak and color physics. Particles of different physics do not have direct interactions and bosons at a higher level of dark matter transform to bosons of a lower level by de-coherence phase transitions. In particular, ordinary intermediate gauge bosons do not decay to the particles of the predicted exotic color and electro-weak physics, and asymptotic freedom can be assumed for all these QCDs.

This forces to consider the possibility that QCDs could exist even in cellular length scales, and that Bose-Einstein condensates of gluons give rise to the opposite color charges of color capacitors. The topological condensation of gluons forces the breaking of the color symmetry for all colored particles, even gluons.

WCW photons?

TGD predicts also WCW color degrees of freedom. What is remarkable is that these states do not carry any energy and momentum. Actually infinite-dimensional super-symplectic representations decomposing into representations of color group are in question. Rigid body color would represent the lowest states of these representations. MEs are especially good candidates for carrying this kind of color. If MEs with sizes below cell membrane thickness are involved with the transfer of color between the color capacitor plates, the energies of the particles involved must be in ultraviolet range by Uncertainty Principle. If the transfer occurs between cells, the length scale could be of order micrometer and thus visible wavelengths would be in question as is indeed natural. Perhaps the structures formed by cell layers are involved with our color qualia.

9.6.5 The Structure Of The Retina And Sensory Organs As Sites Of Sensory Qualia

The assumption that sensory organs are carriers of the sensory representations entangling with symbolic representations realized at the level of cortex does not mean any revolution of neuroscience, just adding something what is perhaps lacking. Neuronal/symbolic level would do its best to symbolically represent what occurs naturally at the level of qualia. Color constancy could be understood as a basic characterstic of color qualia re-realized at the neuronal level.

Center-surround opponency for the conjugate colors is the neural counterpart for the contrast phenomenon in which the boundary for a region of the perceptive field with a given color carries the conjugate color (black-white opponency associated with the luminance is only a special case of this). The contrast phenomenon at the level of visual qualia could derive from the vanishing of the net color quantum numbers for the electrodes of the retinal color capacitors.

The basic prediction is the presence of the back projection at least in the sensory modalities in which hallucinations are possible. MEs with MEs mechanism is the most natural candidate for realizing the back projection, negative/positive energy MEs would realize the back projection based on quantum/classical communications, and the capacitor model of the sensory receptor can be applied to model photoreceptors and retina. This picture integrates nicely with the various speculations about the role of the ciliary micro-tubules in vision. The obvious question is how the presence and character of the back projection reflects itself in the structure of the sensory pathways and sensory organs. Basic facts about how gastrulation and neurulation proceed during the development of the embryo, lead to testable predictions about the character of the back projection for various sensory modalities, and one can speak about "brain senses" and "skin senses" according to whether the back projection is based on quantum or classical communications.

Various micro-tubular structures as photoreceptors/transducers

There is a definite evidence supporting the idea that micro-tubuli might be involved with a primitive vision. The information below is from the lecture "Quantum Vitalism" of Stuart Hameroff during

an online course about quantum consciousness held in Arizona University 1999.

Albrecht-Buehler [I37] has shown that single fibroblast cells move toward red/infra-red light by utilizing their micro-tubule-based centrioles for directional detection and guidance; he also points out that centrioles are ideally designed photodetectors. Photoreception/phototransduction mechanisms at all stages of evolution involve the nine micro-tubule doublet or triplet structures found in centrioles, cilia, flagella and axonemes. The centriole is a pair of micro-tubule-based mega-cylinders arrayed in T shape [I50]. Albrecht-Buehler has identified centrioles as the photoreceptor/phototransducer in photosensitive eukaryotic cells.

Flagellar axonemes are the photosensitive structures in protozoa such as Euglena gracilis. Cilia in rod and cone retinal cells in vertebrate eyes (including humans) bridge two parts of the cells and have length distribution covering visible wavelengths. Photosensitive pigments (rhodopsin) is contained in the outer segment while cell nucleus, mitochondria and synaptic connection are contained in the cell body. Light enters the eye and traverses the cell body and cilium to reach the rhodopsin-containing outer segment.

Mari Jibu, Kunio Yasue and colleagues [J84] have proposed that super-radiance in a micro-tubule could be involved with the photo-reception.

1. The energy gain due to the thermal fluctuations of tubulins is assumed to increase the number of water molecules in the first excited rotational energy state.

2. A collective mode of the system of water molecules in rotationally excited states is generated. A long-range coherence is achieved inside a micro-tubule by means of spontaneous symmetry breaking. The collective mode of the system of water molecules in rotationally excited states loses its energy collectively, and creates coherent photons in the quantized electromagnetic field inside a micro-tubule.

3. Water molecules, having lost their first excited rotational energies by super-radiance, start again to gain energy from the thermal fluctuation of tubulins, and the system of water molecules ends up to the initial state. Jibu and collaborators have predicted that cellular vision depends on a quantum state of ordered water in micro-tubular inner cores. The authors postulate a nonlinear quantum optical effect termed "super-radiance" conveying evanescent photons by a process of "self-induced transparency" (the optical analogue of super-conductivity) involving formation of BE condensate of photons.

Interestingly, the energy scale of the rotational excitations of water is that of microwave photons, and microwave MEs play a key role in bio-control in the TGD based model of living matter. Perhaps the mechanism proposed by Jibu and collaborators could have a variant realized in terms of TGD based physics and involving microwave-, visible-, and very low frequency MEs. In particular, the collective excitation of the water inside micro-tubule could be generated by coherent radiation of microwave photons accompanying microwave MEs rather than thermally. On basis of the second law one could indeed argue that thermal excitations cannot lead to the generation of macroscopic quantum coherent states.

In simple multicellular organisms, eyes and visual systems began with groups of differentiated light-sensitive ciliated cells which formed primitive "eye cups" (up to 100 photoreceptor cells) in many phyla including flatworms, annelid worms, molluscs, crustacea, echinoderms and chordates (our original evolutionary branch). The retinas in human eyes include over 4×10^8 rod and cone photoreceptors each comprised of an inner and outer segment connected by a ciliated stalk. Since each cilium is comprised of about 3×10^5 tubulins, our retinas contain about 3×10^{13} tubulins per eye. Retinal rods, cones and glia are interconnected by gap junctions [J120] and this could be crucial for the generation of the macro-temporal quantum coherence, which quite generally relies on the generation of flux tubes connecting the boundaries of the space-time sheets forming the bound state in question.

It is usually assumed that the cilium is a purely structural element, but the centriole/cilium/flagella micro-tubular structure, which Albrecht-Buehler has analyzed as an ideal directional photoreceptor, may detect or guide photons in eye spots of single cells, primitive eye cups in early multicellular organisms, and rods and cones in our retinas. The proposal that retinal macro-temporal quantum coherence leading to a new qualitative level of consciousness with much longer de-coherence time could have emerged in sheets of gap junction-connected ciliated cells in eye cups of early Cambrian worms, generalizes the vision of Hameroff and Penrose to TGD context.

The identification of the color capacitor structure

The first segment of the photoreceptor consists of the cell soma and a part containing mitochondria. This segment is connected by ciliated stalk to a layered structure containing the photosensitive pigments. The length distribution of the ciliary micro-tubuli covers visible wavelengths.

The closing of eyes generates so called dark current [J82] flowing along the receptor and inducing the hyper-polarization of the receptor membrane. Since visual consciousness is not lost, the natural TGD inspired conclusion is that dark current is the neural correlate for the quale black as a background color quale which in turn results by the color capacitor mechanism.

The fact that vertebrate retina differs by inversion from the retina of invertebrates [I62] inspires the question whether the micro-tubular vision of invertebrates about external world might have been inverted to produce "inner vision" providing back projection in the case of the vertebrates. If so vertebrate cilia would receive the "inner light" or generate it itself with brain remotely controlling the process. Mitochondria in turn could provide the needed metabolic energy but could also act as amplifiers of the incoming light.

The photosensitive layers consist of endoplasma membranes so that the realization of the capacitor mechanism would be the same as for the ordinary axonal membrane (nerve pulse inducing flows of ions giving rise to the neuronal chemical qualia). The membrane would be at criticality as regards to the occurrence of the spontaneous color discharge and incoming photon would cause the breakdown. Since the color discharge can be assumed to flow from the side determined by the direction of the membrane electric field, each layer generates same visual qualia although the direction of the color discharge varies. Layered structure would increase the sensitivity of the retina and facilitate the recharging of the capacitors since discharge would make intermediate regions charged and thus unstable.

It would not be surprising if also the endoplasma membranes filling the cell interior might serve the purpose of acting as quantum capacitors providing neuron with sensory receptors of various kinds. Also neuronal vision is quite possible: the difference from our vision would be that our vision involves integration of a very large number of neuronal experiences (more than.1 billion receptors) by quantum entanglement to form our vision. The gap junctions between visual receptors would make possible macro-temporal quantum coherence and the fusion of receptor level visual mental images to our visual mental images.

Back projection mechanism

The basic mechanism responsible for the back projection would involve curved low frequency MEs. Low frequency MEs could be regarded as topological light rays inside effective wave cavities defined by the magnetic flux tubes parallel to the axons, and leading from the cortex to lateral geniculate nucleus to ganglions to the retina. These magnetic flux tubes would form a part of the magnetic body associated with the retina and have quite large a size. Inside low frequency MEs high frequency MEs would propagate as effectively massless particles. In the case of vision high frequency MEs would have lengths in the wavelength range covering that of the visible light.

1. The inverted structure of retina and back projection hypothesis

Photo receptors consist of rods and cones. Only rods are active at low luminance level (black-white vision). Cones are active at high luminance levels and sensitive to the wavelength of the light. Receptor cells are coupled via bipolar cells to ganglions which in turn feed the sensory input along the inner surface of the retina to the blind spot, and from the blind spot to the lateral geniculate nucleus (LGN) of the thalamus. Below (above) bipolar cells are horizontal (amacrine) cells responsible for the lateral couplings between receptor bipolar synapses.

Back projection hypothesis could allow to understand why the incoming light meets first ganglions and wanders through amacrine, bipolar, and horizontal cells to receptors. The inverted structure is indeed required by the back projection: the inner light (coming along, say curved MEs parallel to magnetic flux tubes parallel to micro-tubuli to ganglions or even remotely generated in the ciliated stalk), must superpose with the incoming light. If the structure would be what a naïve engineering argument would suggest, the inner light should meet the receptors from an opposite side than the light from the external world, and thus from a wrong side.

2. Back projection and retinal magnetic body

It is interesting to relate back projection to the retinal magnetic body. The following two arguments lead to the same estimate for the size of the retinal magnetic body.

1. The value of the ratio f_h/f_l of high and low frequencies appearing in the scaling law of [I11] [K53] determines f_l. For the value $f_h/f_l \simeq 2 \times 10^{11}$ identifiable as the ratio of the ionic zero point kinetic energy at atomic space-time sheets and ionic cyclotron energy E_c in the Earth's magnetic field, this would predict that f_l is about $f_l \sim 3$ kHz so that retinal magnetic body would have size of order 100 km.

2. The scaling law relating the sizes L_{CNS} of brain structures to the sizes L_{magn} of the corresponding magnetic bodies would give in the case of eye $L_{magn} = (c/v)L_{CNS}$, where v is the conduction velocity of nerve pulses or some other relevant velocity parameter. For $v = 10$ m/s and the size of retina about $L_{CNS} \sim 1/3$ cm, this would give $L_{magn} \sim 300$ kilometers so that the estimates are of same order of magnitude.

The ratio c/v could be interpreted as the ratio of the ionic zero point kinetic energy at the cell membrane space-time sheet and of the ionic cyclotron energy E_c. The thickness of the ionospheric cavity is approximately $d = 100$ km. Could this mean that the size of the retinal magnetic body is determined by the thickness of this cavity believed to also give rise to Schumann resonances? If so, then low frequency retinal MEs could be seen as correlates for a radiation moving between the Earth's surface and ionospheric lower boundary forth and back, somewhat like between two mirrors. For $d = 100$ km the period for a single forth-back reflection would be $\tau = .67$ ms, which is near to the duration .78 ms for a single bit of the memetic codon. For $d = 118$ km the duration of the memetic bit would result. Of course, retinal magnetic flux tubes could also be loops returning from the surface of the ionosphere which would make τ longer. If this identification is correct, the temporal variations of various perceptive time scales, say the time resolution of visual perception, determined by the duration of memetic bit, could correlate directly with those of d. In particular, during night time, when ionosphere tends to fall to lower heights, the time scales would become shorter making reaction times shorter.

3. Negative or positive energy MEs or both?

There are reasons to believe that negative energy MEs act as quantum entanglers whereas positive energy MEs are dissipative structures in the sense that the effective phase velocity of the classical fields associated with them is much slower than light velocity. The quantum mechanism leading to the lowering of the effective phase velocity would be basically the sticking of the ME along its boundaries to say cell membrane space-time sheet and to the magnetic flux tube of the Earth's magnetic field.

According to the general model of the motor action as a geometric time reversal of the sensory perception, motor action involves always the generation of low frequency negative energy MEs. Their presence explains the findings of Libet related to the active aspects of consciousness and implies that motor action involves precognitive aspect. The interpretation would be that some higher level structure of CNS or even magnetic body draws negative energy from the motor organs with the mediation of the negative energy MEs. In the case of sensory perception low frequency negative energy MEs would act as bridges allowing the sharing of the mental images between brain and sensory organ.

To sum up, one has two basic options: classical and quantum:

1. Positive energy MEs are involved with the back projection. In this case back-projection would be based on classical communications.

2. Negative energy MEs are responsible for the back projection which might be regarded as a generalized motor action. The phase conjugate of the laser wave would be the standard physics analog. If so then buy now-let other pay mechanism making possible remote metabolism could be involved with the back-projection. This mechanism is the basic mechanism of the metabolism in TGD framework [K59] and implies extreme flexibility.

There are reasons to believe that both options are realized, and one can classify sensory modalities according to whether the back projection is realized by classical or quantum communications. One can also relate these two options to what happens to the embryo during the gastrulation and neurulation.

4. Where the control of back projection mechanism is?

One should also understand where the MEs at visible frequencies are generated.

1. Fractality suggests that the back projections are generated at several levels: ganglions, LGN and various sensory areas. For option 2) the generation of the inner light could mean generation of the quantum entangling negative energy low frequency ME carrying inside it negative energy visible frequency MEs to the appropriate part of the brain. The process could be interpreted as sucking of negative energy from retina.

2. Back projection could be partially responsible for the appearance of the conjugate color at the boundary of a region of given color to improve contrast. Neuronal level would mimic this qualia level phenomenon at levels of the hierarchy. Whether back-projection from ganglia could relate the on-off structure of the receptive fields even at ganglion level, is an open question. The appearance of the conjugate color at the boundaries of a region of the visual field of a given color could relate to the vanishing of the net color charge for the "positive" electrodes of the system of parallel color capacitors formed by the photoreceptors coupled by gap junctions to form single macroscopic color neutral system.

3. The chromo-oxidase (CO) blobs associated with the visual areas V1 and V2 [J107] are a signature of high metabolic activity. For option 2) this would mean that the mitochondria in the neurons of CO blobs suck negative energy photons from some part of the retina, perhaps from the micro-tubuli in the ciliated stalk. The interpretation would be that retina shares the mental image representing the desire of some higher level structure to modify the sensory image and acts accordingly. For option 1) CO blobs would generate positive energy visual MEs propagating to the retina along low frequency MEs: this communication would be classical and limited by the effective phase velocity of the positive energy MEs, presumably of order 10 m/s.

5. Which cellular structures are involved with the generation of the inner light?

The basic question is which cellular structures are involved with the, possibly non-local, generation of the inner light and which are the mechanisms involved. One can imagine several options. Option 1) is most plausible in the case of vision and olfaction whereas option 2) might be realized when the back projection occurs via classical communications.

1. Mitochondria could act as suckers of the negative energy from the retina. Cytochrome oxidase (CO) [J107] is involved with the liberation of the metabolic energy and is associated with mitochondria which are everywhere. The large amount of CO in CO blobs suggest that they are metabolically very active. This could be due to the sucking of negative energy photons responsible for the remote metabolism at retina. Note that this mechanism would be essentially lossless and could be said to involve a temporal change of the arrow of the geometric time at the level of MEs. In fact, it is known that metabolism is almost lossless.

2. Mitochondrial autofluorescence could generate the inner light actively [I38] rather than as a mere by-product of metabolism: in this case however positive energy photons would be generated at CO blobs. The study of fluorescent life forms, say fireflies and life forms able to change their skin color might provide understanding about the feasibility of back projection using this mechanism (applying for option 1)).

3. Also cell nucleus must be considered as a candidate for the source of the inner light. Cell nucleus is believed to produce bio-photons and they cover just the right frequency range. The TGD based model for bio-photons leads to the conclusion that pairs of positive and negative energy MEs are involved with the standard mechanism of the bio-photon emission. Nucleus could participate in the processing of the neuronal sensory input actively if the intronic portion of the genome expresses itself using MEs obeying swift dynamics. In the case of positive energy MEs communications would be classical and memetic code could be involved. The nuclear inner light is naturally involved with the communications between cell nucleus and membrane and cellular vision. If the cell nucleus is the brain of the cell,

one must keep mind open for the possibility that cell nuclei inside CO blobs control the generation of inner light by drawing negative energy photons from receptors. The absorbtion of compensating positive energy photons from the mitochondria would be however necessary and make the mechanism too complicated. A somewhat more natural mechanism would be based on sending of negative energy bio-photons to mitochondria and positive energy bio-photons to the retinal receptors along low frequency MEs. Certainly the simplest option is that mitochondria control back-projection by sucking negative energy from retina.

6. Do the cilia/mitochondria in photoreceptors serve as pre-amplifiers?

Cilia might act as pre-amplifiers for the light coming the external world, at least in the case that the illumination is very weak. If the inner light comes from brain as positive energy photons (option 1)), it is expected to have extremely weak intensity and pre-amplification mechanism could be at work also now. For option 2) the pre-amplification mechanism would be replaced by the sharing of the mental image representing the desired modification of the visual mental image and realized by buy now-pay later mechanism.

One can consider at least two different options for the pre-amplification mechanism.

1. Cilia act as pre-amplifiers and the process is triggered by the incoming inner light by a stimulated emission mechanism for which the rate for the generation of photons is proportional to N^2, N the number of photons already existing in the system. For option 1) this mechanism would be at work also for the inner light.

2. The article about reversible excited light induced enhanced fluorescence (briefly RELIEF [I38]) supports the view that mitochondria need not only produce fluorescence as a passive by-product of energy yield but could act as amplifiers of the incoming light [I38]. Also now buy now-pay later mechanism could be involved. RELIEF phenomenon allows to consider the possibility that the large number of mitochondria preceding cilia in the visual receptors could serve as a pre-amplifier for the incoming inner light. The precise information about the mechanism of autofluorescence in the case of fireflies and life forms able to change their skin color might provide strong constraints on the model.

Does the back projection emerge in the transition from invertebrates to vertebrates?

Three inversions characterize the transition from invertebrates to vertebrates.

1. The inversion of the retina occurs [I62].

2. In vertebrates *resp.* invertebrates incoming color generates hyper-polarization *resp.* polarization of the receptor membrane [I62]. Thus it would seem that the roles of white and black are changed in the vision of invertebrates: invertebrates detect the lack of light.

3. During morphogenesis the generation of neural tube giving rise to spinal cord, motor nerve, eyes and other sensory organs in head occurs [A21], [I21]. Neural tube is formed through a folding process implying that neural tube results essentially from an inside-outside inversion of the outer epithelial sheet of the skin.

The finding that neural tube and skin are related by inversion inspires the following questions.

1. Could one relate the first two inversions to the the third one? The following arguments summarizing the basic facts about gastrulation and neurulation support this guess.

2. What implications the inversion could have for consciousness? Did it change the character of some sensory modalities in a decisive manner so that one see "skin senses" and "brain senses" as inversions of each other in some sense. Could it be that the "skin senses" do not involve the telepathic back projection and that the possible back projection is based on classical communications in this case? Could one understand the emergence of the vertebrates as a step in which the telepathic back projection emerged in vision and perhaps also in some other sensory modalities like olfaction, and made vertebrates dreamers and artists building visual representations as charicatures? Could it be that under appropriate circumstances

tactile senses could provide telepathic information from the external world making possible a telepathic remote sensing which in general need however not provide information directly conscious-to-us?

1. Gastrulation and the differences between vertebrates and invertebrates

Gastrulation [A21], [I21] during which the growing embryo gets gut, is said to be the most important and vulnerable period in the life cycle of a multi-cellular organism. During this period the embryo begins to express its own genome (mother's genome has taken care of development hitherto). The details of this process differ for invertebrates (sea urchin is standard example), amphibians (say frog), and higher vertebrates (birds, reptiles, mammals). In the case of vertebrates the process leads to the generation of essentially three kinds of cell populations. Endoderm develops to inner organs like stomach, intestine and lungs. Mesoderm consists of cells originally contained by the surface of the blastula and differentiates to muscles and inner organs like heart. Ectoderm is the outermost cell layer of the embryo consisting two parts which differentiate later to the nervous system and skin.

For invertebrates gastrulation occurs through a process known as invagination, which is essentially the inpocketing of the epithelial sheet. The pocket like structure elongates to gut tube like structure consisting mainly of endoderm. The nervous system develops from the mesoderm.

Gastrulation occurs differently for amphibians and higher vertebrates. In the case of amphibians gastrulation involves so called involution which means that the mesoderm part of the epithelial sheet rolls below the epiderm to form a double-layered structure (the folding of a rug gives idea of what happens). This process occurs for both halves of the embryo and give. In the case of birds, reptiles, and mammals the gastrulation starts from a situation to which gastrulation leads in the case of amphibians. This in the sense that the outer surface of the blastula is a double layered structure consisting of epiblast and hypoblast below it already in the beginning of the gastrulation. The ingression (detachment) of the cells from the the epiblast *resp.* hypoblast sheet to the interior of the blastula gives rise to mesoderm (muscles, heart, ..) *resp.* endoterm (stomach, intestine, lungs, ...). The remaining epiblast will later transform to skin and nervous system.

2. Neurulation and the difference between "skin senses" and "brain senses"

Before neurulation the outer surface of the vertebrate embryo consists of two parts: the future skin and neural plate forming the future nervous system [A21] , [I21]. During neurulation the ectoderm in neural plate invaginates to form neural tube and neural crest between the neural tube and the ectoderm surface forming the future skin. Neural crest is formed by the ingression of cells from the skin and gives rise to sensory and autonomic nerves, Schwann cells, pigment cells, ... Neural tube in turn gives rise to brain, spinal cord, motor nerves, eyes, ...

The surface of the neural tube is essentially the outer layer of the skin, which has suffered inside-outside inversion. The inversion might mean that the external world is replaced effectively by internal world as far as possible sensory experiencing relying on micro-tubule based sensory organs is considered. This suggests that all "brain" senses such as vision and olfaction involve a telepathy based back projection (sharing of mental images) in an essential manner. "Skin senses", in particular hearing, would in turn involve non-telepathic back projection based on classical communications. Invertebrate eye is formed from the surface cell layer which has not suffered inversion: this could explain why vertebrate and invertebrate eyes differ by inversion. Invertebrates are "almost-predicted" to have back projection based on the classical signalling, in particular in the case of vision: this prediction is testable.

If hearing is "skin sense", as suggested by the fact that we "hear" low frequencies by skin (besides my fragmentary information on the development of the embryo), one must conclude that the back projection to ears must be classical. This conforms with the fact that geometro-temporal patterns of sound waves are the key element of audition. Oto-acoustic sounds audible even by outsiders are indeed a well-known phenomenon and also tinnitus should be caused by back projection involving classical signalling, perhaps by MEs inducing oscillations of nuclei and thus sounds in the inner ear. The hallucinations in "skin senses" and "brain senses" should have a different character. This might explain why dreams are usually either visual or based on internal speech whereas the dreams accompanied by auditory hallucinations are rare and those involving tactile sensations even rarer.

Telepathic "skin senses" (with hearing included) are predicted to be possible and should involve a sharing of remote mental images. The shared mental image need not be directly conscious-to-us. Interestingly, galvanic skin response is a well-known physiological correlate of parapsychological effects and skin seems to play an important role quite generally (e.g. healing by touch and the time varying magnetic fields emitted by the hands of some persons with psychokinetic abilities). Blind people can develop tactile vision and also tactile hearing is possible: an interesting question is whether these senses involve quantum entanglement with the object of the perceptive field. The "sense of presence" might also be seen as a remote "skin sense". That car driver experiences the road through the heels of the moving car as if the vehicle were a part of his body, might be understood in terms of the entanglement associated with touch. Furthermore, it is far from trivial how we know that the sounds from the external world really enter from the external world: perhaps quantum entanglement with the sources of the sound waves is part of the explanation.

The notion of bicamerality introduced by Jaynes [J111] inspires the hypothesis that bicamerals and also schizophrenics can receive conscious information from collective levels of consciousness as auditory and visual hallucinations (see the last part of the book). The direct sharing of sensory mental images or of symbolic mental images back projected to sensory mental images would be in question. In the case of auditory hallucinations this process should involve classical back projection unless a genuine telepathy is in question. This prediction could be perhaps tested by studying the physiological correlates of hallucinogen induced experiences.

3. Back projection hypothesis and olfaction

Back projection hypothesis could allow to understand also some strange findings about insect olfaction.

1. As Callahan has demonstrated, insects experience odorant molecules through the infrared light that they generate, rather than chemically [I61].

2. Olfactory and visual receptors resemble strongly each other. The fact that olfactory bulb can be seen as part of brain, suggests that the inversion of the receptors occurred also for infrared sensitive micro-tubular receptors, that the back projection is "telepathic" also in the case of the odor perception, and that for "brain senses" the sensory input is always transformed to photons at some wavelength range before it enters to the quantum capacitor and is transformed to qualia.

The infrared light responsible for the "inner odors" could be generated by the same mechanism as the "inner light" the case of vision and would probably involve micro-tubular structures. The microtubuli involved with odor receptors should have lengths in the range 5-100 micrometers. Albrecht-Buehler, who has done a lot of experimental work in cellular infrared vision, has demonstrated that infrared signals affect the behavior of cells and that the infrared detector is in the centrosome [I36].

How to test the general model?

The basic assumption of the model are following.

1. Sensory organs are the seats of the sensory qualia and basic sensory representations are realized at the magnetic bodies associated with the sensory organs.

2. Back projection is based on quantum *resp.* classical communications for "brain senses" *resp.* "skin senses".

There are huge quantities of information about sensory perception so that one can invent tests for these assumptions by just going to Mednet and by loading abstracts.

1. Phantom sensations, back projection, and the notion of magnetic body

Tactile hallucinations provide interesting tests and challenges for the notion of magnetic body and for the assumption about sensory organs as seats of sensory qualia.

1. It is known that a tactile stimulation of the existing leg can evoke a dual phantom sensation in a symmetric position, that visual input affects the spontaneous but not the evoked phantom

sensation, and that sensory-motor input affects the spontaneous phantom leg sensation [J83]. The role of the visual input suggests that the evoked phantom leg sensation involves an erratic localization of the tactile sensation at the level of the sensory map of the geometric now and thus involves cortical information processing. The loss of the leg need not lead to the loss of the magnetic body associated with the leg. The tactile back projection could generate tactile mental image in the stump of the leg, which would be entangled with a point of the magnetic body of the amputated leg at the same position as as the tactile mental image associated with the existing leg.

Phantom leg could be also understood if one accepts the vision about 4-D brain and TGD view about memory. Pain in phantom leg would be sensory memory of pain in the leg, which still existed. The memory feats of idiot savants and people with left brain damage would be most naturally also due to sensory (visual or auditory) memories. Also ordinary people can have sensory memories when neurons in temporal lobes are stimulated electrically.

2. The sharing of mental images in principle makes possible to have sensory experiences without sensory input to cortex, a genuine quantum telepathy in the scale of the human body. Anton's syndrome could be seen as an example of this. Also various bodily sensations experienced when the afferents to the brain are anesthetized could be seen as sensory telepathy. Typically sensations of swelling, elongation, and shortening as well as of cold, warm, and prickling are involved ("numbness" of hand is familiar to anyone) [J91]. The latter sensations could be interpreted as an evidence for the sharing of sensory mental images. The experiences about swelling, elongation and shortening would result from the erratic estimation of the geometric parameters of the body part in the absence of the sensory input to the cortex implying in turn the distortion of the image of the body part at the magnetic body.

2. Basic tests for back projection mechanism

Dreams and hallucinations should not involve "skin senses" except in the case that classical back projection is activated. Auditory/tactile hallucinations should involve classical communications from brain to ears/skin unless geometric memories or remote sharing of mental images are involved. Hypnotically induced hallucinations combined with the physiological monitoring of primary sensory organs and sensory pathways allow to test whether the predicted differences between skin and brain senses are indeed there.

The presence of the back projection could be tested by using hypnotic suggestion to experience particular qualia. One can test whether it is possible at all experience hypnotically induced tactile qualia and does this experience involve classical signalling from brain. One could test whether something occur in color receptors of a person with closed eyes or in a dark room under hypnotic suggestion. One could investigate whether the activity of CO blobs or say P cells in LGN correlates directly with the activity at the retinal level during hallucinations. One could check whether the back projection for invertebrates involves always classical signalling.

3. Hypnosis and back projection

The findings about hypnosis and color vision [J86] suggest more detailed tests for the back projection hypothesis.

1. The study in question was designed to determine whether hypnosis can modulate color perception. Such evidence would provide insight into the nature of hypnosis and its underlying mechanisms.

2. Eight highly hypnotizable subjects were asked to see a color pattern in color, a similar gray-scale pattern in color, the color pattern as gray scale, and the gray-scale pattern as gray scale during positron emission tomography scanning by means of CO_2. The classic color area in the fusiform or lingual region of the brain was first identified by analyzing the results when subjects were asked to perceive color as color versus when they were asked to perceive gray scale as gray scale.

3. When subjects were hypnotized, color areas of the left and right hemispheres were activated when they were asked to perceive color, whether they were actually shown the color or the

gray-scale stimulus. These brain regions had decreased activation when subjects were told to see gray scale, whether they were actually shown the color or gray-scale stimuli. These results were obtained only during hypnosis in the left hemisphere, whereas blood flow changes reflected instructions to perceive color versus gray scale in the right hemisphere, whether or not subjects had been hypnotized.

4. The conclusions were that among highly hypnotizable subjects the observed changes in subjective experience achieved during hypnosis were reflected by changes in brain function similar to those that occur in visual perception. These findings support the claim that hypnosis is a psychological state with distinct neural correlates and is not just the result of adopting a role.

The findings of [J86] inspire following comments.

1. The occurrence of hypnotically induced changes in brain function similar to those occurring in visual perception supports the view that sensory organs are the seats of the primary sensory experience. If eyes are the seats of color qualia, hypnosis should induce back projection as is also obvious from the fact that hypnosis induces hallucinatory experiences. The occurrence of the back projection could be tested by using hypnosis in the absence of external light stimulus by testing what happens whether color receptors are active when person is hypnotized to see color.

2. That the left hemisphere is less gullible in ordinary wake-up consciousness supports the role of right hemisphere as the new-ageish entangler and of the left hemisphere as the skeptic loner. Parts of right brain would become more easier extensions for the brains of suggestive persons even without hypnosis. Right brain hemisphere could also be the sensory artist, and thus the dominating generator of the inner light associated with the back projection. Right brain hemisphere could also generate the inner "voices" of auditory hallucinations as Jaynes proposes [J111] or be entanglement with some higher level of self hierarchy using right brain hemisphere to generate the hallucinations.

4. Models for sensory organs and back projection

The insights provided by the study of the structure of the retina encourage to think that a detailed data about various sensory receptors and their development during embryo period could provide a lot of insights about the mechanisms generating sensory qualia and about the mechanisms of the back projection and lead to testable predictions. This would however require a lot of professional knowhow. Also the possible role of bio-photons in back projection might be amenable to study.

9.6.6 Some Examples About Deficits Of Color Vision As A Test Of The Model For Cognitive Representations

The article "Quining the Qualia" by Daniel Dennett gives [J60] a good view about the difficulties encountered as one tries to understand qualia as a philosopher. Dennett's reaction to the problems is to give up the notion of qualia altogether. To me this is like denying the causal role of consciousness just because we do not have mathematical and conceptual tools to describe it. This is however not the main point now. Dennett lists some fascinating empirical findings related to deficits in color vision, which serve as excellent tests for any theory of qualia.

It is instructive to consider these examples in the framework provided by the model of cognitive representations just discussed. For this purposes let us list the basic general assumptions of the model in the case of color vision.

1. The paradoxical fact that receptor cells hyper-polarize rather than depolarize as they receive light is consistent with the requirement that incoming light must increase the color voltages between cone system and its magnetic body in order to generate color discharge. Rods would differ from cones in that the full color algebra SU(3) to its sub-algebra SU(2) so that only the increments of color isospin I_3 would be perceived and would give rise to black and white as

primary qualia. Thus only charged SU(2) gluons are exchanged between the magnetic body associated with the rod system.

In the case of cones the most natural assumption is that all 3+3 colors (black and white are counted as colors) are perceived and correspond to increments of color isospin and two generators carrying hyper charge. Single cone could be specialized to produce up the increment of color quantum numbers corresponding to a particular primary color. The increment of color quantum numbers should always have the same sign in the ideal situation (only quale which is red or green, blue or yellow, black or white is produced if the highest weight or lowest weight states of the representation of color algebra (or color Kac-Moody algebra) define the ground state of the system.

2. Cortex is assumed to participate actively to the coloring of the sensory map by using back projections to retina and the experienced color map is an outcome of a complex information processing.

3. The magnetic bodies of retina would contain regions where colors are cognitively represented as an analog of color circle so that the over all color sensation generates cognitive and emotional representations as a "somatosensory" experience at the magnetic body realized as cyclotron phase transition patterns. Pure colors would correspond to patterns localized at single point of the magnetic body whereas mixed colors would correspond to de-localized patterns.

First example

Objects to the right of the vertical meridian appeared to be of normal hue, while to the left they were perceived only in shades of gray, though without distortions of form... He was unable to recognize or name any color in any portion of the left field of either eye, including bright reds, blues, greens and yellows. As soon as any portion of the colored object crossed the vertical meridian, he was able to instantly recognize and accurately name its color.

This finding could reduce the plausibility of the hypothesis that sensory organs are seats of sensory qualia and of primary cognitive and emotional representations. The hypothesis passes the test. Retina decomposes to nasal and temporal retina. This corresponds to the decomposition of the visual field of retina to right and left hemifields [L83]. The inability to recognize and name colors in the left visual could be simply due to the fact that cones sensitive to color are not functioning properly or at all in the left temporal and right nasal retina. A more complex situation would results if parts of cortex responsible for the back projections to the left visual field want to "see the world as grey" and actively reduce the color map to the shades of grey.

Second example

The patient failed in all tasks in which he was required to match the seen color with its spoken name. Thus, the patient failed to give the names of colors and failed to choose a color in response to its name. By contrast, he succeeded on all tasks where the matching was either purely verbal or purely nonverbal. Thus, he could give verbally the names of colors corresponding to named objects and vice versa. He could match seen colors to each other and to pictures of objects and could sort colors without error.

What was remarkable that the patient was not aware of any deficit.

There is an obvious analogy with the phenomenon of absolute ear. Almost anyone can tell whether two notes have the same pitch but only people with absolute ear learn to name the heard note. In the case of color vision almost all of us have "absolute eye" in the sense that we can recognize the perceived color and name it but in the above described case this ability would be lost. The analogy is weakened by the fact that musicians not possessing absolute ear are quite well aware of their "deficit".

Accepting the analogy, the TGD based model for absolute ear generalizes as such to the recent situation. The model of absolute ear is based on a comparison in which reference dark photon signal is sent from the temporal planum [J96] to the magnetic body assignable to the cochlea. Recognition relies on the constructive interference of the dark photon signals from cochlea and temporal planum enhancing the rate for the cyclotron phase transition. This model generalizes

to a general model for how conscious pattern recognition occurs at the level of the magnetic body and applies in the case of vision too.

1. There should exists a region of visual or associative cortex analogous to the temporal planum sending a dark photon signal to the magnetic body of retina.

2. That the patient is not aware of the syndrome suggests that the reference signal representing given name of color as actual color is sent but goes to a "wrong address" at the magnetic body and is not compared with the real signal. If the cognitive "color circle" correspond to a small portion of the magnetic body as the general model for cognitive representations suggests, the resonance could indeed occur at wrong position of the magnetic body receiving different kind of cognitive input.

Third example

One morning in November 1977, upon awakening, she noted that although she was able to see details of objects and people, colors appeared "drained out" and "not true." She had no other complaint... her vision was good, 20/20 in each eye... The difficulty in color perception persisted, and she had to seek the advice of her husband to choose what to wear. Eight weeks later she noted that she could no longer recognize the faces of her husband and daughter... [So in] addition to achromatopsia, the patient had prosopagnosia, but her linguistic and cognitive performances were otherwise unaffected. The patient was able to tell her story cogently and to have remarkable insight about her defects.

This case could be understood as the failure of the back projection mechanisms making possible coloring of the percept and the generation of the caricature like percept allowing recognition of faces. Also the recognition of faces could rely on the resonance mechanism in which signal is sent from cortex to an appropriate magnetic body.

These examples should demonstrate that the TGD based notion of qualia combined with the general model for cognitive and emotional representations can easily explain the findings discussed in [J60].

9.6.7 Odor Perception And Quantum Coherence

In Discover magazine there is an article titled *Is Quantum Mechanics Controlling Your Thoughts?* [I51] telling among other things about the latest direct evidence of quantum effects provided by experiments related to odor perception. The article discusses the work of the biophysicist Luca Turin [J123] about odor perception as an additional support for quantum brain. Before going to the article it is good to summarize the basic ideas about sensory qualia (colors, odors, ...) in TGD inspired theory of consciousness.

1. In TGD framework the identification of qualia follows from the identification of quantum jump as a moment of consciousness. Just as quantum numbers characterize the physical state, the increments of quantum numbers characterize the quantum jump between two states. This leads to a capacitor model of the sensory receptor in which the sensory perception corresponds to a generalized di-electric breakdown in which various particles carrying some quantum numbers flow between electrodes and the change of the quantum numbers at second electrodes gives rise to the sensory quale in question.

2. It is important that sensory qualia are assigned to the sensory receptors rather than to the neural circuitry of brain as in standard neuroscience. This leads to objections (phantom leg for instance) which are circumvented in TGD based vision about 4-D brain. For instance, phantom leg would correspond to sensory memory resulting by sharing the mental image about pain residing in the geometric past when the leg still existed. A massive back-projection generating virtual sensory input from brain (or from the magnetic body via brain) is needed to build the actual perception as a kind of art-work by filtrating from the actual sensory input a lot of unessential stuff and amplifying the essential features.

3. The discovery of Callahan [I61] that odor perception of insects seems to be based on IR light inspired my own the proposal that photons at IR frequencies could be involved with the odor

perception so that odor perception would be at molecular level seeing by IR light. Even hearing could involve similar "seeing" in appropriate frequency range. Massless extremals (topological light rays) would serve as kind of wave guides parallel to axons along which light would propagate as kind of laser beams between receptor and brain. This would also explain why the mediation of auditory input takes so rapidly.

4. I have also proposed frequency coding for the sensory qualia. The first proposal which I dubbed as "Spectroscopy of Consciousness" stated that cyclotron frequencies assignable to various biologically important ions -much below IR range- associated with as such correspond to sensory qualia. Later I gave up this idea and proposed that frequencies code provide only a symbolic representations- define their names- as one might say. The information about qualia and more general sensory data would be represented in terms of cyclotron frequencies inducing dynamical patterns of the cyclotron Bose-Einstein condensates of biologically important ions residing at the magnetic body receiving the sensory information.

Vibrational theory of odor perception

I attach a small piece of the article here to give a popular summary about the work of Luca Turin [J124].

Quantum physics may explain the mysterious biological process of smell, too, says biophysicist Luca Turin, who first published his controversial hypothesis in 1996 while teaching at University College London. Then, as now, the prevailing notion was that the sensation of different smells is triggered when molecules called odorants fit into receptors in our nostrils like three-dimensional puzzle pieces snapping into place. The glitch here, for Turin, was that molecules with similar shapes do not necessarily smell anything like one another. Pinanethiol [C10H18S] has a strong grapefruit odor, for instance, while its near-twin pinanol [C10H18O] smells of pine needles. Smell must be triggered, he concluded, by some criteria other than an odorant's shape alone.

What is really happening, Turin posited, is that the approximately 350 types of human smell receptors perform an act of quantum tunnelling when a new odorant enters the nostril and reaches the olfactory nerve. After the odorant attaches to one of the nerve's receptors, electrons from that receptor tunnel through the odorant, jiggling it back and forth. In this view, the odorant's unique pattern of vibration is what makes a rose smell rosy and a wet dog smell wet-doggy.

The article "A spectroscopic mechanism for primary olfactory perception" [J124] by Turin explains in detail his theory and various experimental tests. Here are the core ideas in more quantitative terms.

1. The theory originates from the proposal of Dyson proposed already 1938 that odor perception might rely on the vibrational spectrum of the odorant rather than its shape alone. The spectrum would be in the wave length range 2.5-10 μm corresponding to photon energies in the range.5 eV -.125 eV. This vibrational spectrum would be excited by the current of electrons tunnelling from the receptor to the odorant molecule.

2. The proposal is that odor receptor can be regarded as a pair formed by a source and sink of electrons. If there is nothing between source and sink, tunnelling can occur if there is electronic energy state with same energy in both source and sink. If there is an odorant molecule between source and sink with vibrational energy E, tunnelling can occur indirectly: the electron can excite a vibrational state with this energy and tunnelling can occur only if the difference of electron energies in source and sink is E. Therefore the presence of odor molecule would be detected from the occurrence of the tunnelling and vibrational energy spectrum would characterize the odor molecule.

Comparison of Turin's model with TGD and Callahan's theory

One can compare the model of Turin with TGD based ideas.

1. The theory of Turin conforms at the general level with the receptor model. The "electrodes" of the sensory capacitor would correspond to the source and sink of electrons and the presence of the odorant molecule between the "electrodes" would induce the current. The current of

electrons from the source to the sink should induce the change of total quantum numbers defining the odor quale.

2. The first thing to notice is that the upper bound.5 eV for IR energies corresponds to the nominal value of the metabolic energy quantum identified as the energy liberated as proton drops from the atomic space-time sheet with $k = 137$ to a very large space-time sheet or the same process for electron Cooper at $k = 149$ space-time sheet. If Cooper pairs are involved, the latter process would occur in the length scale defined by the thickness of the lipid layer of the cell membrane (5 nm). The lower bound corresponds to a metabolic energy quantum assignable to $k = 139$ for protons and $k = 151$ transition for electrons (thickness of cell membrane).

3. Second point to notice is that TGD predicts a fractal hierarchy of spectra of metabolic energy quanta [K12] coming as $E(\Delta k, n) = 2^{-\Delta k} E_0(1 - 2^{-n})$, $n = 1, 2, ...$, converging to $E(\Delta k, \infty) = 2^{-\Delta k} E_0$ for given p-adic length scale characterized by the difference $\Delta k = k - k_0$. E_0 denotes the zero point kinetic energy of particle at space-time sheet with p-adic length scale $k = k_0$ and is inversely proportional to the mass of the particle. The transfer of electrons and/or protons between different space-time sheets with any perception for purely metabolic reasons. The simplest option is that since the electrons at the side of the source receive their energy in this manner, their energy spectrum is given by $E(\Delta k, n)$ (there is of course some resolution meaning a cutoff in n). The specificity of the receptor would require preference of some specific metabolic energy quanta $E(\Delta k, n)$. If this spectrum characterizes the receptor independently of its chemistry, then not only metabolic energy quanta but also the mechanism of sensory perception is universal. This proposal fails if the receptor has always same spectrum of $E(\Delta k, n)$ since all receptors would detect all odors.

It is interesting to relate the theory of Turin with the hypothesis of Callahan that the odor perception of insects uses IR light.

1. Callahan's work [I61] suggests that the IR photons emitted by the odorant in the transitions between the vibrational states and received by the odor receptor are basically responsible for the odor perception. Turin in turn proposes that the pattern of vibrational excitations in the odor molecule characterizes the perception. These views are consistent if the pattern of vibrational excitations is in 1-1 correspondence with the flow pattern of electrons between different space-time sheets at the receptors if a kind of self-organization pattern results: this is expected to take place in presence of a metabolic energy feed.

2. In Callahan's model for the odor perception of insects the simplest odor receptor would "see" the IR light emitted by the odor molecules. Also Turin explains -with different assumptions- that the situation is analogous to that prevailing in retina in that there are receptors sensitive to characteristic energy ranges of photons. One would expect that the odor perception of insects is something very simple. The so called vomeronasal organ [J3] is known to be responsible for the perception of socially important odors not generating conscious experience at our level of self hierarchy but having important effect on behavior (perfume industry has long ago realized this!). Vomeronasal organ could utilize this kind of primitive odor receptors.

3. The rate for the spontaneous transitions emitting IR light could be rather low. A more advanced receptor would induce more transitions by using tunnelling electrons to excite vibrational energy levels in the odorant. This would be like using lamp to see better! The analogy with the transistor is also suggestive: the small base current induced by IR radiation generated by the odor molecule would be amplified in the process. Since the source contains electrons in excited states (at smaller space-time sheets), odor molecules could send negative energy photons dropping electrons to the large space-time sheet along which tunnelling is possible. Induced emission would cause a domino like flow of electrons and excitations of the vibrational states of the odor molecule as the counterpart of di-electric breakdown would take place.

4. What could then the physical correlates for the primary odor qualia? The increments of some quantum numbers assignable to electrons at the source should be in question. Could

the energies $E(k,n)$ characterizing the receptor define the primary odors? Odors and tastes are indeed very intimately related to metabolic activities. A natural consequence would be that besides the radiation generated by the transfer of electrons between space-time sheets would induce odor and perhaps also taste sensation. Organisms serve as food for other organisms so that an optimal detection of nutrients would be the outcome. The objection is that similar "metabolic qualia" would result in all receptors. This is not a problem if these qualia are qualia not conscious to us but conscious to neuronal selves. For instance, in TGD based model for visual colors color the increments of quantum numbers define the basic colors.

Could one assume that also other receptors use metabolic energy quanta as basic excitation energies?

1. The first objection is that similar "metabolic qualia" would result in all receptors. This is not a problem if these qualia are qualia not conscious to us but conscious to neuronal selves. For instance, in the TGD based model for visual colors the increments of color quantum numbers (in QCD sense!) define the basic colors, which means that colored particles must be in question (TGD variant of quark color implies the existence of scaled variants of QCD like physics and predicts that also electrons have colored excitations for which there is indeed a growing experimental evidence [K130]).

2. Second objection is that it does not seem possible to identify $E(k,n)$ as excitation energies in the case of vision. The relevant range of photon energies is [1.65, 3.3] eV. By scaling the metabolic energy quantum by a power of 2, the nominal values of relevant maximal metabolic energy quanta $E(k,n=\infty)$ are 2 eV and 4 eV. The series of energies approaching 2 eV below 2 eV is 1, 1.5, 1.75, ..., 2 eV so that the range below 2 eV representing red light would be covered. Above 2 eV the series is 2, 3, 3.50, ..., 4 eV so that the region above 2 eV (orange, yellow, green, blue, indigo, violet) would contain only single line at 3 eV (violet). If the incoming photon can kick the electron to an excited state with energy E_0 at the smaller space-time sheet the spectrum contains also the energies $E(k,n)+E_0$. For $E_0 = 1.3$ eV these excitation energies would come as 2.3, 2.8, 3.05, ... 3.3 eV and cover this range.

Isotope effect of olfaction as an additional guideline

The above considerations are still rather speculative and leave a loot of room for alternatives. The additional guideline leading to a surprisingly simple TGD inspired model of odor perception comes from the observation that flies can smell the difference between normal hydrogen and deuterium (see `http://tinyurl.com/6equps5`) [J145]. This is not in accordance with the standard theory of olfaction which says that olfaction relies on the shape of the molecule but conforms with the vibration theory of Luca Turin [J123, J124], who is one of the co-authors of the article [J94] reporting the discovery. The theory assumes that olfaction relies on molecular vibrational frequencies depending on the mass of the isotope.

1. Turin's theory

From Turin's video lecture (see `http://tinyurl.com/nupwwl`) and Wikipedia article (see `http://tinyurl.com/a945lsu`) [J31] about vbration theory of olfaction one learns why reductionism is so nice when it can be applied.

1. If the molecular vibrations in a reasonable approximation reduce to independent vibrations assignable to various chemical bonds, the problem of predicting the odor of the molecule reduces to the calculation or measurement of the oscillation frequencies associated with the chemical bonds of between two atoms or between two molecules forming a bigger molecule as a composite. Near IR frequencies in.8-2.5 μm wavelength range associated with vibrational spectrum are inversely proportional to the reduced mass of the pair of atoms or molecules connected by the chemical bond and the IR frequencies related to rotational-vibrational transitions depending on more complex manner on the molecular mass are good candidates for inducing the olfactory qualia at least in the case of insects.

2. Situation is also simplified by the fact that only a finite range of frequencies is expected to induce odor sensation just as only finite range of frequencies induces visual percept. Hence the engineering of odors becomes possible by considering only some basic bonds. One can test the model by replacing the hydrogen with deuterium in some constituent of the molecule and this was done in the article referred above.

3. The odor of the molecule should be a superposition of the basic odors assignable to the basic chemical bonds just like visual color is a superposition of primary colors. One must however remember that the quantum phase transition inducing the odor sensation itself need not have anything to do with the IR photons and many frequencies could induce the same quantum phase transition. The innocent novice is also allowed to ask whether the harmonics of the fundamental oscillation frequency could give rise to the olfactory analogy of timbre distinguishing between different musical instruments and whether octaves correspond to more or less similar odor sensation. The following considerations suggest that the answer to these questions is negative.

In Turin's theory vibrational frequencies are interpreted in terms of a model of receptor based on the idea that electron tunnelling occurs between odor molecule and receptor and generates odor sensation if the energies of the electron states at the both sides are same. In general the ground state energies of the electron at the two sides are different but it can happen that the condition is satisfied for some excited state of electron of the acceptor so that odor perception is due to a tunnelling to an excited state. The model requires the fusion of the odorant molecule to the receptor so that there is a close relationship with the standard theory assuming lock-and-key mechanism.

2. Callahan's theory

The finding conforms also with the old discovery of Callahan that the olfaction of insects is analogous to seeing at IR frequencies. This hypothesis explains among other things the finding that insects seem to love candles [I61].

If I have understood Callahan's theory correctly, the IR photons emitted by the odorant would induce transitions of electrons or Cooper pairs of the odor receptor. This would allow "radiative smelling" without a direct contact between odor molecules and olfactory receptors and at the first glance this seems like an unrealistic prediction. However, since the average power of radiation is proportional to $1/r^2$, where r is the distance between the receptor and molecule, radiative smelling would in practice be limited to rather short distances unless the radiation is guided. Maybe this could be tested experimentally by using coherent beam of IR light as a candidate for an artificial odorant.

3. TGD based theory

In TGD inspired theory of qualia one must distinguish between the sensory input inducing the quale and its secondary representation in terms of Josephson and cyclotron frequencies.

1. All qualia are coded (but not necessarily induced!) by various frequencies and communication using dark photons with various values of Planck constant meaning scaling down of visible basic frequencies is an essential element of communications at the level of biological body and between magnetic body and biological body. Josephson frequencies and cyclotron frequencies with so large Planck constant that energies are above thermal energy play a key role in the these communications. Note that cyclotron frequencies are inversely proportional to the mass of the ion so that isotope effect also at this level is predicted.

   Josephson frequencies are assignable to cell membrane and one ends up with a nice model for the visual qualia assuming some new physics predicted by TGD. Josephson frequencies and their modulation (as in the case of hearing) should be highly relevant for all qualia.

2. The capacitor model for sensory qualia assumes that all qualia are generated via the quantum analog of dielectric breakdown in which particles with given quantum numbers characterizing the quale flow between the plates of the capacitor. For sensory receptors the capacitor is obtained by a multi-layered structure obtained by a multiple folding of the cell membrane so that the efficiency of the sensory receptor increases.

3. In Turin's model the second plate of the capacitor model would correspond to the odorant molecule. This does not however allow anything resembling di-electric breakdown. It is difficult to imagine how to achieve a quantum phase transition involving simultaneous tunnelling of a large number of electrons unless the receptor binds a large number of odorant molecules. Odor molecules should also form a quantum coherent state: a molecular analog of atomic Bose-Einstein condensate would be required. This would mean that only very special odor molecules could be smelled.

4. For the Callahan's variant of the theory the IR photons could excite the Cooper pairs of the other plate of the capacitor so that the tunnelling becomes possible and quantum variant of di-electric breakdown can take place. This model is consistent also with the assumption that cell membrane acts as a Josephson junction and fundamental sensory capacitor. The energy of electron gained in the electric field of the cell membrane is in the range.04-.08 eV which indeed corresponds to IR frequencies. The variation of the membrane potential would give rise to the spectrum of basic odors. Roughly one octave of frequencies could be smelled if the cell membrane defines the fundamental nose smelling the energy of electron.

   This option allows also the coding of odors by IR frequencies themselves so that brain could generate virtual odors by sending quantum coherent IR light to the odor receptors. This would explain odor hallucinations (and also other sensory hallucinations) as virtual percepts generated by brain itself. This sensory feedback would be absolutely essential for building up of standardized sensory percepts.

5. The difference between visual and odour receptors would be that the ground states of the cell membrane would correspond to near to vacuum extremals *resp.* far from vacuum extremals and therefore Josephson frequencies would be in visible *resp.* IR range respectively.

9.6.8 Is It Possible To See Without Brain?

Science News (see `http://tinyurl.com/ch2ppzo`) [J16] tells about a finding that transplanted eyes located far outside the head of vertebrate can see without a direct connection to brain. The connection to spine is however present.

The experimenters surgically removed donor embryo eye primordia, marked them with fluorescent proteins, and grafted them into the posterior region of recipient embryos. This induced the growth of the ectopic eyes. The natural eyes of recipients were removed. Fluorescent spectroscopy revealed the natural innervation patterns but none of the animals developed connections to brain.

To determine whether the animals having only ectopic eyes could see the training system was divided to quadrants of water illuminated by either red or blue LED light, and experimenters gave slight electric shocks in a particular quadrant. What was found that about 19 per cent of animals with optic nerves connected to the spine learned to avoid the quadrant in which they received electric shocks.

What experiments show that it is possible to see without neural connections to brain. The question is whether only the spinal cord or also the brain was involved with the learning. Probably neuroscientist could immediately answer this question but for an innocent layman like me the answer is far from obvious. Experimenters seem to think that brain is involved. As Douglas J. Blackinston, the first author of the paper (see `http://tinyurl.com/ybo4yydy`) "Ectopic Eyes Outside the Head in Xenopus Tadpoles Provide Sensory Data For Light-Mediated Learning, " in the February 27 issue of the Journal of Experimental Biology [J49], states "Here, our research reveals the brain's remarkable ability, or plasticity, to process visual data coming from misplaced eyes, even when they are located far from the head."

If brain is involved and the learned response is not a mere reflex involving only the spine, there must be information transfer to brain - perhaps along spine - but not as nerve pulses.

In TGD framework these findings inspire several questions.

1. Does the ability to see colors mean that visual colors are perceived at the level of retina rather than brain? The phenomenon of phantom limb supports strongly the standard view that various qualia emerge at the level of brain. On the other hand, the almost-prediction of TGD inspired theory of consciousness is that the primary sensory percept - and therefore

also color qualia - can be assigned with the sensory organs. In TGD framework brain and body are 4-dimensional so that the pain in non-existing limb would be pain in the real limb of the geometric past.

Brain would build cognitive representations - standardized mental images - about the sensory input by decomposing the perceptive field to objects. Brain would of course induce also motor response by associating to these standardized mental images motor actions.

2. In order to build standardized mental images brain would generate feedback as a virtual sensory input to the sensory receptors. Virtual sensory input would be realized using what I have called dark photons having "topological light rays" as space-time correlates and assignable to the magnetic flux tubes connecting body parts together. Two new notions are involved: magnetic body - the primary intentional agent - and the signalling using photons, which are dark in the sense that they are characterized by a large effective value $\hbar_{eff}$ of Planck constant coming as an integer multiple of $\hbar$ so that for say energy of visible photon the wavelength can be much longer than micrometer.

3. It has of course been known for a long time that EEG carries precise information about the state of brain, and the natural question is why so? Magnetic body must receive data from biological body and the hypothesis is that EEG and its variants and possible scaled variants of EEG involving dark photons with large enough value of Planck constant to make their energies higher than thermal energy make this communications possible. Dark photons would be assigned to what I have used to call "topological light rays" assignable to magnetic flux tubes. The basic functions of EEG would therefore be communication to and control by magnetic body.

   For instance, quite recent experiment (see `http://tinyurl.com/boljuyh` [J90, J15] involved two rats as model animals. The first rat learned to press one of the two levers in response to a light signal over the correct level to get the reward. Second rat received the EEG response of the first rat and learned to respond in the same manner on basis of this response only so that this sensory response served as a virtual sensory or cognitive input for it.

   Magnetic body would generate also motor response using brain as a control instrument. Is the motor response in the recent case a kind of reflex action using only spine? Or are brain and magnetic body involved? Certainly the magnetic body could use brain as an intermediate control instrument. How much of the plasticity usually assigned with brain is actually flexibility of the magnetic body? And who is learning: is it brain or the magnetic body?

4. The communication using dark photons and the presence of magnetic body would make possible the participation of also brain to the learning process. For instance, the communication from the ectopic eye to brain could utilize quantum coherent dark photons travelling along the route ectopic eye $\rightarrow$ appropriate layer of magnetic body $\rightarrow$ brain. One can imagine also a dark photon communication along magnetic flux tubes parallel to spine.

9.6.9 How Are The Visual Percepts Constructed?

How does visual system analyze the incoming visual information and reconstruct from it a (highly artistic) picture of the external world? I encountered this problem for the first time for about 35 years ago while listening some lecture about what happens in retina. I was working with my thesis as an unemployed in a job with the (hidden for me) purpose to make me capable of getting a job in a real world (as a person suffering from a tendency to use my brains to thinking I was (and still am) labelled as a kind of socially handicapped person: in former Soviet Union I would have been labelled as a paranoid). The job itself was a purely formal duty and I was allowed to prepare my thesis rather freely (this would not be possible nowadays). I had also opportunity to listen lectures and this particular lecture series about neuroscience by Kari Kaila has teased me since then.

1. In the primary visual cortex there are so called orientation columns `http://tinyurl.com/y9c93lq7`. The are geometrically flat slabs parallel to each other and orthogonal to the surface of the cortex being arranged like slices of bread. The neurons inside the columns are highly

discriminatory for visual orientations and their motion. Wikipedia article also mentions pinwheels: orientation columns characterized by different orientation angles meet at singular points. This bring in mind radial lines emanating from origin and defining discretization of the azimutal angle.

This sounded very strange to me. Why not divide visual field to small cycles or squares and be sensitive to the light in a particular square defining the bit?

2. I learned that there are also simple and complex cells. Simple cells are sensitive to a particular line. Complex cells are sensitive to all lines with same direction.

3. I was also told that ganglions in retina have receptive fields. There are ganglions with on-center and off-center receptive fields. There is also a saccadic motion (`http://tinyurl.com/n3g3g5`), which is essential for visual consciousness: if it is prevented, subject persons first begins to see just darkness and eventually the visual consciousness fades away.

How to integrate these pieces to a coherent picture? During morning hours this problem popped up in my mind and I got some ideas and decided to check from Wikipedia what is known. I of course thought that this whole thing has been well-understood for decades and maybe it is! If so, I am making myself a fool: it does not however matter much at this age! I found an article about orientations columns (`http://tinyurl.com/y9c93lq7` containing a brief mention about a model for how the orientation map is constructed.

So called Moire interference (see `http://tinyurl.com/yd2jsk32`) of identical or nearly identical patterns rotated with respect to each other by an angle produces a non-localized representation of a definite orientation. By putting the visual representation associated with approximately hexagonal lattices formed by on-centre and off-centre ganglions, one would obtain a representation of orientation somehow. I must be honest: I did not understand the idea at all! Is this really so complex? There was a reference to an article in Nature: Paik, S., Ringach, D. L. (2011): Retinal origin of orientation maps in the visual cortex. Nature Neuroscience, 14(7), 919-925. I do not have access to this article so that I can continue making naïve questions and stupid arguments.

1. Primary visual cortex performs the roughest processing of visual information. What are the simplest possible visual representations of the external world? Drawings of course. Painters make first a a sketch. We have cartoons. Visualizations are typically 2-D drawings. It would not be surprising if visual system would not obey the same strategy. In finite resolution they consist of pieces of lines forming what looks like continuous structures when the length of basic piece is short enough as anyone who has used drawing programs knows. Maybe brain and retina first build this kind of representation and add colours and other details later.

2. Could ganglia or possible linear structures formed from them effectively see through slits? They would be specialized to detect the presence of this kind of lines of some minimal length defining the resolution and going through through the centre of retina. When the line is parallel to the slit associated with the detector, the line detector sends nerve pulses to brain.

3. There is a problem. If the orientation of eye remains fixed, the line detector sees only the lines going through the normal of the retina at its centre and usually sees nothing. Most of visual field would remain unseen.

   Saccadic motion saves the situation. When the normal of the line detector intersects the line of visual field with a proper orientation, it detects a line. For a given light intensity the input is maximal if the line is longer than the maximal length of line source for which detector is sensitive. The total intensity of incoming light through the slit is enough to build the representation. The output is bit telling whether a piece of line is there or not.

4. These inputs from slit detectors would be the basic inputs fed to the complex cells forming representations of the lines. In visual cortex the information from the orientation of retina combined with the bits produced by slit detectors during a saccadic motion lasting so long a period that large enough number of orientations of normal are scanned, are combined to a drawing.

   $T = .1$ seconds is the croon of time for sensory percepts. and is the natural guess for this period of integration. The maximal angular speed of saccadic motion is for humans about

900 degrees/second making 90 degrees per time interval T (see `http://tinyurl.com/n3g3g5`).

Certainly there must exist a feedback from brain favoring preferred saccades using already existing information about the distribution of lines so that for targets which are stationary saccades would go along the lines of the already existing picture and detect if changes have occurred. The signals from orientation columns of primary cortex might be important part of this feedback.

5. If the object remains in good approximation at rest during this period, a drawing about the external world is obtained as an outcome. The simplest guess is that orientation column at particular point of visual cortex corresponds to a point in the visual field and if there is line of defined direction going through that point of visual field, simple cell sensitive to that orientation receives input.

6. Could ganglia themselves see the world through a slit? One can argue that if this were the case, it would have been observed experimentally. I tend to agree. One can of course ask whether saccadic motion necessary for visual consciousness effective blurs the visual field of the ganglion so that it is disk of radius defined by the maximal length of line for which ganglion is sensitive.

   The simplest and probably the correct assumption is that ganglia indeed detect spots of light or absence of it. Line detectors would correspond to lines formed by ganglia or perhaps similar structures at higher levels of the neural hierarchy.

   Since I love magnetic flux tubes, I cannot resist the temptation to connect the ganglia by flux tubes to form these lines so that one would have a grid lines of ganglia analogous to a the radial lines of a coordinate grid of cylindrical coordinates with origin at the centre of retina. Peripheral regions would correspond to a poorer resolution if this is the case. Maybe macroscopic quantum coherence would enter the stage here and allow to bind the percepts about spots to a percept about line.

Of, course this idea is just a first guess reflecting my deep ignorance about how visual representations are formed, and certainly the details, if not the whole idea, are wrong.

9.7 TGD Based Models For Cell Membrane As Sensory Receptor

The emergence of zero energy ontology, the explanation of dark matter in terms of a hierarchy of Planck constants requiring a generalization of the notion of embedding space, the view about life as something in the intersection of real and p-adic worlds, and the notion of number theoretic entanglement negentropy lead to the breakthrough in TGD inspired quantum biology and also to the a view of qualia and sensory representations including hearing.

One of the basic challenge has been to construct a quantitative model for cell membrane.

1. The first model was based on the assumption that long range weak forces however play a key role [K12]. They are made possible by the exotic ground state represented as almost vacuum extremal of Kähler action for which classical em and Z^0 fields are proportional to each other whereas for the standard ground state classical Z^0 fields are very weak. Neutrinos are present but it seems that they do not define cognitive or Boolean representations in the time scales characterizing neural activity. Electrons and quarks for which the time scales of causal diamonds correspond to fundamental biorhythms - one of the key observations during last years- take this role. The essential element is that the energies of the Josephson photons are in visible range. This would explain bio-photons and even why the frequencies assignable to visual receptors. Skeptic can of course argue that the energies at which receptors are most sensititive to incoming light need not have anything to do with the Josephson frequencies. Skeptic might be right but it is interesting to see if this hypothesis might work.

   A possible problem is that Weinberg angle must be assumed to be much smaller in the near vacuum extremal phase than in standard model if one wants to explain the photon

energies at which color receptors have maximum absorption assuming *same voltage* over the Josepshon junction defined by the receptor protein. A way out of problem is to assume that the voltage through the transmembrane protein depends on the ion (Na^+, K^+, Cl^- or Ca^{++}) characterizing the color receptor and is therefore different for the color receptors.

2. Second model is based on Gerald Pollack's findings about the fourth phase of water and exclusion zones [L31]. These zones inspire a model for pre-biotic cells. The outcome is a modification of the simplest model of Josephson junction. Besides resting potential also the difference between cyclotron energies between the two sides of the membrane plays a key role. This model allows to understand what happens in metabolism in terms of a quantum model replacing the thermodynamical model for cell membrane with its quantal "square root" inspired by Zero Energy Ontology. The model allows also to understand bio-photons as decay products of dark photons.

3. The success of the latter model does not of course mean that the weak forces could not be important in cell membrane scale and the realistic model could be a hybrid of these two models. The inclusion of Z^0 contribution to the effective magnetic field could also to the fact that the endogenous magnetic field deduced from Blackman's experiments is $B_{end} = 2B_E/5$ rather than B_E (Earth's magnetic field).

9.7.1 Could Cell Correspond To Almost Vacuum Extremal?

The question whether cell could correspond almost vacuum extremal of Kähler action was the question which led to the realization that the frequencies of peak sensitivity for photoreceptors correspond to the Josephson frequencies of biologically important ions if one accepts that the value of the Weinberg angle equals to $sin^2(\theta_W) = .0295$ instead of the value.23 in the normal phase, in which the classical electromagnetic field is proportional to the induced Kähler form of CP_2 in a good approximation. The assumption about the value of Weinberg angle can be used as the basic objection against the model. Another implication made possible by the large value of Planck constant is the identification of Josephson photons as the counterparts of bio-photons one one hand and those of EEG photons on the other hand. These observation in turn led to a detailed model of sensory qualia and of sensory receptor. Therefore the core of this argument deserves to be represented also here although it has been discussed in [K97].

Cell membrane as almost vacuum extremal

Although the fundamental role of vacuum extremals for quantum criticality and life has been obvious from the beginning, it took a long time to realize how one could model living cell as this kind of system.

1. Classical electric fields are in a fundamental role in biochemistry and living biosystems are typically electrets containing regions of spontaneous electric polarization. Fröhlich [I44] proposed that oriented electric dipoles form macroscopic quantum systems with polarization density serving as a macroscopic order parameter. Several theories of consciousness share this hypothesis. Experimentally this hypothesis has not been verified.

2. TGD suggests much more profound role for the unique di-electric properties of the biosystems. The presence of strong electric dipole fields is a necessary prerequisite for cognition and life and could even force the emergence of life. Strong electric fields imply also the presence of the charged wormhole BE condensates: the surface density of the charged wormholes on the boundary is essentially equal to the normal component of the electric field so that wormholes are in some sense "square root" of the dipole condensate of Fröhlich! Wormholes make also possible pure vacuum polarization type dipole fields: in this case the magnitudes of the em field at the two space-time sheets involved are same whereas the directions of the fields are opposite. The splitting of wormhole contacts creates fermion pairs which might be interpreted as cognitive fermion pairs. Also microtubules carry strong longitudinal electric fields.

   This formulation emerged much before the identification of ordinary gauge bosons and their superpartners as wormhole contacts. In the recent view about TGD based on the weak

form of electric-magnetic duality wormhole magnetic flux tubes having magnetically charged wormhole throats at their ends could be interpreted as scaled up variants of elementary particles having a large value of Planck constant.

Cell membrane is the basic example about electret and one of the basic mysteries of cell biology is the resting potential of the living cell. Living cell membranes carry huge electric fields: something like 10^7 Volts per meter. For neuron resting potential corresponds to about.07 eV energy gained when unit charge travels through the membrane potential. In TGD framework it is not at all clear whether the presence of strong electromagnetic field necessitates the presence of strong Kähler field. The extremely strong electric field associated with the cell membrane is not easily understood in Maxwell's theory and almost vacuum extremal property could change the situation completely in TGD framework.

1. The configuration could be a small deformation of vacuum extremal so that the system would be highly critical as one indeed expects on basis of the general vision about living matter as a quantum critical system. For vacuum extremals classical em and Z^0 fields would be proportional to each other. The second half of Maxwell's equations is not in general satisfied in TGD Universe and one cannot exclude the presence of vacuum charge densities in which case elementary particles as the sources of the field would not be necessarily. If one assumes that this is the case approximately, the presence of Z^0 charges creating the classical Z^0 fields is implied. Neutrinos are the most candidates for the carrier of Z^0 charge. Also nuclei could feed their weak gauge fluxes to almost non-vacuum extremals but not atomic electrons since this would lead to dramatic deviations from atomic physics. This would mean that weak bosons would be light in this phase and also Weinberg angle could have a non-standard value.

2. There are also space-time surfaces for CP_2 projection belongs to homologically non-trivial geodesic sphere. In this case classical Z^0 field can vanish and the vision has been that it is sensible to speak about two basic configurations.

   (a) Almost vacuum extremals (homologically trivial geodesic sphere).

   (b) Small deformations of non-vacuum extremals for which the gauge field has pure gauge Z^0 component (homologically non-trivial geodesic sphere).

   The latter space-time surfaces are excellent candidates for configurations identifiable as TGD counterparts of standard electroweak physics. Note however that the charged part of electroweak fields is present for them.

3. To see whether the latter configurations are really possible one must understand how the gauge fields are affected in the color rotation.

   (a) The action of color rotations in the holonomy algebra of CP_2 is non-trivial and corresponds to the action in $U(2)$ sub-group of $SU(3)$ mapped to $SU(2)_L \times U(1)$. Since the induced color gauge field is proportional to Kähler form, the holonomy is necessary Abelian so that also the representation of color rotations as a sub-group of electro-weak group must correspond to a local $U(1)$ sub-group local with respect to CP_2 point.

   (b) Kähler form remains certainly invariant under color group and the right handed part of Z^0 field reducing to $U(1)_R$ sub-algebra should experience a mere Abelian gauge transformation. Also the left handed part of weak fields should experience a local $U(1)_L$ gauge rotation acting on the neutral left handed part of Z^0 in the same manner as it acts on the right handed part. This is true if the $U(1)_L$ sub-group does not depend on point of CP_2 and corresponds to Z^0 charge. If only Z^0 part of the induced gauge field is non-vanishing as it can be for vacuum extremals then color rotations cannot change the situation. If Z^0 part vanishes and non-vacuum extremal is in question, then color rotation rotation of W components mixing them but acts as a pure $U(1)$ gauge transformation on the left handed component.

(c) It might not be without importance that for any partonic 2-surface induced electroweak gauge fields have always U(1) holonomy, which could allow to define what neutral part of induced electroweak gauge field means locally. This does not however hold true for the 4-D tangent space distribution. In any case, the cautious conclusion is that there are two phases corresponding to nearly vacuum extremals and small deformations of extremals corresponding to homologically non-trivial geodesic spheres for which the neutral part of the classical electro-weak gauge field reduces to photon field.

4. The unavoidable presence of long range Z^0 fields would explain large parity breaking in living matter, and the fact that neutrino Compton length is of the order of cell size would suggest the possibility that within neutrino Compton electro-weak gauge fields or even longer scales could behave like massless fields. The explanation would be in terms of the different ground state characterized also by a different value of Weinberg angle. For instance, of the p-adic temperature of weak bosons corresponds to $T_p = 1/2$, the mass scale would be multiplied by a factor $\sqrt{M_{89}}$ and Compton lengths of weak bosons would be around 10^{-4} meters corresponding to the size scale of a large neuron. If the value of Planck constant is also large then the Compton length increases to astrophysical scale.

5. From the equations for classical induced gauge fields in terms of Kähler form and classical Z^0 field (see the appendix of any of the books about TGD)

$$\gamma = 3J - \frac{p}{2}Z^0 \quad , \quad Q_Z = I_L^3 - pQ_{em} \quad , \quad p = sin^2(\theta_W) \tag{9.7.1}$$

it follows that for the vacuum extremals the part of the classical electro-weak force proportional to the electromagnetic charge vanishes for $p = 0$ so that only the left-handed couplings to the weak gauge bosons remain. The absence of electroweak symmetry breaking and vanishing or at least smallness of p would make sense below the Compton length of dark weak bosons. If this picture makes sense it has also implications for astrophysics and cosmology since small deformations of vacuum extremals are assumed to define the interesting extremals. Dark matter hierarchy might explain the presence of unavoidable long ranged Z^0 fields as being due to dark matter with arbitrarily large values of Planck constant so that various elementary particle Compton lengths are very long.

6. The simplest option is that the dark matter -say quarks with Compton lengths of order cell size and Planck constant of order $10^7\hbar_0$ - are responsible for dark weak fields making almost vacuum extremal property possible. The condition that Josephson photons correspond to EEG frequencies implies $\hbar \sim 10^{13}\hbar_0$ and would mean the scaling of intermediate gauge boson Compton length to that corresponding to the size scale of a larger neuron. The quarks involved with with DNA as topological quantum computer model could be in question and membrane potential might be assignable to the magnetic flux tubes. The ordinary ionic currents through cell membrane -having no coupling to classical Z^0 fields and not acting as its source- would be accompanied by compensating currents of dark fermions taking care that the almost vacuum extremal property is preserved. The outcome would be large parity breaking effects in cell scale from the left handed couplings of dark quarks and leptons to the classical Z^0 field. The flow of Na^+ ions during nerve pulse could take along same dark flux tube as the flow of dark quarks and leptons. This near vacuum extremal property might be fundamental property of living matter at dark space-time sheets at least.

Ionic Josephson frequencies defined by the resting potential for nearly vacuum extremals

If cell membrane corresponds to an almost vacuum extremal, the membrane potential potential is replaced with an effective restoring potential containing also the Z^0 contribution proportional to the ordinary resting potential. The surprising outcome is that one could understand the preferred frequencies for photo-receptors [J22] as Josephson frequencies for biologically important ions. Furthermore, most Josephson energies are in visible and UV range and the interpretation in terms of

$E(Ion)/eV$	$V = -40\ mV$	$V = -60\ mV$	$V = -70\ mV$
Na^+	1.01	1.51	1.76
Cl^-	1.40	2.11	2.46
K^+	1.64	2.47	2.88
Ca^{+2}	1.68	2.52	2.94

Table 9.1: Values of the Josephson energy of cell membrane for some values of the membrane voltage for $p = .23$. The value $V = -40$ mV corresponds to the resting state for photoreceptors and $V = -70$ mV to the resting state of a typical neuron.

bio-photons is suggestive. If the value of Planck constant is large enough Josephson frequencies are in EEG frequency range so that bio-photons and EEG photons could be both related to Josephson photons with large $\hbar$.

1. One must assume that the interior of the cell corresponds to many fermion state -either a state filled with neutrinos up to Fermi energy or Bose-Einstein condensate of neutrino Cooper pairs creating a harmonic oscillator potential. The generalization of nuclear harmonic oscillator model so that it applies to multi-neutrino state looks natural.

2. For exact vacuum extremals elementary fermions couple only via left-handed isospin to the classical Z^0 field whereas the coupling to classical em field vanishes. Both K_+, Na_+, and Cl_- $A - Z = Z + 1$ so that by p-n pairing inside nucleus they have the weak isospin of neuron (opposite to that of neutrino) whereas Ca_{++} nucleus has a vanishing weak isospin. This might relate to the very special role of Ca_{++} ions in biology. For instance, Ca_{++} defines an action potential lasting a time of order.1 seconds whereas Na_+ defines a pulse lasting for about 1 millisecond [J4]. These time scales might relate to the time scales of CDs associated with quarks and electron.

3. The basic question is whether only nuclei couple to the classical Z^0 field or whether also electrons do so. If not, then nuclei have a large effective vector coupling to em field coming from Z^0 coupling proportional to the nuclear charge increasing the value of effective membrane potential by a factor of order 100. If both electrons and nuclei couple to the classical Z^0 field, one ends up with difficulties with atomic physics. If only quarks couple to the Z^0 field and one has $Z^0 = -2\gamma/p$ for vacuum extremals, and one uses average vectorial coupling $\langle I_L^3 \rangle = \pm 1/4$ with + for proton and - for neutron, the resulting vector coupling is following

$$\begin{aligned} (\frac{Z-N}{4} - pZ)Z^0 + q_{em}\gamma &= Q_{eff}\gamma \ , \\ Q_{eff} &= -\frac{Z-N}{2p} + 2Z + q_{em} \ . \end{aligned} \tag{9.7.2}$$

Here γ denotes em gauge potential. For K^+, Cl^-, Na^+, Ca^{++} one has $Z = (19, 17, 11, 20)$, $Z - N = (-1, -1, -1, 0)$, and $q_{em} = (1, -1, 1, 2)$. **Table 9.1** below gives the values of Josephson energies for some values of resting potential for $p = .23$. Rather remarkably, they are in IR or visible range.

Are photoreceptors nearly vacuum extremals?

In Hodgkin-Huxley model ionic currents are Ohmian currents. If one accepts the idea that the cell membrane acts as a Josephson junction, there are also non-dissipative oscillatory Josephson currents of ions present, which run also during flow equilibrium for the ionic parts of the currents. A more radical possibility is that the dominating parts of the ionic currents are oscillatory Josephson currents so that no metabolic energy would be needed to take care that density gradients for ions are preserved. Also in this case both nearly vacuum extremals and extremals with nearly vanishing

Z^0 field can be considered. Since sensory receptors must be highly critical the natural question is whether they could correspond to nearly vacuum extremals. The quantitative success of the following model for photoreceptors supports this idea.

Photoreceptors can be classified to three kinds of cones responsible for color vision and rods responsible for black-white vision. The peak sensitivities of cones correspond to wavelengths (405, 535, 565) nm and energies (3.06, 2.32, 2.19) eV. The maximum absorption occurs in the wave length range 420-440 nm, 534-545 nm, 564-580 nm for cones responsible for color vision and 498 nm for rods responsible black-white vision [J22, L83]. The corresponding photon energies are (2.95, 2.32, 2.20) eV for color vision and to 2.49 eV for black-white vision. For frequency distribution the maxima are shifted from these since the maximum condition becomes $dI/d\lambda + 2I/\lambda = 0$, which means a shift to a larger value of λ, which is largest for smallest λ. Hence the energies for maximum absorbance are actually lower and the downwards shift is largest for the highest energy.

From **Table 9.1** it is clear that the energies of Josephson photons are in visible range for reasonable values of membrane voltages, which raises the question whether Josephson currents of nuclei in the classical em and Z^0 fields of the cell membrane could relate to vision.

Consider first the construction of the model.

1. Na^+ and Ca^{++} currents are known to present during the activation of the photoreceptors. Na^+ current defines the so called dark current [J22] reducing the membrane resting potential below its normal value and might relate to the sensation of darkness as eyes are closed. Hodgkin-Huxley model predicts that also K^+ current is present. Therefore the Josephson energies of these three ion currents are the most plausible correlates for the three colors.

2. One ends up with the model in the following manner. For Ca^{++} the Josephson frequency does not depend on p and requiring that this energy corresponds to the energy 2.32 eV of maximal sensitivity for cones sensitive to green light fixes the value of the membrane potential during hyper-polarization to $V = .055$ V, which is quite reasonable value. The value of the Weinberg angle parameter can be fixed from the condition that other peak energies are reproduced optimally. The result of $p = .0295$.

The predictions of the model come as follows summarized also by the **Table 9.2** below.

1. The resting potential for photoreceptors is $V = -40$ mV [J24]. In this case all Josephson energies are below the range of visible frequencies for $p = .23$. Also for maximal hyper-polarization Na^+ Josephson energy is below the visible range for this value of Weinberg angle.

2. For $V = -40$ mV and $p = .0295$ required by the model the energies of Cl^- and K^+ Josephson photons correspond to red light. 2 eV for Cl^- corresponds to a basic metabolic quantum. For Na^+ and Ca^{++} the wave length is below the visible range. Na^+ Josephson energy is below visible range. This would conform with the interpretation of Na^+ current as a counterpart for the sensation of darkness.

3. For $V = -55$ mV - the threshold for the nerve pulse generation- and for $p = .0295$ the Josephson energies of Na^+, Ca^{++}, and K^+ a correspond to the peak energies for cones sensitive to red, green, and blue respectively. Also Cl^- is in the blue region. Ca^{++} Josephson energy can be identified as the peak energy for rods. The increase of the hyper-polarization to $V = -59$ mV reproduces the energy of the maximal wave length response exactly. A possible interpretation is that around the criticality for the generation of the action potential ($V \simeq -55$ mV) the qualia would be generated most intensely since the Josephson currents would be strongest and induce Josephson radiation inducing the quale in other neurons of the visual pathway at the verge for the generation of action potential. This supports the earlier idea that visual pathways defines a neural window. Josephson radiation could be interpreted as giving rise to bio-photons (energy scale is correct) and to EEG photons (for large enough values of $\hbar$ the frequency scales is that of EEG).

4. In a very bright illumination the hyper-polarization is $V = -65$ mV [J24], which the normal value of resting potential. For this voltage Josephson energies are predicted to be in UV region except in case of Ca^{++}. This would suggests that only the quale "white" is generated at the level of sensory receptor: very intense light is indeed experienced as white.

Ion	Na^+	Cl^-	K^+	Ca^{+2}
$E_J(.04\ \ mV, p = .23)/eV$	1.01	1.40	1.51	1.76
$E_J(.065\ \ V, p = .23)/eV$	1.64	2.29	2.69	2.73
$E_J(40\ \ mV, p = .0295)/eV$	1.60	2.00	2.23	1.68
$E_J(50\ \ mV, p = .0295)/eV$	2.00	2.49	2.79	2.10
$E_J(55\ \ mV, p = .0295)/eV$	2.20	2.74	3.07	2.31
$E_J(65\ \ mV, p = .0295)/eV$	2.60	3.25	3.64	2.73
$E_J(70\ \ mV, p = .0295)/eV$	2.80	3.50	3.92	2.94
$E_J(75\ \ mV, p = .0295)/eV$	3.00	3.75	4.20	3.15
$E_J(80\ \ mV, p = .0295)/eV$	3.20	4.00	4.48	3.36
$E_J(90\ \ mV, p = .0295)/eV$	3.60	4.50	5.04	3.78
$E_J(95\ \ mV, p = .0295)/eV$	3.80	4.75	5.32	3.99
Color	R	G	B	W
E_{max}	2.19	2.32	3.06	2.49
energy-interval/eV	1.77-2.48	1.97-2.76	2.48-3.10	

Table 9.2: Table gives the prediction of the model of photoreceptor for the Josephson energies for typical values of the membrane potential. For comparison purposes the energies E_{max} corresponding to peak sensitivities of rods and cones, and absorption ranges for rods are also given. R, G, B, W refers to red, green, blue, white. The values of Weinberg angle parameter $p = sin^2(\theta_W)$ are assumed to be .23 and.0295. The latter value is forced by the fit of Josephson energies to the known peak energies.

The model reproduces basic facts about vision assuming that one accepts the small value of Weinberg angle, which is indeed a natural assumption since vacuum extremals are analogous to the unstable extrema of Higgs potential and should correspond to small Weinberg angle. It deserves to be noticed that neutrino Josephson energy is 2 eV for $V = -50$ mV, which correspond to color red. 2 eV energy defines an important metabolic quantum.

It interesting to try to interpret the resting potentials of various cells in this framework in terms of the Josephson frequencies of various ions.

1. The maximum value of the action potential is +40 mV so that Josephson frequencies are same as for the resting state of photoreceptor. Note that the time scale for nerve pulse is so slow as compared to the frequency of visible photons that one can consider that the neuronal membrane is in a state analogous to that of a photoreceptor.

2. For neurons the value of the resting potential is -70 mV. Na^+ and Ca^{++} Josephson energies 2.80 eV and 2.94 eV are in the visible range in this case and correspond to blue light. This does not mean that Ca^{++} Josephson currents are present and generate sensation of blue at neuronal level: the quale possibly generated should depend on sensory pathway. During the hyper-polarization period with -75 mV the situation is not considerably different.

3. The value of the resting potential is -95 mV for skeletal muscle cells. In this case Ca^{++} Josephson frequency corresponds to 4 eV metabolic energy quantum as**Table 9.1** shows.

4. For smooth muscle cells the value of resting potential is -50 mV. In this case Na^+ Josephson frequency corresponds to 2 eV metabolic energy quantum.

5. For astroglia the value of the resting potential is -80/-90 mV for astroglia. For -80 mV the resting potential for Cl^- corresponds to 4 eV metabolic energy quantum. This suggests that glial cells could also provide metabolic energy as Josephson radiation to neurons.

6. For all other neurons except photo-receptors and red blood cells Josephson photons are in visible and UV range and the natural interpretation would be as bio-photons. The bio-photons detected outside body could represent sensory leakage. An interesting question is whether the IR Josephson frequencies could make possible some kind of IR vision.

The basic criticism against the model is that the value of Weinberg angle must be by a factor of 1/10 smaller than the standard model value, and at this moment it is difficult to say anything about its value for nearly vacuum extremals.

A possible cure could be that the voltage is not same for different ions. This is possible since at microscopic level the Josephson junctions correspond to transmembrane proteins acting as channels and pumps. The membrane potential through receptor protein is different for color receptors. For this option one would have the correspondences
$Na^+ \leftrightarrow$ 2.19 eV (R) and $eV = 86.8$ eV,
$Cl^- \leftrightarrow$ 2.32 eV (G) and $eV = 65.8$ eV,
$K^+ \leftrightarrow$ 2.49 eV (W) and $eV = 60.2$ eV,
$Ca^{++} \leftrightarrow$ 3.06 eV (B) and $eV = 67.3$ meV.
For Na^+ the value of the membrane potential is suspiciously large.

It is interesting to look what happens when the model is generalized so that Josephson energy includes the difference of cyclotron energies at the two sides of the cell membrane and Weinberg angle has its standard model value.

1. Consider first *near to vacuum extremals*. In the formula for cyclotron frequencies in the effective magnetic field the factor Z/A in the formula of is replaced with

$$\frac{\frac{N-Z}{2p} + 2Z + q_{em}}{A} \ ,$$

   which is not far from unity so that the cyclotron frequency would be near to that for proton for all ions. Also neutral atoms would experience classical and magnetic Z^0 fields. Cyclotron frequency would be almost particle independent so that cyclotron contribution gives an almost constant shift to the generalized Josephson energy. When the difference of cyclotron energies vanishes, the model reduces to that discussed above.

   The weak independence of the cyclotron frequency on particle properties does not conform with the idea that EEG bands correspond to bosonic ions or Cooper pairs of fermionic ions.

2. For *far from vacuum extremals* the proportionality of cyclotron energy to h_{eff} and B_{end} allows easy reproduction the energies for which photon absorption is maximal if one allows the cyclotron energies to differ at the two sides of the membrane for sensory receptors.

9.7.2 Pollack's Findings About Fourth Phase Of Water And The Model Of Cell

The discovery of negatively charged exclusion zone formed in water bounded by gel phase has led Pollack to propose the notion of gel like fourth phase of water. In this article this notion is discussed in TGD framework. The proposal is that the fourth phase corresponds to negatively charged regions - exclusion zones - with size up to 100-200 microns generated when energy is fed into the water - say as radiation, in particular solar radiation. The stoichiometry of the exclusion zone is $H_{1.5}O$ and can be understood if every fourth proton is dark proton residing at the flux tubes of the magnetic body assignable to the exclusion zone and outside it.

This leads to a model for prebiotic cell as exclusion zone. Dark protons are proposed to form dark nuclei whose states can be grouped to groups corresponding to DNA, RNA, amino-acids, and tRNA and for which vertebrate genetic code is realized in a natural manner. The voltage associated with the system defines the analog of membrane potential, and serves as a source of metabolic energy as in the case of ordinary metabolism. The energy is liberated in a reverse phase transition in which dark protons transform to ordinary ones. Dark proton strings serve as analogs of basic biopolymers and one can imagine analog of bio-catalysis with enzymes replaced with their dark analogs. The recent discovery that metabolic cycles emerge spontaneously in absence of cell support this view.

One can find a biographical sketch [I16] (`http://tinyurl.com/ycqtuchp`) giving a list of publications containing items related to the notions of exclusion zone and fourth phase of water discussed in the talk.

Pollack's findings

I list below some basic experimental findings about fourth gel like phase of water made in the laboratory led by Gerald Pollack [L31].

1. In water bounded by a gel a layer of thickness up to 100-200 microns is formed. All impurities in this layer are taken outside the layer. This motivates the term "exclusion zone". The layer consists of layers of molecular thickness and in these layers the stoichiometry is $H_{1.5}O$. The layer is negatively charged. The outside region carries compensating positive charge. This kind of blobs are formed in living matter. Also in the splitting of water producing Brown's gas negatively charged regions are reported to emerge [H3, H1].

2. The process requires energy and irradiation by visible light or thermal radiation generates the layer. Even the radiation on skin can induce the phase transition. For instance, the blood flow in narrow surface veins requires metabolic energy and irradiation forces the blood to flow.

3. The layer can serve as a battery: Pollack talks about a form of free energy deriving basically from solar radiation. The particles in the layer are taken to the outside region, and this makes possible disinfection and separation of salt from sea water. One can even understand how clouds are formed and mysteries related to the surface tension of water as being due the presence of the layer formed by $H_{1.5}O$.

4. In the splitting of water producing Brown's gas [H3, H1] having a natural identification as Pollack's fourth phase of water the needed energy can come from several alternative sources: cavitation, electric field, etc...

Dark nuclei and Pollack's findings

While listening the lecture of Pollack I realized that a model for dark water in term of dark proton sequences is enough to explain the properties of the exotic water according to experiments done in the laboratory of Pollack. There is no need to assume sequences of half-dark water molecules containing one dark proton each.

1. Model for the formation of exclusion zones

The data about formation of exclusion zones allows to construct a more detailed model for what might happen in the formation of exclusion zones.

1. The dark proton sequences with dark proton having size of order atomic nucleus would reside at the flux tubes of dark magnetic field which is dipole like field in the first approximation and defines the magnetic body of the negatively charged water blob. This explains the charge separation if the flux tubes have length considerably longer than the size scale of the blob which is given by size of small cell. In the model inspired by Moray B. King's lectures charge separation is poorly understood.

2. An interesting question is whether the magnetic body is created by the electronic currents or whether it consists of flux tubes carrying monopole flux: in the latter case no currents would be needed. This is obviously purely TGD based possibility and due to the topology of CP_2.

3. This means that in the model inspired by the lectures of Moray B. King discussed above, one just replaces the sequences of partially dark water molecules with sequences of dark protons at the magnetic body of the $H1.5O$ blob. The model for the proto-variants of photosynthesis and metabolism remain as such. Also now genetic code would be realized [K53, L3].

4. The transfer of impurities from the exclusion zone could be interpreted as a transfer of them to the magnetic flux tubes outside the exclusion zone as dark matter.

These primitive forms of photosynthesis and metabolism form could be key parts of their higher level chemical variants. Photosynthesis by irradiation would induce a phase transition generating dark magnetic flux tubes (or transforming ordinary flux tubes to dark ones) and the

dark proton sequences at them. Metabolism would mean burning of the resulting blobs of dark water to ordinary water leading to the loss of charge separation. This process would be analogous to the catabolism of organic polymers liberating energy. Also organic polymers in living matter carry their metabolic energy as dark proton sequences: the layer could also prevent their hydration. That these molecules are typically negatively charged would conform with the idea that dark protons at magnetic flux tubes carry the metabolic energy.

The liberation of energy would involve increase of the p-adic prime characterizing the flux tubes and reduction of Planck constant so that the thickness of the flux tubes remains the same but the intensity of the magnetic field is reduced. The cyclotron energy of dark protons is liberated in coherent fashion and in good approximation the frequencies of the radiation corresponds to multiplies of cyclotron frequency: this prediction is consistent with that in the original model for the findings of Blackman and others [J57].

The phase transition generating dark magnetic flux tubes containing dark proton sequences would be the fundamental step transforming inanimate matter to living matter and the fundamental purpose of metabolism would be to make this possible.

2. Minimal metabolic energy consumption and the value of membrane potential

This picture raises a question relating to the possible problems with physiological temperature.

1. The Josephson radiation generated by cell membrane has photon energies coming as multiples of ZeV, where V is membrane potential about.06 V and $Z = 2$ is the charge of electron Cooper pair. This gives $E = .12$ eV.

2. There is a danger that thermal radiation masks Josephson radiation. The energy for photons at the maximum of the energy density of blackbody radiation as function of frequency is given as the maximum of function $x^3/(e^x - 1)$, $x = E/T$ given by $e^{-x} + x/3 - 1 = 0$. The maximum is given approximately by $x = 3$ and thus $E_{max} \simeq 3T$ (in units $c = 1, k_B = 1$). At physiological temperature $T = 310$ K (37 C) this gives .1 eV, which is slightly below Josephson energy: living matter seems to have minimized the value of Josephson energy - presumably to minimize metabolic costs. Note however that for the thermal energy density as function of *wavelength* the maximum is at $E \simeq 5T$ corresponding to 1.55 eV which is larger than Josephson energy. The situation is clearly critical.

3. One can ask whether also a local reduction of temperature around cell membrane in the fourth phase of water is needed.

   "Electric expansion" of water giving rise to charge separation and presumably creating fourth phase of water is reported to occur [H3, H1].

   (b) Could the electric expansion/phase transition to dark phase be adiabatic involving therefore no heat transfer between the expanding water and environment? If so, it would transform some thermal energy of expanding water to work and reduce its temperature. The formula for the adiabatic expansion of ideal gas with f degrees of freedom for particle ($f = 3$ if there are no other than translational degrees of freedom) is $(T/T_0) = (V/V_0)^{-\gamma}$, $\gamma = (f + 2)/f$. This gives some idea about how large reduction of temperature might be involved. If p-adic scaling for water volume by a power of two takes place, the reduction of temperature can be quite large and it does not look realistic.

   (c) The electric expansion of water need not however involve the increase of Planck constant for water volume. Only the Planck constant for flux tubes must increase and would allow the formation of dark proton sequences and the generation of cyclotron Bose-Einstein condensates or their dark analog in which fermions (electrons in particular) effectively behave as bosons (the anti-symmetrization of wave function would occur in dark degrees of freedom corresponding to multi-sheeted covering formed in the process).

Fourth phase of water and pre-biotic life in TGD Universe

If the fourth phase of water defines pre-biotic life form then the phase transition generating fourth phase of water and its reversal are expected to be fundamental elements of the ordinary metabolism, which would have developed from the pre-biotic metabolism. The following arguments conforms with this expectation.

1. Metabolism and fourth phase of water

1. Cell interiors, in particular the interior of the inner mitochondrial membrane are negatively charged as the regions formed in Pollack's experiments. Furthermore, the citric acid cycle, (`http://tinyurl.com/y8ubjgnc`), which forms the basic element of both photosynthesis (`http://tinyurl.com/yauwzkho`) and cellular respiration `http://tinyurl.com/ybeefxmb`, involves electron transport chain (`http://tinyurl.com/yat3m4vk`) in which electron loses gradually its energy via production of NADP and proton at given step. Protons are pumped to the other side of the membrane and generates proton gradient serving as metabolic energy storage just like battery. The interpretation for the electron transport chain in terms of Pollack's experiment would be in terms of generation of dark protons at the other side of the membrane.

2. When ATP is generated from ADP three protons per ATP flow back along the channel formed by the ATP synthase molecule (`http://tinyurl.com/yd5ndcyk`) (perhaps Josephson junction) and rotate the shaft of a "motor" acting as a catalyst generating three ATP molecules per turn by phosphorylating ADP. The TGD based interpretation is that dark protons are transformed back to ordinary ones and possible negentropic entanglement is lost.

3. ATP is generated also in glycolysis (`http://tinyurl.com/ybzgdgve`), which is ten-step process occurring in cytosol so that membrane like structure need not be involved. Glycolysis involves also generation of two NADH molecules and protons. An open question (to me) is whether the protons are transferred through an endoplasmic reticulum or from a region of ordered water (fourth phase of water) to its exterior so that it would contribute to potential gradient and could go to magnetic flux tubes as dark proton. This would be natural since glycolysis is realized for nearly all organisms and electron transport chain is preceded by glycolysis and uses as input the output of glycolysis (two pyruvate molecules (`http://tinyurl.com/y8v7aq9s`)).

4. Biopolymers - including DNA and ATP - are typically negatively charged. They could thus be surrounded by fourth phase of water and neutralizing protons would reside at the magnetic bodies. This kind of picture would conform with the idea that the fourth phase (as also magnetic body) is fractal like. In phosphorylation the metabolic energy stored to a potential difference is transferred to shorter length scales (from cell membrane scale to molecular scale).

In glycolysis (`http://tinyurl.com/ybzgdgve`) the net reaction $C_6H_{12}O_6+6O_2 \rightarrow 6CO_2(g)+6H_2O(l)+heat$ takes place. The Gibbs free energy change is $\Delta G = -2880$ kJ per mole of $C_6H_{12}O_6$ and is negative so that the process takes place spontaneously. Single glucose molecule is theoretized to produce $N = 38$ ATP molecules in optimal situation but there are various energy losses involved and the actual value is estimated to be 29-30. From $Joule = 6.84 \times 10^{18}$ eV and $mol = 6.02 \times 10^{23}$ and for $N = 38$ one would obtain the energy yield.86 eV per single ATP. The nominal value that I have used.5 eV. This is roughly 5 to 8 times higher than $E = ZeV, Z = 2$, which varies in the range.1-.16 eV so that the metabolic energy gain cannot be solely due to the electrostatic energy which would actually give only a small contribution.

In the thermodynamical approach to metabolism the additional contribution would be due to the difference of the chemical potential μ for cell exterior and interior, which is added to the membrane potential as effective potential energy. The discrepancy is however rather large and this forces the question the feasibility of the model. This forces to reconsider the model of osmosis in the light of Pollack's findings.

2. Pollack's findings in relation to osmosis and model for cell membrane and EEG

Osmosis (http://tinyurl.com/yc5dbtzv) has remained to me poorly understood phenomenon. Osmosis means that solvent molecules move through a semipermeable membrane to another side of the membrane if the concentration of solute is higher at that side. Solute can be water or more general liquid, supercritical liquid, and even gas.

Osmosis is not diffusion: it can occur also towards a higher concentration of water. Water molecules are not attracted by solute molecules. A force is required and the Wikipedia explanation is that solute molecules approaching pores from outside experience repulsion and gain momentum which is transferred to the water molecules.

The findings of Pollack inspire the question whether the formation of exclusion zone could relate to osmosis and be understood in terms of the fourth phase of water using genuine quantal description.

In the thermodynamical model for ionic concentrations one adds to the membrane resting potential a contribution from the difference of chemical potentials μ_i at the two sides of the membrane. Chemical potentials for the ions parametrize the properties of the cell membrane reducing basically to the properties of the channels and pumps (free diffusion and membrane potential do not entirely determine the outcome).

If the transfer of ions - now protons - through cell membrane is quantal process and through Josephson junctions defined by transmembrane proteins, then the thermodynamical model can at best be a phenomenological parameterization of the situation. One should find the quantum counterpart of thermodynamical description, and here the identification of quantum TGD as square root of thermodynamics in Zero Energy Ontology (ZEO) suggests itself. In this approach thermodynamical distributions are replaced by probability amplitudes at single particle level such that their moduli squared give Boltzmann weights.

1. Simplest Josephson junction model for cell membrane

The first guess is that quantum description is achieved by a generalization of the Josephson junction model allowing different values of Planck constant at magnetic flux tubes carrying dark matter.

1. Josephson junctions correspond microscopically to transmembrane proteins defining channels and pumps. In rougher description entire cell membrane is described as Josephson junction.

2. The magnetic field strength at flux tube can differ at the opposite side of the membrane and even the values of h_{eff} could in principle be different. The earlier modelling attempts suggest that $h_{eff}/h = n = 2^k A$, where A is the atomic weight of ion, is a starting assumption deserving testing. This would mean that each ion resides at its own flux tubes.

   The phase transitions changing the value of h_{eff} could induce ionic flows through cell membrane, say that occurring during nerve pulse since the energy difference defining the ratio of square roots of Boltzmann weights at the two sides of the membrane would change. Also the change of the local value of the magnetic field could do the same.

Consider first the simplest model taking into account only membrane potential.

1. The simplest model for Josephson junction defined by the transmembrane protein is as a two state system (Ψ_1, Ψ_2) obeying Schrödinger equation.

$$i\hbar_1 \frac{\partial \Psi_1}{\partial t} = ZeV\Psi_1 + k_1\Psi_2 \ ,$$

$$i\hbar_2 \frac{\partial \Psi_2}{\partial t} = k_2\Psi_2 \ .$$

   One can use the decomposition $\Psi_i = R_i exp(i\Phi(t)$ to express the equations in a more concrete form. The basic condition is that the total probability defined as sum of moduli squared equals to one: $R_1^2 + R_2^2 = 1$. This is guaranteed if the hermiticity condition $k_1/\hbar_1 = \overline{k_2}\hbar_2$ holds true. Equations reduce to those for an ordinary Josephson junction except that the frequency for the oscillating Josephson current is scaled down by $1/h_{eff}$.

2. One can solve for R_2 assuming $\Phi_1 = eVt/\hbar_{eff}$. This gives

$$R_2(t) = sin(\Phi_0) + \frac{k_1}{\hbar_1} sin(\frac{eVt}{\hbar_1}) \ .$$

R_2 oscillates around $sin(\Phi_0)$ and the concentration difference is coded by $\Phi 0$ taking the role of chemical potential as a phenomenological parameter.

3. The counterparts of Boltzmann weights would be apart from a phase factor square roots of ordinary Boltzmann weights defined by the exponent of Coulomb energy:

$$R = sin(\phi_0) = exp(\frac{ZeV(t)}{2T}) \ .$$

Temperature would appear as a parameter in single particle wave function and the interpretation would be that thermodynamical distribution is replaced by its square root in quantum theory. In ZEO density matrix is replaced by its hermitian square root multiplied by density matrix.

2. The counterpart of chemical potential in TGD description

This model is not as such physically realistic since the counterpart of chemical potential is lacking. The most straightforward generalization of the thermodynamical model is obtained by the addition of an ion dependent chemical potential term to the membrane potential: $ZeV \to ZeV + \mu_I$. This would however require a concrete physical interpretation.

1. The most obvious possibility is that also the chemical potential actually correspond to an interaction energy - most naturally the cyclotron energy $E_c = \hbar_{eff} ZeB_{end}/m$ of ion - in this case proton - at the magnetic flux tube. Cyclotron energy is proportional to h_{eff} and can be rather large as assumed in the model for the effects of ELF em fields on brain.

2. This model would predict the dependence of the effective chemical potential on the mass and charge of ion for a fixed value of on h_{eff} and B_{end}. The scales of ionic chemical potential and ion concentrations would also depend on value of h_{eff}.

3. The model would provide a different interpretation for the energy scale of bio-photons, which is in visible range rather than infrared as suggested by the value of membrane potential.

   The earlier proposal [K50] was that cell membrane can be in near vacuum extremal configuration in which classical Z^0 field contributes to the membrane potential and gives a large contribution for ions. The problematic aspect of the model was the necessity to assume Weinberg angle in this phase to have much smaller value than usually. This difficulty could be perhaps avoided by noticing that the membrane potentials can differ for color receptors so that the earlier assignment of specific ions to color receptors could make sense for ordinary value of Weingerg angle. Second problem is that for proton the Z^0 contribution is negligible in good approximation so that this model does not explain the high value of the metabolic energy currency.

4. The simplest model the communications to magnetic body rely on Josephson radiation whose fundamental frequency f_J is at resonance identical with the cyclotron frequency $f_c(MB)$ at particular part of the flux tube of the magnetic body: $(f_c(MB) = f_J$. $f_c(MB)$ corresponds to EEG frequency in the case of brain and biophotons are produced from dark EEG photons as ordinary photons in phase transition reducing $h_{eff} = n \times h$ to h.

   In the modified model the sum $f_c + f_{J,n}$ ($f_{J,n} = E_J/n \times h$) of h_{eff}-independent cyclotron frequency and Josephson frequency proportional to $1/h_{eff}$ equals to cyclotron frequency $f_c(MB)$ at "personal" magnetic body varying slowly along the flux tube: $f_c + f_{J,n} = f_c(MB)$. If also the variation of f_J assignable to the action potential is included, the total variation of membrane potential gives rise to a frequency band with width roughly

$$\frac{\Delta f}{f} \simeq \frac{2f_{J,n}}{f_c + f_{J,n}} = \frac{2f_{J,1}}{nf_c + f_{J,1}} \ .$$

If dark photons correspond to biophotons the energy is of cyclotron photon is in visible and UV range one has $nf_c = E_{bio}$ and

$$\frac{\Delta f}{f} \simeq \frac{2ZeV}{E_{bio} + ZeV} \quad .$$

The prediction is scale invariant and same for all ions and also electron unless E_{bio} depends on ion. For $eV = .05$ eV, $Z = 1$, and $E_{bio} = 2$ eV ($f \simeq 5 \times 10^{14}$ Hz) one has $\Delta f/f \sim .1$ giving 10 per cent width for EEG bands assumed in the simpler model.

If this vision is on the correct track, the fundamental description of osmosis would be in terms of a phase transition to the fourth phase of water involving generation of dark matter transferred to the magnetic flux tubes. For instance, the swelling of cell by an in-flow of water in presence of higher concentration inside cell could be interpreted as a phase transition extending exclusion zone as a process accompanied by a phase transition increasing the value of h_{eff} so that the lengths of the flux tube portions inside the cell increase and the size of the exclusion zone increases. In general case the phase transitions changing h_{eff} and B_{end} by power of two factor are possible. This description should bring magnetic body as part of bio-chemistry and allow understanding of both equilibrium ion distributions, generation of nerve pulse, and basic metabolic processes leading to the generation of ATP.

One can also model sensory receptors and try to understand the maximal sensitivity of color receptors to specific wavelengths in this framework. The new degrees of freedom make this task easy if one is only interested in reproducing these frequencies. More difficult challenge is to understand the color receptors from the first principles. It is also possible to combine the new view with the assumption that sensory receptor cells are near to vacuum extremals. This would add a cyclotron contribution to the generalized Josephson frequency depending only weakly on particle and being non-vanishing also for em neutral particles.

3. Why would charge separation generate large h_{eff}?

The basic question is whether and how the separation of electron and proton charges generates large h_{eff}? A possible mechanism emerged from a model [K117] explaining anomalously large gravimagnetic effect claimed by Tajmar *et al* [E4, E5] to explain the well-established anomaly related to the mass of Cooper pairs in rotating super-conduction. The mass is too large by fraction of order 10^{-4} and the proposal is that gravimagnetism changes slightly the effective Thomson magnetic field associated with the rotating super-conductor leading to wrong value of Cooper pairs mass when only ordinary Thomson field is assumed to be present. The needed gravimagnetic field is however gigantic: 28 orders larger than that predicted by GRT. Gravimagnetic field is proportional h_{eff}^2 in TGD and if one uses h_{gr} for electron-Earth system one obtains correct order of magnitude.

Nottale's finding that planetary orbits seem to correspond to Bohr orbits in gravitational potential with gigantic value of gravitational Planck constant is the basic input leading to the model of gravimagnetic anomaly.

1. By Equivalence Principle h_{gr} has the general form $\hbar_{gr} = GMm/v_0$, where M and m are the interacting masses and v_0 is a parameter with dimensions of velocity. For three inner planets one has $v_0/c \simeq 2^{-11}$.

2. The notion of h_{gr} generalizes to that for other interactions. For instance, in electromagnetic case the formation of strong em fields implying charge separation leads to systems in which $h_{em} = Z_1 Z_2 e^2/v_0$ is large. Pollack's exclusion zone and its complement define this kind of systems and is identified as prebiotic life form.

3. Since the natural expansion parameter of perturbative expansion is the $g^2/4\pi\hbar$, one can say that transition to dark matter phase make the situation perturbative. Mother Nature is theoretician friendly.

h_{em} might be large in the exclusion zones (EZ) appearing in the water bounded by gel and their variants could play central role in living matter.

1. EZ carries very large negative charge with positive charge outside the exclusion zone.

2. TGD interpretation is in terms of $H_{1.5}O$ phase of water formed when every 4: th proton is transferred to magnetic body as dark particle with large value of h_{eff}. The proposal is that primitive life form is in question.

3. The pair formed by EZ and its complement could have large value of $h_{eff} = h_{em} = Z^2e^2/v_0$.

4. The velocity parameter v_0 should correspond to some natural rotation velocity. What comes in mind is that complement refers to Earth and v_0 is the rotation velocity at the surface of Earth. The prediction for h_{eff} would be of order $h_{em}/h = 4\pi\alpha Z^2 \times .645 \times 10^6 \simeq 5.9 \times 10^4 Z^2$.

5. Cell membrane involves also large charge separation due to very strong electric field over the cell membrane. Also now dark phases with large h_{em} or h_{gr} could be formed.

I have proposed that metabolic machinery generates large h_{eff} phase somehow. $h_{eff} = h_{em}$ hypothesis allows to develop this hypothesis in more detail.

1. I have speculated earlier [K60] that the rotating shaft of a molecular motor associated with ATP synthase plays a key role in generating dark matter phase. What comes in mind is that charge separation takes place associating exclusion zone with the shaft and the rotational velocity v_0 of the shaft appears in the formula for h_{em}. Of course, some numerical constant not far from unity could be present. The electric field over the mitochondrial membrane generates charge separation. One can imagine several identifications for the product of charges. The charge Z associated with the complement would be naturally associated with single dark flux tube containing dark nucleon consisting of dark protons. For instance, the charge associated with the exclusion zone could be the charge of the electronic Cooper pair giving $h_{em} = 2e \times Z/v_0$.

2. The value of v_0/c is expected to be of order 10^{-14} from the angular rotation rate of ADP synthase about few hundred revolutions per second. The order of magnitude for h_{em} could be same as for h_{gr} associated with Earth-particle system.

$h_{eff}(ATPsynthase) = h_{gr}(2e, Earth)$ would make possible reconnection of electromagnetic flux tubes with gravimagnetic flux tubes [K95].

4. Which came first: metabolism or cell membrane?

One of the basic questions of biology is whether metabolism preceded basic biopolymers or vice versa. RNA world scenario assumes that RNA and perhaps also genetic code was first.

1. The above view suggests that both approaches are correct to some degree in TGD Universe. Both metabolism and genetic code realized in terms of dark proton sequences would have emerged simultaneously and bio-chemistry self-organized around them. Dark proton sequences defining analogs of amino-acid sequences could have defined analogs of protein catalysts and played a key role in the evolution of the metabolic pathways from the primitive pathways involving only the phase transition between ordinary water and fourth phase of water.

2. There is very interesting article (see `http://tinyurl.com/ycdhd4fd`) [?]eporting that complex metabolic pathways are generated spontaneously in laboratory environments mimicking hot thermal vents. Glycolysis and pentose phosphate pathway were detected. The proposal is that these pathways are catalyzed by metals rather than protein catalysts.

3. In standard biology these findings would mean that these metabolic pathways emerged before basic biopolymers and that genetic code is not needed to code for the metabolic pathways during this period. In TGD framework dark genetic code [K53, L3] would be there, and could code for the dark pathways. Dark proton strings in one-one correspondence with the amino-acid sequences could be responsible for catalysts appearing in the pathways. Only later these catalysts would have transformed to their chemical counterparts and might be accompanied by their dark templates. One cannot even exclude the possibility that the chemical realization of the DNA-amino-acid correspondence involves its dark analog in an essential manner.

9.7.3 Phase transitions generating dark phases and sensory perception

The TGD based model for biological self-organization relies on the hierarchy $h_{eff} = nh_0$ of effective Planck constants labelling dark phases of ordinary particles residing at magnetic flux quanta [L84, L85, L97] [K93, K92]. This model generalizes and suggests the replacement of non-equilibrium thermodynamics as basis of self-organization with its quantum variant based on dark matter hierarchy. The challenge is to formulate basic thermodynamical notions like work in terms TGD based quantum theory relying on zero energy ontology (ZEO) [K78].

The basic mechanism would be a phase transition creating dark matter phase as a Bose-Einstein condensate like state with particles having identical conserved quantum numbers. Conservation laws would force the ordinary matter to have opposite total charges. For instance, in the case of work one has momentum or angular momentum as a conserved charge. In the case of charge separation and high Tc superconductivity it would be em charge. Even color charges can correspond to conserved charges in TGD framework allowing scaled variants of strong interaction physics.

Basic biological functions involving the notion of work and also the formation of sensory percepts would rely on this mechanism. Also the ZEO based theory of consciousness predicting the change the arrow of time in ordinary state function [L72] reduction plays a central role and a model of nerve pulse is discussed as an example.

Sensory perception (time reversal of motor action [L86]) could involve generation of coherent phases of dark matter carrying collective quantum numbers in 1-1 corresponds with the sensory qualia. This would represent a general charge separation process.

Consider first sensory capacitor model for color qualia [K50].

1. The notion of QCD color as analog of ordinary visual colors was originally introduced as a joke since the algebra of color summation resembles that for the summation of QCD colors in tensor product. In TGD however the dark hierarchy (h_{eff}) and p-adic length scale hierarchy predict that scaled variants of QCD type physics are possible for arbitrarily large length scales. In cellular scales scaled up QCDs are predicted. In the length scale range between cell membrane thickness and nucleus size there are as many as 4 Gaussian Mersennes, which is a number theoretical miracle. They could label copies of QCDs with size scale for the analogs of hadrons given by the corresponding p-adic length scales. QCD type colors could correspond to perceived colors [K50] [L83].

2. Gluons or quarks labelled by color charge characterizing particular color quale would flow between the plates of "capacitor" associated with the sensory receptor. The amount of particular color charge increases at the other plate giving rise to sensation of this particular color quale and its complement at the other plate - by color confinement also the same plate could also contain regions with complementary colors. This would explain why we see around a region of particular color a narrow boundary with complementary color.

3. The model for sensory perception as sequences of analogs of weak measurements suggest that the flow of color charges could induce color qualia. The prediction emerging from the structure of SU(3) color algebra would be four pairs of basic color and complement color: 3 ordinary pairs and white-black pair. They could correspond to particular changes of color quantum numbers and color quantum numbers of gluons. Also color mixing could be understood.

4. Photons are not coloured but gluons (and also quarks) are, and the latter and could be responsible for color sensation. How photon flux can generate a flow of color quantum numbers? The notion of induced gauge field -classical color gauge potentials would be projections of $SU(3)$ Killing vectors - explains this.

   In TGD classical em field is sum of two terms induced Kähler form and neutral vectorial component of spinor curvature [L2]. Classical gluon field has components proportional to classical color Hamiltonian (function in CP_2 which can be said to have quantum numbers of gluon) and induced Kähler form. In general case any classical em field is accompanied by a classical color field.

Photons are accompanied by classical em fields and therefore also by classical gluon fields at the fundamental level: this correspondence disappears at QFT limit unable to describe biology and sensory experience. The flow of photons to retina would be accompanied by classical em and color fields and therefore a flow of gluons. Also quark flow between the plates of sensory capacitor could generate the color qualia.

5. A simple model for the visual qualia is in terms of a phase transition transforming gluons of a scaled copy of QCD to ordinary gluons. Dark gluons would form a BE condensate and force a formation its shadow at the level of ordinary matter. This is a variant of sensory receptor as quantum capacitor. The plates of capacitor correspond to dark and ordinary phase and the analog of electric breakdown means formation of the dark phase. Cooper pairs of quarks with quantum numbers of gluon would be second option but gluons in TGD framework are actually this kind of pairs!!

9.8 Some objections against TGD view of qualia

I have considered the problem of qualia several times and have proposed several models for qualia [K50] [L104]. I have not been quite happy with the details of the original proposal. A lot of progress in the understanding of TGD has taken place since I considered qualia from the TGD point of view for the first time, and it is appropriate to take a new look at the situation.

9.8.1 Recalling the general ideas about qualia

The obvious idea is that qualia can be assigned with a state function reduction (SFR) as measurement of observables [K50].

1. The first class of basic qualia would correspond to infinitesimal generators of the fundamental symmetries. Spin, color and electroweak quantum numbers would represent fundamental qualia. Supersymplectic group for the product of light-cone boundary and CP_2 would act as isometries of the "world of classical worlds" and this would give rise to dynamical symmetry groups [K104] and corresponding qualia.

   Momentum and position are certainly fundamental observables. M^8-H duality [L127, L128] has an interpretation as a generalization of momentum position duality of wave mechanics forced by the replaced of point like-particle with 3-surface whose orbit defines space-time surface as analog of Bohr orbit realizing holography forced by 4-D general coordinate invariance.

   At the level of M^8 momentum eigenstates correspond to states for which mass shells are determined by the roots of the polynomial defining 4-D surface of M^8 by holography. This surface is mapped by M^8-H duality to a space-time surface in H as a minimal surface with singularities in H [L163, L164].

   Measurement of momentum produces a state localized to a set of points of mass shells of M^8 corresponding to quark momenta. The measurement of position as a dual variable for momentum gives rise to a superposition of this kind of states with coefficients $exp(ip\cdot m)$ mapped by M^8-H duality to a state within a single causal diamond (CD) H localized to the point. These two state bases correspond to H-picture and M^8 picture.

   Twistor lift of TGD generalizes this duality also to the spin and electroweak spin and one can say that spin 1/2 state with a given quantization axis corresponds in M^8 to either point defined by the discrete direction of quantization axes at unit sphere. In the twistor space of H it corresponds to a wave function at the twistor sphere CP_1.

2. There would also be geometric qualia related to the shape and size of objects. The flag manifolds defined by Cartan groups of symmetry groups and having interpretation as a space for the choices of quantization axes would represent example of geometric qualia, which I have called flag manifold qualia [K50] [L83]. The flag manifold $SU(3)/U(1)\times U(1)$ for color group defines twistor space for CP_2 and the model for honeybee dance involves this space as discovered by topologist Barbara Shipman [A10].

The twistor space CP_3 for Minkowski space has interpretation as a choice of the origin of Minkowski coordinate and spin quantization axis. Points of M^4 separated by light-like distance would be equivalent. The product of these twistor spaces appears in the twistor lift of TGD [K126, L71] [L163, L164]. The space of the quantization axis for weak isospin corresponds to a sphere but the breaking of weak isospin symmetry at the level of geometry of CP_2 could fix the quantization axis.

3. What about qualia such as acceleration? Acceleration corresponds to the rate of change for momentum. Momentum is a relative notion by Lorentz invariance and always relative to some system. This requires two systems. I have proposed that the relative motion of the magnetic body and biological body is behind the experience of acceleration that is force.

   In wave mechanics, force would be represented as a commutator of the Hamiltonian of the system representing the magnetic body (MB) and biological body with the momentum related to relative motion. The measurement would give an eigenstate of this operator with a constant force. If the scaling for the entire system determines the analog of the time evolution, one should decompose this scaling to single particle operators associated with the magnetic and biological body and the part representing the force when time evolution corresponds to scaling instead of translation. Eigenstates of this term would result in the measurement of force.

The basic objection against the identification of state function reduction as a moment of consciousness is that sensory mental images have a finite duration.

One can imagine two ways of identifying qualia: as an outcome of quantum measurement or in terms of a change/transfer of quantum numbers. Both the resolution of the objection and the two alternative identifications of qualia will be discussed in the context provided by the recent view of TGD. For definiteness, the discussion will be restricted to color qualia since it provides an opportunity to discuss how the new physics predicted by TGD would be involved with qualia.

9.8.2 How can the perception of quale have a finite duration?

There is a philosophical problem related to the fact that the experience of, say, color has a duration. One could argue that the idea that color sensations correspond to SFRs, that is, a single moment of consciousness, is not consistent with this. One can imagine two ways to overcome this objection.

First option

One could argue as follows.

1. It is not possible to experience that one is not conscious so that the illusion of finite duration of sensory quale is created.

2. The "small" SFR as the TGD counterpart of a weak measurement in quantum measurement theory based on zero energy ontology (ZEO) begins as a cognitive measurement cascade in a Galois group of extension of rationals associated with a rational polynomial defining a given space-time region [L134, L165].

   This cascade corresponds to a decomposition of the representation of Galois group for a functional composite polynomial $P_1 \circ ... \circ P_n$ for which Galois group of the algebraic extension has decomposition to a semidirect product of relative Galois groups G_i associated with pairs P_i, P_{i+1}. This yields a product of irreps of G_i.

3. The cognitive cascade as a quantum correlate of analysis, is followed by measurements in quark spin and momentum degrees of freedom for the quark states defining the irreps of G_i. One can argue that the duration of the qualia mental image corresponds to the geometric lifetime of this sequence since eventually a BSFR, which means the death of the qualia mental image occurs. By the above argument, the steps in this sequence would not be experienced separately.

4. There is an objection against this view. ZEO [L108, L158] motivates the proposal is that we are during sleep living in an opposite direction of time and *classically* it is impossible to receive signals from that period since the signals travel in an opposite time direction (TGD predicts that also signals with "wrong" time direction can be received and sent but are rare and the process involves BSFR at the level of system representing mental images as subself). However, when we wake up in the morning, we remember that we were conscious yesterday and realize that we do not remember anything about the period of sleep. Could the same argument apply to mental images related to qualia?

Second option

One could also argue as follows.

1. State function reductions (SFRs) (actually "small" SFRs responsible for the "flow of consciousness"") *initiate* a conscious experience of say some quale realized as subself, mental image. The next "small" SFR would end this experience and initiate a new one. If SFR is "big", the mental image dies and reincarnates with the opposite arrow of time and experience disappears from the consciousness of self.

   Mathematicians would say that a delta function is replaced with a step function as far as interpretation is considered. Nothing at the level of mathematical formalism has changed.

   The structure of conscious experiences reflects the structure of the physical states. In this spirit, one could argue that SFRs serve as a holographic data at the ends of the duration of the conscious experience, which determine the conscious experience associated with the duration itself.One would have have holography of consciousness.

2. Is this interpretation consistent with the fact that change is necessary for qualia as already basic physiological facts show? For instance, if the saccadic motion of the eye is prevented, the perceptive field becomes dark first and after that the visual consciousness disappears. This finding can be consistent with the new view since the lifetimes of the qualia mental images as subselves are certainly finite.

Critical reader could ask whether the two options are only slightly different verbalizations of the same basic intuition and perhaps regard the latter verbalization as mathematically clearer. The latter option looks clearer than the first one although it does not literally conform with what I have been telling for three decades about SFRs as basic building bricks of conscious experience! It can take decades to express really clearly what you have understood!

9.8.3 How can qualia be reliable if they are associated with quantum jumps?

The popular article "Scientists Quantified The Speed of Human Thought, And It's a Big Surprise" (see this)) tells about the article "The unbearable slowness of being: Why do we live at 10 bits/s?" of Zheng and Meister [J115]. The speed of human thought would be 1 step per .1 seconds. This time interval corresponds to 10 alpha rhythm.

The conclusion is rather naive and reflects the failure to realize that consciousness is a hierarchical structure. This failure is one of the deep problems of neuroscience and also of quantum theories of consciousness. Although the physical world has a hierarchical structure and although the structure of consciousness should reflect this, it seems impossible to realize that it indeed does so!

TGD view about conscious experience, predicts this hierarchy [K68, K50, **?**]. Only a very small part of this hierarchical structure is conscious to us. Conscious entities, selves, have subselves (associated with physical subsystems), which they experience as mental images. Also subselves have subselves as sub-subselves of us. The hierarchy continues downwards and upwards and the latter predicts collective levels of consciousness.

TGD assumes that the period of subjective time between two "small" state function reductions gives rise to a moindent of consciousness with an experienced duration and that these

moments integrate to a flow of consciousness. The objection is that the contents of conscious experience would be highly random. How to overcome this objection?

We do not experience these subsubselves as separate entities but only their statistical average [K50, **?**]. This makes possible statistical determinism of mental images so that they do not fluctuate randomly. For instance, this statistical averaging explains the summation of visual colors. This conforms with the fact that there is a large number of sensory receptors.

This applies also to cognition and quantum computation-like processes in which the outcomes are sub-sub-selves giving rise to cognitive mental image, self, as a conscious average. This averaging applies also in time direction since zero energy ontology [L108, L189] predicts a slight failure of classical non-determinism, which makes possible conscious memories containing information about previous state function reductions [K101, L186]. Averaging as a basic operation in quantum theory computations giving rise to predictions would have a counterpart at the level of conscious experience.

The view is discussed in more detail in the article [L187] proposing that life could be universal in the sense that it can emerge in all systems involving cold plasmas and involving quantum computation like-processes and memory based on the classical non-determinism of TGD. At the neuronal level various EEG rhythms would define analogs of the computer clock and each tick of the clock would define a potential seat of memory.

9.8.4 Two alternative identifications of qualia

One can consider two alternative identifications of qualia: as an outcome of quantum measurement or as a change/transfer of quantum numbers.

Quale as an outcome for a measurement of quantum numbers?

Quantum measurement theory suggests the identification of qualia as resulting in quantum measurement and therefore labelled by eigenvalues of the measured observables. Qualia would therefore characterize the quantum state emerging in SFR (most naturally SSFR) and one might say that qualia are determined by the properties of the state.

How does this relate to the long held TGD based view that since SFRs are the basic building bricks of conscious experience, conscious experience cannot be regarded as a property of a physical state as physicalists argue. Hence "consciousness" is a misleading term. Holography of consciousness suggests the interpretation that conscious experience and qualia are about the properties of the state emerging in SFR but are not its properties.

There is a finite classical non-determinism associated with the space-times surfaces as analogs of 4-D soap films. A possible interpretation is as a correlate for the intentional component of the conscious experience. This would fit with the vision that life and intentionality, which is essential for life, emerge at quantum criticality. SSFRs would be behind sensory experience and classical non-determinism behind the intentional component of the experience.

Consider color vision as an example.

1. Sensory receptors (such as the eye) could be seen in this framework as a collection of subsystems (rods and cones), which together form a quantum coherent state. SFR would produce a collection of different outcomes and the experienced quale would be a statistical average of the outcomes. In the ensemble interpretation, the probabilities of various quantum number combinations (basic colors) would be given by the reduction probabilities. This explains color summation. In holography with a slight failure of determinism, one cannot exclude temporal averages.

2. "Color symmetry" was originally a joke inspired by the algebraic correspondence with visual colors. The proposal was that visual colors could correspond to quark colors. Perception would be measurement of color quantum numbers. This would predict 3 colors for quarks and 3 complementary colors for antiquarks. White and black are also considered as colors.

3. This sounds outlandish but makes sense in the TGD framework, where quarks are the only fundamental fermions in the recent formulation of TGD. Moreover, TGD predicts a hierarchy of effective Planck constants $h_{eff} = nh_0$, where n has a number theoretic interpretation as

dimension of an extension of rationals associated with a polynomial defining a space-time region considered. n measures the algebraic complexity and serves as a kind of IQ.

$h_{eff} = nh_0$ labels phases of ordinary matter and these phases behave like dark matter relative to each other. Field bodies carry these phases and magnetic bodies MBs with various values of h_{eff} can act as "bosses" controlling lower levels, in particular the ordinary matter at the bottom of the master-slave hierarchy.

4. Compton lengths are scaled up by n and MBs can carry dark quarks and gluons even in cellular length scales. Below the confinement scale which is the natural scale now quarks and gluons are effectively massless. One could say that we directly see quarks!

   This is true also also for the weak interactions and the presence of dark weak variants of weak bosons at magnetic body (MB) could explain the chiral selection in living matter, which is very difficult to understand in the standard model because the violation of parity in weak interactions is extremely small above Compton length of weak bosons. In living matter the Compton length would scale up at MBs and MBs acting as "bosses" would induce large parity violation even in cell scale.

Quale as a change of quantum numbers?

An alternative option has been that the classical flows of color quantum numbers could correspond to qualia. This led to the sensory capacitor model of cell membrane [K50, K92].

1. Since the changes for quark quantum numbers correspond to gluons, there would be 3+3 colors corresponding to color charged gluons. Classically one could think that the flow of color quantum numbers between two subsystems in a sensory receptor could give rise to an experience of quale such as color. This led to the sensory capacitor model of cell membrane [K50, K92].

2. At elementary particle level, the change of color quantum numbers for a single particle could be induced by an exchange of a gluon between quarks. But can one associate this flow with a quantum measurement of something? For quantum groups and Yangians the color charge operators are sums of single particle contributions and many particle contributions. Two-quark contributions would make possible opposite change of color quantum numbers for the members of a quark pair. Could the measurement of the quantum group counterpart of color charge give rise to this kind of change? The first option is the simpler and more natural one.

3. In the sensory capacitor model, one could model the situation as a pair of harmonic oscillator wells representing the plates of a capacitor characterized by Hamiltonian $H = H_0 + V$. The presence of the capacitor plates would be described by a sum $H_0 = -\hbar^2\partial_x^2/2m + kx^2/2 + k(x-d)^2/2$ of harmonic oscillator Hamiltonians describing a double potential well. The potential driving the particles between the plates would be described by $V = -qEx$.

   The commutator $[H, V] = \hbar^2\partial_x E/m = i\hbar Ep$, $p = i\hbar\partial_x/m$ and non-hermitian in plane wave basis at the limit of infinite distance between the plates.

4. p is a linear combination of creation and annihilation operator for the harmonic oscillator quanta and one can ask whether the analogs of eigenstates of p correspond to coherent states for the annihilation operator having in general complex eigenvalues. Instead of eigenstate, a coherent state for the negative energy part of force could be created at the plate which contains the particle in the initial state. The coherent state would be a harmonic oscillator state for which the origin would be shifted along the line connecting the plates. The probabilities for eigenstates would be given by the overlap of the coherent states as Gaussian with the original ground state or excited state at either plate.

5. A more realistic formulation could be as a quantum phase transition for a cyclotron condensate of quarks and antiquarks assignable to the opposite layers of the sensory capacitor carrying opposite color charges. This phase transition is analogous to a spontaneous magnetization, or rather its reversal, and would emit a burst of gluons changing the quantum numbers of cyclotron condensates at the layers.

The TGD view about dark matter leads to the notion of dark N-particle as an analog of a Bose-Einstein condensate. A dark N gluon would be emitted.

The description of the dynamics of this transition could involve the bilinear coupling of classical induced color field components $G^A_{\alpha\beta} = H_A J_{\alpha\beta}$ proportional Kähler form and Hamiltonians of color isometries with gluon field, and associated with a "massless" extremal (ME) connecting the plates. ME or MEs would serve as a classical space-time correlate for a mode of a generic radiation field with a fixed polarization and direction of propagation.

9.8.5 Zero energy ontology, holography = holomorphy vision and TGD view of qualia

Zero energy ontology (ZEO) and holography = holomorphy vision providing an exact solution of classical field equations allow to solve some earlier problems of TGD inspired theory of consciousness and to sharpen earlier interpretations. Holography = holomorphy vision generalizes 2-D conformal invariance to 4-D situation and provides a universal solution of field equations in terms of minimal surfaces defined as roots for pairs of generalized analytic functions of the generalized complex coordinates of $H = M^4 \times CP_2$ (one of the coordinates is hypercomplex coordinate with light-like coordinate curves) [L177, L184].

Consider first the implications of ZEO [L108] [K143].

1. ZEO predicts that in "big" state function reductions (BSFRs) as counterparts of ordinary SFRs the arrow of time changes. "Small" SFRs (SSFRs) are the counterpart for repeated measurements of the same observables, which in standard QM leave the system unaffected (Zeno effect). In SSFRs, the state of the system however changes but the arrow of time is preserved. This has profound implications for the understanding of basic facts about consciousness.

2. The sequence of SSFR corresponds to a sequence of delocalizations in the finite-dimensional space of causal diamonds $CD = cd \times CP_2$ [L180] and consists of delocalizations (dispersion) followed by localizations as analogs of position measurements in the moduli parameterizing the CD. This sequence gives rise to subjective existence, self.

3. BSFR has interpretation is accompanied by reincarnation with an opposite arrow of geometric time. BSFR means the death of self as a sequence of "small" SFRs (SSFRs) and corresponds to falling asleep or even death. Death is therefore a completely universal phenomenon. The next BSFR means birth with the original arrow of time: it can be wake-up in the next morning or reincarnation taking place considerably later, life time is the first guess for the time scale. This follows from the fact that causal diamond $CD = cd \times CP_2$ increases in size during the sequence of SSFRs.

4. What forces the ZEO is holography which is slightly non-deterministic due to the classical non-determinism of an already 2-D minimal surface realized as a soap film for which the frame spanning it does not fix it uniquely. This means that the 4-D space-time surface located inside CD and identifiable as the analog of Bohr orbit determined by holography must be taken as a basic object instead of a 3-surface. In SSFRs, the state at the passive light-like boundary of CD is unaffected just as in Zeno effect but the state at the active boundary changes. Due to the dispersion in the space of CDs the size of CD increases in statistical sense and the geometric time identifiable as the distance between the tips of CD increases and correlates with the subjective time identifiable as sequence of SSFRs.

5. In standard quantum theory, the association of conscious experience with SFRs does not allow us to understand conscious memories since the final state of state function reduction does not contain any information about the earlier states and state function reductions. Zero energy ontology leads to a concrete view of how conscious memories can be realized in the TGD Universe [L186]. The superposition of space-time surfaces between fixed initial state and changing final state of SSFR contains the classical information about previous states and state function reductions and makes memory possible. The slight non-determinism of the classical time evolution implies loci of non-determinism as analogs of soap film frames and memory recall corresponds to a quantum measurement at these memory seats.

6. SSFRs correspond to repeated measurements of the same observable and the eigenvalues of the measured observables characterize the conscious experience, "qualia", partially. Also new commuting observables related to the non-determinism can appear and the set of observables can be also reduced in size. The superposition of the space-time surfaces as analogs of non-deterministic Bohr orbits however changes in the sequence of SSFRs and the associated classical information changes and can give rise to conscious experiences perhaps involving also the qualia remaining constant as long as self exists.

   The eigenvalues associated with the repeatedly measured observables do not change during the sequence of SSFRs and one can ask if they can give rise to a conscious experience, which should be assignable to change. Could these constant qualia be experienced by a higher level self experiencing self as sub-self defining a mental image? This higher level self would indeed experience the birth and death of subself and therefore its qualia.

   The observables at the passive boundary of CD correspond qualia of higher level self and the additional observables associated with SSFRs correspond to those of self. They would be associated with self measurements.

7. Note that self dies when the measured observables do not commute with those which are diagonalized at the passive boundary. It is quite possible that these kinds of temporary deaths take place all the time. This would allow learning by trial and error making possible conscious intelligence and problem solving since the algebraic complexity is bound to increase: this is formulated in terms of Negentropy Maximization Principle [L178].

ZEO and holography = holomorphy vision allow us to understand some earlier problems of TGD inspired theory of consciousness and also to sharpen the existing views.

Two models for how sensory qualia emerge

Concerning sensory qualia [K50] I have considered two basic views.

1. The first view is that the sensory perception corresponds to quantum measurements of some observables. Qualia are labelled by the measured quantum numbers.

2. The second, physically motivated, view has been that qualia correspond to increments of quantum numbers in SFR [K50]. This view can be criticized since the quantum numbers need not be well-defined for the initial state of the SFR. One can however modify this view: perhaps the redistribution of quantum numbers leaving the total quantum numbers unaffected, is what gives rise to the sensory qualia.

   The proposed physical realization is based on the sensory capacitor model of qualia. Sensory receptors would be analogous to capacitors and sensory perception would correspond to dielectric breakdown. Sensory qualia would correspond to the increments of quantum numbers assignable to either cell membrane in the generalized di-electric breakdown. The total charges of the sensory capacitor would vanish but they would be redistributed so that both membranes would have a vanishing charge. Membranes could be also replaced with cell exterior and interior or with cell membrane and its magnetic body. Essential would be emergence or disappearance of the charge separation.

   This picture conforms with the recent view about the role of electric and gravitational quantum coherence assignable to charged and massive systems. In particular, electric Planck constant would be very large for charged systems like cell, neuron, and DNA and in the dielectric breakdown and its time reversal its value would change dramatically. If this is the case the dynamic character of effective Planck constant involving phase transition of ordinary to dark matter and vice versa would be essential for understanding qualia.

3. As the above argument demonstrated, the qualia can be decomposed to internal and external qualia. The internal qualia correspond to self-measurements of sub-self occurring in SSFRs whereas the external qualia correspond to the qualia measured by self having sub-self as a mental image. They are not affected during the life-time of the mental image. Whether the self can experience the internal qualia of subself is far from clear. The sensory capacitor model

would suggest that this is the case. Also the model for conscious memories suggests the same. The internal qualia would correlate with the classical dynamics for the space-time surfaces appearing in the superposition defining the zero energy state and make possible, not only conscious memory and memory recall based on the failure of precise classical determinism, but also sensory qualia as subselves experienced as sensory mental images.

Geometric and flag manifold qualia and the model for the honeybee dance

One can decompose qualia to the qualia corresponding to the measurement of discrete observables like spin and to what might be called geometric qualia corresponding to a measurement of continuous observables like position and momentum. Finite measurement resolution however makes these observables discrete and is realized in the TGD framework in terms of unique number theoretic discretization of the space-time surface.

Especially interesting qualia assignable to twistor spaces of M^4 and CP_2.

1. Since these twistor spaces are flag manifolds, I have talked about flag-manifold qualia. Their measurement corresponds to a position measurement in the space of quantization axes for certain quantum numbers. For angular momentum this space would be $S^2 = SO(3)/SO(2)$ and the localization S^2 would correspond to a selection of the quantization axis of spin. For $CP_2 = SU(3)U(2)$ the space of the quantization axis for color charges corresponds to 6-D $SU(3)(U(1) \times U(1)$, which is identifiable as a twistor space of CP_2.

2. The twistor space of M^4 can be identified locally as $M^4 \times S^2$, where S^2 is the space of light-like rays from a point of M^4. This space however has a non-trivial bundle structure since for two points of M^4 connected by a light-like ray, the fibers intersect.

What is the corresponding flag manifold for M^4?

1. The counterpart of the twistor sphere would be $SO(1,3)/ISO(2)$, where $ISO(2)$ is the isotropy group of massless momentum identifiable as a semidirect product of rotations and translations of 2-D plane. $SO(1,3)/ISO(2)$ corresponds to the 3-D light-cone boundary (other boundary of CD) rather than S^2 since it has one additional light-like degree of freedom. Is the twistor space as a flag manifold of the Poincare group locally $M^4 \times SO(1,3)/ISO(2)$. This is topologically 7-D but metrically 6-D. Since light rays are parametrized by S^2 one can also consider the possibility of replacing $M^4 \times SO(1,3)/ISO(2)$ with S^2 in which case the twistor space would be 6-D and represented a non-trivial bundle structure.

2. Could one restrict M^4 to E^3 or to hyperbolic 3-sphere H^3 for which light-cone proper time is constant? In these cases the bundle structure would trivialize. What about the restriction of M^4 to the light-like boundaries of CD? The restriction to a single boundary gives non-trivial bundle structure but seems otherwise trivial. What about the union of the future and past boundaries of CD? The bundle structure would be non-trivial at both boundaries and there would also be light-like rays connecting future and past light-like boundaries.

   The unions $\cup_i H_i^3(a_i)$ of hyperbolic 3-spaces corresponding different values $a = a_i$ of the light-cone propert time a emerge naturally in $M^8 - H$ duality and could contain the loci of the singularities of space-time surfaces as analogs of frames of soap filmas. Also these would give rise to a non-trivial bundle structure.

   These identifications differ from the usual identification of the M^4 twistor space as CP_3: note that this identification of the M^4 twistor space is problematic since it involves compactification of M^4 not consistent with the Minkowski metric. Holography = holomorphy vision in its recent form involves a general solution ansatz in terms of roots of two analytic functions f_1 and f_2 and $f_2 = 0$ [L184], which identifies the twistor spheres of the twistor spaces of M^4 and CP_2 represented as metrically 6-D complex surfaces of H. M^4 twistor sphere corresponds to the light-cone boundary in this identification. This identification map also defines cosmological constant as a scale dependent dynamical parameter.

A basic application for the twistor space of CP_2 has been in the TGD based model [K50, L82] for the findings of topologist Barbara Shipman [A10, A11, A12, A13, A9], who made the surprising

finding that the twistor space of CP_2, naturally assignable to quarks and color interactions, emerges in the model for the dance of honeybee. This kind of proposal is nonsensical in the standard physics framework but the predicted hierarchy of Planck constants and p-adic length scales make possible scaled variants of both color and electroweak interactions and there is a lot of empirical hints for the existence of this hierarchy, in particular for the existence as a scaled up variants of hadron physics leading to a rather radical proposal for the physics of the Sun [L188].

A basic application for the twistor space of CP_2 has been in the TGD based model [K50] for the findings of topologist Barbara Shipman [A10], who made the surprising finding that the twistor space of CP_2, naturally assignable to quarks and color interactions, emerges in the model for the dance of honeybee. This kind of proposal is nonsensical in the standard physics framework but the predicted hierarchy of Planck constants and p-adic length scales make possible scaled variants of both color and electroweak interactions and there is a lot of empirical hints for the existence of this hierarchy, in particular for the existence as a scaled up variants of hadron physics leading to a rather radical proposal for the physics of the Sun [L188].

Shipman found that the honeybee dance represents position in $SU(3)/U(1) \times U(1)$ coding for the direction and distance of the food source in 2-D plance! Why should this be the case? The explanation could be that the space-time surfaces as intersections of 6-D counterparts of the twistor spaces $ISO(2) \times \cup_i H^3(a = a_i)$ *resp.* $SU(3)/U(1) \times U(1)$ identified as a root of analytic function f_1 *resp.* f_2 [L184] have space-time surface as 4-D intersection so that honeybee dance would map the point of the flag manifold $SU(3)/U(1) \times U(1)$ to a point of $M^4 \times S^2$ or $\cup_i H^3(a = a_i) \times ISO(2)$ (locally). The restriction to a 2-D subset of points could be due to the measurement of the distance of the food source represented by the point of H_i^3 (or M^4).

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Chapter 10

Dark valence electrons and color vision

10.1 Introduction

By its large orbital radius dark valence electron (dark in TGD sense, $h_{eff} = n \times h$) sees atomic nucleus and other electrons, which are ordinary, effectively as an object of charge $Z_{eff} = 1$. Dark valence electron has reduced mass which in excellent approximation equals to that of electron so that the spectrum of bound state energies and transition energies is scaled down by the factor $(h/h_{eff})^2$. This irrespective of what the atom is. The only condition is that there is single unpaired valence electron guaranteed if Z for the atom is odd. For even Z an odd number of valence electrons must be associated with valence bonds: this would be the case for OH radical for instance.

The dynamics of dark valence electrons is universal with universal transition energy spectrum. One obtains a fractal hierarchy of dynamics labelled by the value of $(h/h_{eff})^2$, where $h_{eff} = n \times h_0$, h_0 the minimal value of Planck constant, not necessary equal to h so that one has $h = n_0 \times h_0$. The quantum critical dynamics characterizing living matter in TGD Universe is indeed universal.

The dark photon communications in living matter could utilize these universal energy spectra besides cyclotron energy spectrum and Larmor spectrum assignable to dark particles at flux tubes and the spectrum of generalized Josephson frequencies assignable to cell membrane [K50, K37]. In particular, vision and even other sensory modalities could rely on the transitions induced by the absorption of dark valence electron. In TGD also other sensory percepts are communicated from sensory receptors to the sensory areas of cortex [L60] and also here same universal transition energies of dark valence electrons might be involved.

This hypothesis when combined with the earlier ideas about color qualia leads to a highly predictive and testable model for the perception of colors. In particular the condition $h = n_0 \times h_0$, $n_0 > 1$, is necessary for the model to work. $n_0 = 4$ and $n_0 = 6$ look the most realistic options. For $n_0 = 4$ the number of values of $n = 8, 9, 10$ and correspond to the number 3 of color sensitive receptors whereas $n_0 = 6$ the number of values $n = 12, 13, 14, 15$ suggests the existence of a fourth color receptor sensitive to red light.

The statistical aspects of color summation can be understood from TGD inspired theory of consciousness in terms of the hypothesis that self experiences the mental images of sub-self as kind of statistical averages. The identification of quark colors as fundamental color qualia, the entanglement of quarks and antiquarks to form states in one-one correspondence with charged gluons, and the twistor space of CP_2 play key roles in the model of color summation.

Remark: There is experimental evidence for the notion of dark valence electron coming from the decades old anomaly related to rare Earth metals [L67] (see `http://tinyurl.com/ybejzq87`) for which TGD provides an explanation [L67] (see `http://tinyurl.com/y8pqcc8s`). This finding led to a proposal that valence bonds could also involve non-standard values of Planck constant [L65] (see `http://tinyurl.com/ycg94xpl`).

10.1.1 What could happen in seeing?

For years ago I developed a model for color qualia [K50]. In QCD strong interactions are jokingly called color interactions because the algebra of color charges for quarks is analogous to that assignable to color summation. The sum of color charges of quarks vanishes and the situation is analogous to the summation of the basic colors with proper intensities to white color. If one considers charged gluons, one can extend the algebraic picture so that one has 3 pairs of complementary colors with black and white included as a complementary pair.

In case of quarks one has also the interpretation that quarks and antiquarks have complementary colors so that black and white are included as a pair of complementary colors. In this case the standard color summation would mean that white color assignable to rods and black color assignable to dark current would remain in visual field. This interpretations seems to be the most reasonable one.

As I realized that TGD "almost-predicts" a hierarchy of p-adic fractal copies of hadron physics and that the length scale range 10 nm -2.5 μm contains as many as 4 Gaussian Mersenne primes defining excellent candidates for copies of hadron physics, it became obvious that much more than analogy could be in question. Also the finding of topologist Barbara Shipman [A10, A13, A9] that honeybee dance seems to relate to the flag manifold $F = SU(3)/U(1) \times U(1)$ defining the twistor space of CP_2 and playing a key role in twistor lift of TGD [K126, K13, L71, L88] suggests that dark hadron physics might be highly relevant for living matter and visual consciousness [L82]. The realization of the hierarchy of Planck constants $h_{eff} = n \times h_0$ defining second length scale hierarchy gave further good reasons to take the analogy very seriously.

I have also studied several models for the visual qualia and perception.

1. TGD approach differs from neuroscience in that our sensory qualia are assigned to sensory receptors [K50] [L60] (see `http://tinyurl.com/yczv2o5b`). Note that we would represent only single level in self hierarchy. Entanglement would allow brain and also our magnetic body to share these qualia. In neuroscience approach they are believed to be somehow generated in brain, and the basic unsolved problem is to understand how this is possible: the neural network looks locally exactly the same at various sensory areas.

   Phantom limb phenomenon is the basic objection against this proposal but can be circumvented [K101]. The pain in non-existing limb would be memory of pain and sensory memories can be induced by electrical stimulation of temporal lobes. In zero energy ontology (ZEO) the pain would be in geometric past where the pain was felt in still existing limb.

   What is essential would be quantum entanglement between magnetic body, brain, and sensory organs and classical communications using dark photons propagating with light velocity. This allows very rapid virtual sensory input as feedback from brain (and MB) to brain and allows to build standardized sensory mental images by forth-and-back communications between brain and sensory organ [L60]. This is nothing but pattern recognition leading to standardized sensory mental images nearest to the sensory input. In the case of REM dreams one would have only the virtual sensory input.

2. Sensory capacitor model for sensory receptor [K50] assumes that sensory qualia correspond to flows of particles with fixed quantum numbers specifying the quale in question. In the case of color qualia quantum numbers would be color quantum numbers of quark or gluon. One would have the analog of di-electric breakdown occurring at critical voltage, whose analog would be generated by sensory input. Note that this model is based on kinetics but that the identification of quale as color quantum numbers resulting in state function reduction is an essential element of the model.

3. Second - more quantal - model for sensory receptor emerged during writing this article. One would have a pair (A,B) of systems such that A contains quarks and B antiquarks (possible in principle since TGD predicts hierarchy of QCDs), which are entangled to form states analogous to gluon like states. The density matrix is 3×3 matrix and measurement of color quantum numbers produces an ensemble of quark states. The 3 quark states would correspond to basic colors (blue, red, white) having (yellow, green, black) as complementary colors represented by antiquarks.

The ensemble would give rise to the experience of colors obtained by color summation: density matrix would correspond to intensities of various colors in color summation. White/dark would correspond to brightness/darkness of the color. If the ensemble would be associated with sub-self of self (perceiver) TGD inspired theory of consciousness [K68] [L72] predicts that the experience corresponds to a kind of ensemble average.

4. I have constructed a ZEO based model for the generation of color qualia. In ZEO [L72] ordinary states are replaced by zero energy states identified as pairs of ordinary states at opposite boundaries of causal diamond (CD, intersection of future and past directed light-cones of M^4 with points replaced with CP_2) serving as the embedding space correlate for self as a conscious entity and analogous to events. "Zero energy" means that the total conserved quantum numbers of the members of the pair are opposite, which is only a way state the conservation laws used also in QFT context. At either boundary one has ordinary states with a fixed sign of energy.

   CD sizes form a hierarchy and for sensory qualia the sizes are rather small: time scale would be around .1 seconds. During the sequence of state function reductions determining the life cycle of self the active boundary of CD drifts farther away from the passive one (flow of geometric time) and the states at it change reduction by reduction. These reductions would be analogous to so called weak measurements in standard quantum measurement theory. The states at the passive boundary of CD are unaffected in the sequence of state function reductions as also passive boundary itself. As a special case these states could correspond to quarks in eigenstates of color quantum numbers (Y, I_3) giving rise to a sensation of pure basic color with black and white counted also as pair of conjugate colors.

   The ensemble of quarks with well-defined color quantum numbers would correspond to sub-selves of sub-self and would give rise to color summation at the level of conscious experience.

At this moment it is better to keep mind open for various options. The kinetic picture could be consistent with this picture if the particles with fixed quantum numbers correspond to the passive boundaries of sub-CDs associated with sub-CD.

I was somewhat surprised as I realized that I have not considered what might happen in the series of events leading to color sensation at the first step atter photon is absorbed by sensory receptor. In the following I shall look what comes out if one takes the idea about the universality of color vision realized in terms of transitions of dark valence electrons.

10.1.2 Could the transitions of dark valence electron produce the universality associated with quantum criticality?

The basic hypothesis is that the value of Planck constant is quantized: $h_{eff} = n \times h_0$. Here h_0 is the minimum value of h_{eff}, which need not be equal to ordinary Planck constant h but one has $h = n_0 \times h_0$. $n_0 > 1$ is quite possible, and the experiments of Randell Mills in fact suggest $h = 6 \times h_0$ [L46](see `http://tinyurl.com/goruuzm`). What Mills claims [D9] is that hydrogen has states with binding energy scale larger that for the ordinary hydrogen atom. Therefore the scaling factor binding energy scale would be. The scaling factor for the binding energy scales would be

$$(\frac{h}{h_{eff}})^2 = (\frac{n_0}{n})^2 \quad , \quad n = 2n_0, 2n_0 + 1, ...$$

At fundamental level the real Planck constant would be h_0, and h_{eff} would be effective Planck constant and due the n-sheet covering character of the space-time surface equal the dimension of extension rationals defining the adele at the given level of hierarchy of adeles giving rise to a number theoretic characterization of evolutionary hierarchy [L69, L70].

The orbital radius of dark electron scales as $(n/n_0)^2$. This might have dramatic consequences concerning the understanding of the quantum criticality of biology strongly suggested by the quantum criticality of TGD Universe meaning that any system is quantum critical in some scale. Quantum criticality implies universal dynamics and this would be obviously true for dark valence electrons. Quantum criticality involves also fractality and the hierarchy of size scales of dark electron orbits would imply this.

1. Lonely dark electron of any atom seems the effective charge $Z_{eff} = 1$ because almost complete screening takes place because of other electrons with much smaller orbital radii. The atom behaves effectively like hydrogen as far as the lonely valence electron is considered.

2. The spectra of effective dark hydrogen could correspond to energies central for biology. Note that the frequencies (wavelengths) would be scaled down (up) by n_0/n (n/n_0). These energies would correspond to transitions $n_P = m_1 \to m_2$, $m_i = 1, 2, ...$ of hydrogen atom changing the principal quantum number denoted by n_P instead of n now). The transition energies would be given by

$$E(n, m_1, m_2) = (\frac{n_0}{n})^2[\frac{1}{m_1^2} - \frac{1}{m_2^2}] \times E_I(H) \quad , \quad E_I(H) = 13.6 \ eV \quad .$$

   These spectra produce a fractal being related to each other by a scaling of a square of rational number.

3. What ranges of n one can consider for given n_0?

   (a) A reasonable working hypothesis is that the values of n are such that the energies are above thermal energy about .027 eV at physiological temperature 37 K. The maximal value of n would correspond to $n_{max} \in \{89, 112, 134\}$ for $n_0 \in \{4, 5, 6\}$ and lowest value of n taken to be $2n_0$ and corresponding to the energy 3.4 eV somewhat above the visible energies (2.39 eV corresponds to the boundary between UV and visible).

   (b) A stronger working hypothesis is that the values of n are such that the transition energy associated with the ionizing transition $n_P = 1 \to \infty$ is such that the transition energies belong to the energy range of bio-photons containing at least visible and UV photons. UV region corresponds to the values $n < 2n_0$.

   (c) Even stronger condition is that these energies containing the energy range of visible photons spanning in good approximation one octave. For given value of n_0 this would give $n = 2n_0, 2n_0 + 1, ..., 2n_0 + \Delta$, where Δ is determined by octave condition and therefore satisfies $\Delta \geq 2(\sqrt{2} - 1) \times n_0$.

Some remarks are in order.

1. An energy conserving h_{eff} changing transition increasing n_0 to n must occur before the transition of dark valence electron. These transitions would be fundamental in TGD and could also involve emission or absorption of energy. I have proposed that the temporary reduction of the value of h_{eff} liberating energy and followed by return to the original value is a basic mechanism of catalyst action [**?**]see `http://tinyurl.com/goruuzm`). The reduction of h_{eff} would reduce the length of flux tubes connecting the reacting molecule and catalyst and liberate this energy kicking the reacting molecules over the potential wall making reaction fast. In particular, the transitions changing the value of n for lonely dark valence electron could play an important role in bio-catalysis. If so, the dynamics behind bio-catalysis could be extremely simple at the dark level.

2. The model for visual perception would fail for the conservation option $n_0 = 1$ so that the finding of Mills [**?**]onforms with the proposed view about vision. The model is most realistic for $n_0 = 4$ and $n_0 = 6$. for $n_0 = 6$ the model however suggets a yet un-identified photoreceptor sensitive to red light.

3. How the model of color qualia in terms of measurement of color quantum numbers of quark and antiquark could relate to the proposed model? The most natural proposal is that the excited dark electron returns to a lower excited state by emitting dark photon decaying to dark quark-antiquark pair. Quarks could correspond to the p-adically scaled up variants of hadron physics assignable to the Gaussian Mersennes with p-adic length scales in the length scale range relevant for cell nucleus are excellent candidates.

10.2 Could dark photon absorption give rise to visual perception?

What really happens as photon is absorbed by photoreceptor? Could the absorption give rise to transitions of dark valence electrons and have therefore scaled variant of hydrogen spectrum? In studying this hypothesis I will utilize information about visual perception in Wikipedia (see `http://tinyurl.com/y88k583f` and `http://tinyurl.com/d6tdw54`) and various web sources (see for instance `http://tinyurl.com/yarthc6u`).

10.2.1 Is vision at basic level seeing of dark photons?

Before continuing some general remarks are in order.

1. Color perception is defined as the ability of organism to distinguish between different wavelengths (or frequencies). In standard quantum theory one could replace wavelength with energy but if the hierarchy of Planck constants is accepted one must be cautious. If incoming photons have $h_{eff} = h = n_0 \times h_0$ the dark photons produced in the process have longer wavelength but same energy.

2. The colors produced by single frequency are so called pure colors. The mixing of light with different wavelengths and varying intensities produces colors, which need not be pure. For instance, brown cannot be produced by single wavelength. Summation of colors means that the mixing of light with two colors produces large number of colors produced by single wavelength.

3. TGD suggests that all sensory qualia involve transitions of dark valence electrons induced by dark photons in various wavelength ranges. In the case of olfaction there is indeed strong support that it is seeing in infrared [I61], [J124, J3] [K50]. The transitions of dark valence electrons with values of n corresponding to energies outside the visible range might be involved.

4. One cannot exclude the possibility that the absorption of ordinary photons is followed by emission of dark photon generated as dark valence electrons drops to the ground state. This option will not be however considered in the following.

One could argue that visual perception relies on universal mechanisms in the sense that very many molecular structures could allow it. The observations made above inspire the idea that the absorption of photon in photoreceptor involves the transformation of incoming ordinary photons to dark photons with $n = 2n_0, ..., 2n_0 + \Delta$ for n_0, which could be in the range $\{4, 5, 6\}$ as will be found, and induces a transition of dark valence electron to a state with higher energy.

1. This transformation could involve absorption and subsequent emission as dark photon with energy in the spectrum of effective dark hydrogen atom with discrete spectrum in the interval

$$(\tfrac{n_0}{n})^2 E_I(H) \times [3/4, 1] \quad , \quad n \in \{2 \times n_0, ..., 2 \times n_0 + \Delta\}$$

   consisting of lines $(n_0/n)^2 E_I(H) \times [3/4, 8/9, 24/25, ..n^2 - 1/n^2, ...]$. There would be 4 clearly distinguishable basic energies corresponding to $(3/4) \times (n_0/n)^2 E_I(H)$ perhaps identifiable as basic colors. One as $\Delta = 2$ and 3 bands for $n_0 = 4$ and $\Delta = 3$ and 4 bands for $n_0 \in \{5, 6\}$.

   The conditions that the number 3 of cones equals to the number of values of n and that the range of visible wavelengths spans an octave selects $n_0 = 4$ uniquely. $n_0 = 6$ satisfies the octave condition but suggests strongly the existence of 4:th yet un-identified color-sensitive receptor.

   Remark: The transitions $n_P = m_1 > 1 \to m_2$ from higher states would correspond to energies below the visible range and are not considered. They might however plays some role.

2. The model assumes that the incoming light - assuming that it has $h_{eff} = h$ - transforms to dark light in the receptors having $h_{eff} = (n/n_0) \times h$, $n = 2n_0, 2n_0 + 1, ..., 2n_0 + \Delta$, where Δ must be such that the range of visible wavelengths is covered. Wavelength would therefore increase by factor n/n_0 from that for incoming photon wavelength in the range $[2, 2 + \Delta/2]$ whereas energy would be same. Dark valence electron would be kicked to an excited state by the absorption of dark photon. This would lead to the color perception. How this happens is a separate problem.

The beauty of the mechanism would be that the atom involved could be almost anything: what is only required that there is lonely valence electron that can become dark. This hypothesis will be studied in the sequel. I try also to relate it to earlier ideas about vision and color qualia.

10.2.2 Comparison with empirical facts

In the following the predictions of the model are compared with empirical facts about photoreceptors and the conclusion is that $n = 4$ and $n_0 = 6$ options are the most realistic ones. $n = 6$ option however suggests the existence of a not yet identified receptor sensitive to red.

Basic facts about photoreceptors

Consider now a comparison with basic empirical facts about photoreceptors.

1. There are 4 kinds of receptors. 3 photoreceptors giving rise to color sensation are called blue, green, and red cones. Rods are receptors, which do not produce color sensation unless one counts white and black as colors. The sensation of black does not mean absence of visual consciousness so that black could be regarded as color. Black could be interpreted as the color produced by so called dark current (see `http://tinyurl.com/6tu3q26`) present in retina also in the absence of light stimulus. Furthermore, rods are sensitive to same wavelengths as green cones and also other receptors to some extent in accordance with the fact that color is not a property of light but characterizes the qualia induced by the absorption of light.

2. The Wikipedia article gives the wavelengths λ_{max} at which maximum absorbance occurs. Figure 14a)(`http://tinyurl.com/yc6dcqn7`) of the article of Helga Kolb gives slightly different values for λ_{max}. According to the Wikipedia article the maximum absorbance occurs for

   - red cones at $\lambda_{max} = 564$ nm, which is in yellow rather than red. Red cones respond to red, orange and yellow but very weakly to red light, which raises the question whether there could exist yet unidentified receptors sensitive to the red wavelengths;
   - green cones at $\lambda_{max} = 534$ nm; green cones respond mostly to green light;
   - blue cones at $\lambda_{max} = 420$ nm in violet. Blue cones respond to cyane, blue and violet and even in UV but the lense prevents the UV radiation from arriving to the receptors;
   - rods $\lambda_{max} = 498$ nm in cyane at the boundary of cyane and blue.

3. The absorption curves decrease rather rapidly above λ_{max} but approach to much larger value for small wavelengths, which suggests that given receptor is sensitive for values $n \leq n_{max}$ rather than single value of n. The absorbance curves are given only in finite interval, and I do not know whether this is due to the lack of empirical data or whether the absorbance reduces to zero outside the range spanned by the curve. For the model assigning single value of n to the receptor this would happen.

Predictions for $h = n_0 \times h_0$, $n_0 \in \{4, 5, 6\}$

In the following tables the energy and wavelength ranges for options $n_0 \in \{4, 5, 6\}$ are listed together with the list of λ_{max} values to see whether the option is realistic. Energy range for the photons corresponds to the range between the photon energy $3E_I(n, n_0)/4$ associated with

$n_P = 1 \to 2$ transition equal and $E_I(n, n_0)$ corresponds to the ionization energy. The allowed photons energies form a discrete band like structure.

1. $n_0 = 4$ *case*

The predictions for $n_0 = 6$ are given in table 10.1.

n	E/eV	λ/nm	λ_{max}/nm
8	[2.55,3.40]	[365,486]	420
9	[2.02,2.68]	[462,615]	534 (498)
10	[1.63,2.18]	[570,759]	564

Table 10.1: Table gives energy and wavelength ranges for photons for option $n_0 = 4$ for various values of n. The last column gives the values of λ_{max} for cones and rods (in brackets) helping to see whether the option is realistic.

The wave length ranges look rather realistic except that $\lambda_{max}/nm = 534$ for red receptors does not belong to the range of wavelengths for $n = 10$ being slightly below it. Note however that the assumption $n \leq n_{max}$ is strongly suggested (if not forced) by the properties of absorbance curves: since there is considerable overlap between $n = 9$ and $n = 10$ bands, λ_{max} could be shifted towards $n = 9$. Visible spectrum extends to 750 nm in red and the prediction is that it should extend to 759 nm.

2. $n_0 = 5$ *case*

The predictions for $n_0 = 5$ are given in table 10.2.

n	E/eV	λ/nm	λ_{max}/nm
10	[2.55,3.4]	[365,486]	420
11	[2.11,2.81]	[442,588]	534 (498)
12	[1.77,2.36]	[526,700]	564
13	[1.51,2.01]	[617,822]	∼662?

Table 10.2: Table gives energy and wavelength ranges for photons for option $n_0 = 5$ for various values of n. The last column gives the values of λ_{max} for cones and rods (in brackets) helping to see whether the option is realistic.

One can assign to each λ_{max} a unique value of n such that the corresponding wavelength range contains λ_{max}. The visible spectrum extends to 750 nm in red whereas for $n = 12$ the end of the spectrum would be at 700 nm. The inclusion of also $n = 13$: this would give additional wavelength range $[617, 822]$ nm which would contain red wavelength range [620,750] nm. The estimate for the corresponding λ_{max} is obtaining by assuming that is scales like n^2. In this picture, red cones would be called yellow cones, and $n = 13$ would correspond to a new receptor sensitive to red and IR wavelengths. The upper bound 822 nm for visible wave lengths makes possible IR vision unless the receptors absorbing the incoming photons and transforming them to dark photons are insensitive to IR photons.

3. $n_0 = 6$ *case*

The predictions for $n_0 = 6$ are given in table 10.3.

Wave length ranges look rather realistic. If one is accept that $n = 15$ corresponds to a new yet unidentified receptor, one can assign to each n a unique receptor and λ_{max} belongs to the wavelength range in question.

It would not be surprising if λ_{max} would scale as n^2 (for absorbance curves see `http://tinyurl.com/y7t5w2m2`). One should have $r(n) = \lambda_{max}(n+1)/\lambda_{max}(n) = (n/(n+1))^2$. Let

n	E/eV	λ/nm	λ_{max}/nm
12	[2.55-3.4]	[365-486]	420
13	[2.17-2.89]	[429-571]	534 (498)
14	[1.87-2.49]	[498-663]	564
15	[1.63-2.18]	[570-761]	$\sim$ 649?

Table 10.3: Table gives energy and wavelength ranges for photons for option $n_0 = 6$ for various values of n. The last column gives the values of λ_{max} for cones and rods (in brackets) helping to see whether the option is realistic.

$r_1(n)$ denote the corresponding ratio for cones (green/blue and red/green). The ratios $(r(n)/r_1(n)$, $n = 12, 13$ would .9 and 1.1: ideally they should be equal to 1. For $n = 14$ one would $r(n) = (15/14)^2 = 1.15$. This gives an estimate for λ_{max} of possibly existent $n = 15$ receptors as $\lambda_{max} \sim 1.15\lambda_{max}(15) = 649$ nm (red begins at 620 nm).

Remark: That $n = 13$ should correspond to both green and white cones is somewhat disturbing. $n = 14$ receptor for red - or rather yellow - however covers the wavelength range 498-663 nm whereas the upper boundary of $n = 12$ is 486 n. Only the range $[486, 498]$ nm remains uncovered. Could $n = 13$ correspond to color white? Perhaps this could be tested by using incoming radiation in the wavelength range $[486, 498]$ nm.

The cautious conclusion is that $n_0 = 4$ and $n_0 = 6$ are the most realistic options. For $n_0 = 4$ there would be only three cones but for $n_0 = 6$ the existence of new receptor is suggestive.

Some further remarks concerning are in order.

1. The absorbance graphs suggest that the receptors do not correspond to single value of n but to several values $n \leq n_{max}$.

2. Each receptor is sensitive in a region containing two values of n. Consider $n_0 = 6$ as example. $n = 15$ touches $n = 13$ if the transitions inducing large changes of the principal quantum number n_P are allowed (almost ionization). For given receptor the values $n < n_{max}$ are strongly represented: the value of absorbance decreases to a non-vanishing value in the region $\lambda < \lambda_{max}$ and can even slightly increase. For $n > n_{max}$ absorbance approaches zero rapidly. Blue cones would correspond to $n_{max} = 12$ and green cones to $n_{max} = 13$. Red cones would correspond to both $n_{max} = 14$ ja $n_{max} = 15$. Rods would correspond to $n = 13$.

3. Due to the overlap of the energy ranges, the same energy can correspond to two values of n and thus different dark wavelengths. This forces to ask how the color quale is determined: does the transition energy or the corresponding dark wavelength determine the color? If it is energy then very nearly the same transition energies for say $n = 14$ and 15 in case of $n_0 = 6$ would correspond to nearly the same color although the dark wavelengths would differ by factor 14/15. If it is wavelength then same energy for incoming photon could correspond to 2 different colors for overlapping dark energy bands.

   Remark: This raises a question about the determination of the sensitivity to photoreceptors to the incoming visible light: is it wavelength or energy? If would be wavelength according to Wikipedia definition and this one might expect since the experiments about color vision were carried out before emergence of quantum theory. It however seems that the incoming visible light must correspond to $h_{eff} = h = n_0 \times h_0$: otherwise the model leads to difficulties.

4. Evolution as a growth of h_{eff} would predict that small values of n have emerged before the low values. In particular, IR vision would correspond to a higher level in the evolution and larger values of n. Small values of n would correspond to a lower level and would have been reached. Indeed, no examples about IR vision are known whereas UV vision requiring $n < 2n_0$ is common: bees provide one particular example.

5. Tetra-chromacy (see `http://tinyurl.com/mntowuw`) occurs for birds, fish, amphibians, reptiles, insects and some mammals and sometimes even for humans, means that there is additional color receptor in UV with $\lambda_{max} = 370$ nm slightly above minimum wavelength 365 m

for blue cones. For $n_0 = 6$, the most natural interpretation would in terms of $n = 11$ which corresponds to wavelength range [307,408] nm.

Further phenomena that one should understand

Color vision involves several phenomena that one should understand.

1. In the summation of colors light beams with several wavelength and varying intensities are superposed. The perceived color need not correspond to a sensation created by single wavelength. One can however produce colors produced by single wavelength by using summation of two colors (actually not all of them). The perceived color depends on the ratio of the intensities: only its brightness depends on the intensity scale.

   This suggests that at quantum level the perceived color is determined as a kind of statistical average. In TGD inspired theory of consciousness this could mean that color qualia correspond to sub-sub-selves. The resulting mental images is sub-self determined as a kind of statistical average over sub-sub-selves defining mental images of sub-self.

2. In the subtraction of light one mixes different colored substances. In the mixture only the common wavelengths are reflected and the color becomes darker for this reason (one could see this as a mixture of colors with black regarded as a color).

3. There is also the phenomenon of complementary colors. Consider as an example $n_0 = 6$ option.

   (a) Red and green form pair of complementary colors. Complementary colors sum up to white in color summation, when the intensities are suitably chosen. For $n_0 = 6$ red is contained by $n = 14$ and $n = 15$ bands and green by $n = 13$ and $n = 14$. Could the complementary colors of colors in $n = 13$ band be in $n = 14, 15$ bands? Note that $n = 15$ band contains orange and yellow (partially).

   (b) Blue and yellow are also complementary colors. Yellow is contained partially in $n = 14$ ja $n = 15$. Blue is contained $n = 12$ ja partially $n = 13$.

   (c) As already argued that black and white could be seen as complementary colors and this interpretation would allow to see also rods as color receptors and dark currents as a generator of black background color. This view would also fit nicely with the TGD based model of color qualia to be discussed in the sequel.

10.2.3 What color summation could correspond in TGD framework?

In color summation the light stimuli at different wavelengths sum up. By combining two wavelengths one obtains other colors produced by single wavelengths. Not all of them can be produced and there are also composite colors not produced by single wavelength.

The rough rule is that for two colors one can find a third color such that the sum of all three is white. This means that one can construct colors as composites of two basic colors. These wavelengths are not unique but correspond to some wavelengths in some wavelength ranges. The third color corresponds to a suitablefor the intensities of the summands. The empirically deduced summation rules are described by "horse shoe" diagram (see `http://tinyurl.com/yc5yg4dg`).

1. One selects two wavelengths λ_1, λ_2, which correspond to two basic colors, say green and red. One mixes these wavelengths with fractions p ja $1 - p$. Mixing fractions correspond to coordinate axes x for red ja y for green. One assigns to each pair $(p, 1-p)$ a rectangle, whose vertices are at $(0, 0)$ (pure blue), $(0, p)$ (pure green), $(1 - p)$ (pure red), and at $(p, 1 - p)$, which corresponds to the sum color and is located at the edge of a triangle connecting points (1,0) and (0,1). This points of this edge are labelled by wavelengths. The mixing ratios for the desired composite color can be read from the diagrams.

2. One however encounters a problem. One does not obtain all possible colors created by single wavelength in this manner. If one wants all colors one must allow also negative fractions p or $1-p$ so that the portion of one color would be larger than one and that of another color negative. The edge of the triangle indeed continues as "horse shoe" curve (see `http://tinyurl.com/yc5yg4dg`) to the negative values of x coordinate and y-coordinate going through origin (pure blue). The various nuances of blue correspond to the regions $x < 0$ and $y < 0$. In these regions one must use other pair of basic colors to construct the colors.

   At the negative values of x one would have blue, which is even more blue that origin $(0, 0)$ and this is not possible since the portion of red would be negative. Hence one must use another pair of colors to produce the colors along for $x < 0$ portion of the curve.

3. The ratio of the intensities of the mixed colors determines the resulting color. In quantum theory context this would suggests that mixed colors correspond to entangled quantum states such that the eigenvalues of the density matrix correspond to the portions p and $1-p$. A more realistic interpretation would be that quantum measurements of color for these entangled pairs produces pure states with red and green appearing with probabilities p ad $1-p$ in the resulting ensemble.

TGD suggests two basic models for the generation of color qualia quantum model and geometric model, which might correspond to quantum model via quantum classical correspondence.

1. One could assume that a particle with color hyper charge and color isospin given by (Y, I_3) determines basic colors and their number is given by those states of color multiplet for which one has $(Y, I_3) \neq (0, 0)$. For the complementary color of (Y, I_3) the color quantum numbers would be $(-Y, -I_3)$.

   Color summation would correspond to the summation of the quantum numbers of quarks to zero. Quark triplet and its conjugate would give 3 colors and their complementary colors. One would not obtain black and white as colors. It is not however clear how to understand color summation in this picture. As a matter of fact, the color summation means that only the rods contribute to the color sensation and give rise to a sensation of white color. It would be better to say that the sum of color and its conjugate gives no sensation at all.

2. Another option is that the 6 charged members of gluon octet corresponds to the 3 basic colors and their complementary colors. Also now black and white are most naturally counted as a pair of complementary colors.

One can also consider a model in which there is a geometrical entity possessing naturally color quantum numbers. Both quark and gluon option can be formulated in this framework.

1. For quark option the two complex $CP_2 = SU(3)/SU(2) \times U(1)$ coordinates transforming linearly under $U(2)$ satisfy the criterion. The rays of the Hilbert space for 3 quarks could be parameterized by CP_2. Note however that the superposition of states cannot be described if one uses CP_2 since phase information relevant to the superposition is lost in projective equivalence.

   This would suggest a geometric model of color summation in which three basic colors correspond to 3 different coordinate patches of CP_2. Given coordinate patch would correspond to a particular choices of 2 basic colors in the summation. Color rotations acting linearly would generate different choices of complex coordinates in given patch and would correspond to different choices the 2 basic colors. The intensities of summed colors would correspond to the moduli squared for the complex CP_2 coordinates. As a matter fact, the complex coordinates have anomalous hypercharge $-2/3$ due the division of the first two coordinates with the third coordinate having $(Y, I_3) = (2/3, 0)$.

2. For the gluon option the two neutral gluons are eliminated by using instead of C^8 twistor space $F = SU(3)/U(1) \times U(1)$ of CP_2 playing key role in twistor lift of TGD [K126, K13, L71, L88]. F is 6-D and has 3 complex coordinates and is a bundle with CP_1 as fiber and CP_2 as base. CP_1 corresponds to charged members of isospin triplet representing the two colors black and white. CP_2 corresponds to the two gluon pairs with opposite isospins, which correspond two

quarks out of 3 appearing in the color summation with the choice of basic colors interpreted as the choices of a particular coordinate patch for CP_2.

For CP_1 one has two coordinate patches and now the selection of patch would correspond to the selection of black or white as basic color the intensity of this color in the superposition of 3 colors would determine the darkness/brightness of the color. The generalization of color summation would mean that also the effect of the rod receptors is taken into account as counterpart for CP_1.

Could the geometric pictures based on F and CP_2 be interpreted in terms of Hilbert space picture? The twistor space picture indeed suggests quantum classical correspondence at the level of twistor lift of $M^4 \times CP_2$. Since the basic for quarks corresponds to a choice of free basic frequencies, one can however argue that the twistor space actually parametrizes different choices of basic colors.

Generalization of color summation to include black and white as colors

The simplest interpretation for color summation would be in terms of quark triplet representing points of complex Hilbert space C^3.

1. Quarks correspond to three basic colors and antiquarks to their conjugates. Other colors could be described in terms of entanglement of two quark states with reference states. Density matrix would describe the states.

2. The reference states could be states with opposite color quantum numbers that is antiquarks. What comes in mind first is that the entangled state has vanishing color quantum numbers but would be color singlet. This modification of color confinement in TGD framework to require only the vanishing of net values of Y and I_3 has been discussed already earlier in [L88].

3. Standard color summation would correspond to a superposition of two chosen quark states entangled with 2 reference states. The probabilities determined by the density matrix would correspond to normalized intensities for light stimuli at corresponding wavelengths. The perceived colors would be obtained by the empirical "horse shoe" rule (see `http://tinyurl.com/yc5yg4dg`). The statistical aspect could be understood if state function reduction occurs for the ensemble of paired states. The observed color would be determined as the average color quale as already explained.

   In the geometric picture color summation could be interpreted at the level of CP_2 and basic colors would be determined by the moduli of 2 complex CP_2 coordinates. Apart from brightness, the perceived color would depend on the ratio $|\xi^1/\xi^2|$ of these coordinates so that one would obtain the standard view about color summation but black and white could not be understood as colors.

   Ordinary color summation is however problematic from the point of view of Hilbert space interpretation since it means projection to 2-D subspace. Projectivity for Hilbert space does not mean that third state has vanishing coefficient but only that it can be transformed to unity. As a matter of fact, in given coordinate patch of CP_2 the coefficient must be non-vanishing! In Hilbert space interpretation that sum of 3 probabilities equals to one. The 3 probabilities of the density matrix would correspond to the normalized intensities assignable to the three chosen frequencies with one corresponding to white as color (rods).

Ordinary color summation tells nothing about colors dark and white and darkness/brightness of the color. This suggests a modification in which one considers normalized states of quarks in C^3. If the states are entangled pairs of 3 quarks with antiquarks with opposite quantum numbers, the density matrix would reduce to diagonal 3×3 matrix and one would have 3 probabilities summing to unity. Physically the probability for $(Y, I_3) = (2/3, 0)$ state would correspond to the contribution of white and black to the superposition affecting the darkness of the color. Rods would be responsible for white contribution. Black would correspond to the dark current creating kind of background color sensation.

For this option the connection of Hilber space description with flag manifold F and CP_2 would be accidental and different quarks states would not correspond to points of CP_2 or F.

The choices of basic colors triplets as points of flag manifold

There exists an infinite number of choices of the 3 basic colors if the frequencies are continuous: the identification as transition frequencies of dark electrons however discretizes the situation. Could the different allowed choices of these triplets are be related by a discrete subgroup of color rotations relating various state basis for quarks to each other?

1. Color rotations would produce different basis assignable to different choices of three basic frequencies defining the basic colors. Color groups is 8-D $SU(3)$ on 8-D and quark states correspond to C_3. $U(1) \times U(1)$ leaves invariant entangled quark-antiquark states which have vanishing color quantum numbers but are not color singlets. There the space of entangled quark-antiquark states which do not include color singlet is $SU(3)$ orbit for a single state of this kind and equals to flag manifold $F = SU(3)/U(1) \times U(1)$ with complex dimension 3 or equivalently the space for the choices of color quantization axes. I have discussed the space-time representation of points of F in the model of honeybee dance [L82].

2. As explained, F has fiber space structure with CP_1 as a fiber parameterized by a complex coordinate with color isospin $I_3 = 1$. Base is CP_2 has two complex coordinates. This would suggest that the complex coordinate z of CP_1 fiber of F would correspond $n = 13$ and rods and its conjugate to its conjugate and dark current. CP_2 base of F would correspond to all all 4 values of n with coordinates and their conjugates representing colors and conjugate colors identifiable as two pairs (n_1, n_2).

   CP_2 is non-trivial as a manifold and 3 coordinate patches are needed. One can choose from the complex C^3 coordinates (z_1, z_2, z_3) two coordinates and there are 3 choices corresponding to 3 coordinate patches. These would correspond to the 3 choices for basic color pairs used to obtained other colors in color summation. For instance, one could have $z_1 \leftrightarrow$ red, $z_2 \leftrightarrow$ green, $z_3 \leftrightarrow$ blue as basic colors. By projectivity

3. Since the flag manifold F labels the possible choices of color basis, one expects that the choice of the basic color triplets as triplets of frequencies is not completely free. Certainly one must keep the variation of the basic frequencies within some limits. Could only a discrete set of basic frequencies be allowed? Could the allowed frequencies correspond to the transition energies for dark valence electron? Could this discrete set of frequencies correspond to a discrete set of points of F for various values of $n \in \{12, 13, 14, 15\}$. Could this correspond to a number theoretic discretization of F by replacing $SU(3)$ with its discrete finite sub-group $U(1) \times U(1)$ with its discrete counterpart in discrete sub-group of $SU(3)$?

   $\lambda(z_1, z_2, z_3)$ and (z_1, z_2, z_3) correspond to the same point, and one can use the coordinates $(\xi_1 = z_1/z_3, \xi_2 = z_2/z_3, 1)$ in one particular coordinate patch, which could correspond to red and green as basic colors whose mixing would give the remaining colors but not all of them since single coordinate patch is not enough. The ratio $r_{12} = |z_1/z_2|$ would determine the color in the standard picture about color summation. Including white and black, the ratios $r_1 = |z_1/z|$ and $r_2 = |z_2/z|$ would determine the color and its brightness. The phases of the F coordinates would not affect the experienced color quale.

   A couple of remarks are in order.

1. It would seem that the space of color qualia is locally like projective space RP_3, which is real variant of twistor space CP_3 appearing in the twistorialization of 4-momenta to be distinguished from the geometric twistor space $M^4 \times CP_2$ appearing at the level of M^4 geometry and possessing generalized Kähler structure ($M^4 \times CP_2$ is unique because the twistor spaces for the factors allow Kähler structure).

2. The obvious question concerns the qualia assignable to M^4 and interpretation of the corresponding twistor space. The point of twistor space could correspond to the choice of energy and spin quantization axes (energy quantization axis would define the rest frame). A possible identification for qualia could be as energy and spin in the rest frame. They would be analogous to brightness and color. Color triplet would correspond to spin 1 triplet.

How the two views about color vision might relate?

I have discussed above two views about color vision.

1. The transitions of dark valence electrons induced by the absorption of dark photon preceded by the absorption of ordinary visible photon by photoreceptor would represent the first step in the process leading to a color sensation.

2. The second step would give rise to a formation of entangled state of quarks and antiquarks with non-standard value of Planck constant and the measurement of color quantum numbers of quark as a state function reduction for the ensemble of entangled quark pairs would give rise to qualia, which in general would represent mixed colors.

   A more detailed view about the second step could look like follows.

1. Quark-antiquark pair could be formed by the return of the dark valence electron to an excited or ground state by an emission of virtual dark photon decaying to a possibly dark quark-antiquark pair, which should be non-relativistic. This is of course only the simplest option that one can imagine.

2. Quark and antiquark would naturally correspond to a copy of hadron physics labelled by Gaussian Mersenne $M_{G,n}$, $n \in \{151, 157, 163, 167\}$: the appearance of 4 Gaussian Mersennes in the biologically most interesting p-adic length scale range $[10, 250]$ nm covering the length scale relevant to cell nucleus is a number theoretical miracle.

   The p-adic mass scales for quarks need not correspond to those for hadron physics itself. For instance, for ordinary M_{107} hadron physics only c quark corresponds to M_{107} whereas s quark most naturally corresponds to $M_{G,k}$, $k = 113$ assignable to nucleus [K66, K80] and u and d current quarks with masses about 5 and 20 MeV correspond to even longer p-adic length scales. Thus light quarks would correspond to longer mass scales than hadron: the interpretation is in terms of the assignment of quarks to the magnetic body of hadron. t and b quarks would correspond p-adic length scales considerably shorter than hadronic length scales.

   Whatever the detailed picture is, Gaussian Mersennes are excellent candidates for mass scales of u and d quarks involved. The mass scale of quark for $k = 167$ corresponding to a p-adic length scale about 2.5 μm would be same as that of electron scaled from $k = 127$ to $k = 167$ and by p-adic length scale hypothesis equal to $2^{(167-127)/2} \times .5$ MeV $\simeq .5$ eV in IR and identifiable as the nominal value of the metabolic energy quantum. The mass scales for $k = 151, 157, 163$ would be related by the scaling $2^{(k-167)/2}$ to this scale and would be given by 128 eV, 16 eV, and 2 eV (this corresponds to red light) for $k = 151, 157, 163$. For $k = 151$ and $k = 157$ the mass scales are too high for photons in the range of visible energies.

3. $k = 163$ is the most realistic option but also 167 can be considered although now quarks must be produced from virtual photons decaying to a non-relativistic mass shell quark pair. Note that also decays of dark valence quark to excited state are possible and could give rise to on mass shall non-relativistic quark pairs with energies around .2 eV for $k = 167$.

4. Charge separation must take place for quark and antiquark. One option is that negatively (positively) charged quarks and antiquarks move to the outside (interior) of the cell membrane in the membrane potential of photoreceptor neuron.

Chapter 11

Dance of the honeybee and new physics

11.1 Introduction

For more than two decades ago mathematician Barbara Shipman made rather surprising finding while working with her thesis [A11, A12]. The 2-D projections of certain curves in flag manifold $F = SU(3)/U(1) \times U(1)$ defined by the so called momentum map look like the waggle part of the dance of the honey bee (see `http://tinyurl.com/c7pljpw`). Shipman found [A10, A13, A9] that one could reproduce in this framework both waggle dance and circle dance (special case of waggle dance) and the transition between these occurring as the distance of the food source from the nest reduces below some critical distance of about 10-20 meters. Shipman introduced a parameter, which she called α, and found that the variation of α allows to integrate various forms of the honeybee dance to a bigger picture. Since $SU(3)$ is the gauge group of color interactions, this unexpected finding led Shipman to as whether there might be a profound connection between quantum physics at quark level and macroscopic physics at the level of honeybee dance.

The average colleague of course regards this kind of proposal as crackpottery: the argument is that there simply cannot be any interaction between degrees of freedom in so vastly different length scales. This argument actually resembles the argument of nuclear physicists against "cold fusion" and is based on the dogma of length scale reductionism. Personally I however found this finding fascinating and wrote about the interpretation of this finding in the framework of TGD and TGD inspired consciousness [K50, K37].

During more than two decades a lot of progress has taken place in TGD, in particular I have learned that flag manifold F has interpretation as twistor space of CP_2 and plays a fundamental role in twistor lift of TGD [K126, K48, L71, K13]. Hence, when Johan Frisch contacted and asked whether I could help him to get material about the work of Shipman, I got interested in honeybee dance and realized that the earlier picture could be made much more detailed. I am grateful for Jerry Decker for finding links and references to the work of Shipman from web.

It is appropriate to begin by summarizing the new elements of TGD relevant for the honeybee dance.

1. In TGD framework an entire hierarchy of scaled variants of QCD like physics is possible by p-adic length scale hypothesis stating that preferred p-adic length scales $L_p \propto \sqrt{p}$ correspond to primes $p \simeq 2^k$. This hypothesis was inspired by the success of p-adic mass calculations [K79, K66]. In particular, in biologically especially relevant length scale range from 10 nm (cell membrane thickness) to 2-5 μ (size of cell nucleus) as many as 4 candidates for scaled variants of QCDs could exist: they would correspond to Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$, $k = 151, 157, 163, 167$. The existence of so many Gaussian Mersennes in so narrow a length scale range is a number theoretical miracle. The interaction of honeybee could be with scaled up variant of QCD like physics and the quarks could have the size of cell nucleus!

2. The flag manifold $F = SU(3)/U(1) \times U(1)$ has an interpretation as the space for the choices

for the quantization axes of color quantum numbers (color hypercharge and isospin). Few years ago it turned out that F is the twistor space of CP_2 and possesses Kähler structure [K126, K13, L71]. As a matter of fact, S^4 and CP_2 are the only compact spaces with twistor space possessing Kähler structure. Also M^4 and E^4 - kind of non-compact variants of S^4 - allow twistor space with Kähler structure (M^4 in generalized sense). Hence the existence of twistor lift of TGD implies that TGD is completely unique.

TGD inspired theory of consciousness [K68] leads to a proposal concerning the identification of qualia [K50]. One can distinguish between non-geometric qualia - colors, tastes, and odours - and geometric qualia representing geometric information such as angles and distances. Flag manifold qualia would be universal "general purpose" geometric qualia representing geometric information. In the model for the honeybee dance the point of 6-D flag manifold F would represent positional information about the food source and waggle dance would represent this point of F as a dynamical pattern very much like the point of momentum space is represented as orbit in configuration space.

3. TGD predicts hierarchy of Planck constants $h_{eff}/h = n$ labelling the levels of a dark matter hierarchy identified as phases of ordinary matter residing at flux tubes of magnetic bodies (MBs) assignable to ordinary physical systems. In the adelic vision h n corresponds to the dimension of the extension of rationals defining particular adele in the hierarchy of adeles having interpretation in terms of an evolutionary hierarchy [L69] [L70]. The scaling of Planck constant by n means similar scaling of Compton lengths implying zooming up of the microscopic physics. These scaled up variants of particles at the MB of the living system play a crucial role in TGD inspired quantum biology, and even suggests new physics associated with the notion of valence bond highly relevant to metabolism [L65] (see `http://tinyurl.com/ycg94xpl`).

This background gives good motivations for looking whether Shipman's findings could make sense in TGD Universe. It however turned out difficult to find any material relating to Shipman's work in web and the popular articles do not tell the details. There are several questions to be answered.

What do momentum map and 2-dimensional projection really mean? What the curves studied by Shipman really are?

1. Momentum map μ is a standard notion and actually familiar for physics albeit being represented using totally different language. In the case of general Lie group G acting as symmetries of symplectic manifold M, μ maps the elements of g ($su(3)$ now) represented as vector fields of M or the images of corresponding one-parameter groups (flows) to the elements of the co-adjoint algebra g^* of g having Poisson structure. One-parameter groups associated with the elements of g are mapped to conserved Hamiltonians associated with them. Mathematician speaks of co-adjoint orbits as images of orbits in M.

2. Physicist would see the situation either at the level of configuration space ("q-space") or momentum space ("p-space"). Exponential map takes each element X of Cartan algebra $h \subset g$ to an image of corresponding one-parameter group by exponential map, the orbit of the flow defined by X.

   Since M allows symplectic structure and G acts as symmetries, each orbit is characterized by conserved Hamiltonians associated with elements of g. Only the Hamiltonians assignable to h commute with respect to Poisson bracket.

   The image of H in M is spanned by 1-parameter subgroups associated with H. In momentum space picture given orbit corresponds to single point in co-adjoint algebra g^* defined by the two conserved Hamiltonians defining the momentum of the particle.

3. The choices of H are labelled by flag manifold F and each point of F defines a 2-momentum in h^*. The projection of F to $h*$ defines so called momentum polytope, which is hexagon. This notion makes sense completely generally.

What could be the TGD counterpart of this general picture? Consider first the general dynamics.

1. In TGD framework the new element is that the 2-D image Y of $U(1) \times U(1) \subset SU(3)$ in CP_2 is further projected to the space-time surface $X^4 \subset M^4 \times CP_2$: one simply forms the intersection $X = Y \cap X^4$. X (as already Y) carries vanishing induced Kähler form being thus analogous to Lagrangian sub-manifold. X is also analogous to the so called Chladni surface at which electric field vanishes: the physical meaning of these surfaces is discussed in [L44].

   The dynamics of the twistor lift of Kähler action [K126, L71, K13] reducing to a 4-D generalization of a dynamics coupling geodesic motion of point particle to induced Kähler field (analogous to Maxwell field) would fix space-time surfaces and therefore also the surfaces X. This dynamics could be also seen as a generalization of Chladni mechanism. Asymptotic self-organization patterns indeed correspond to the vanishing of the induced Kähler force inside given space-time sheet. These space-time regions correspond to external particles entering CD in ZEO based view about scattering. At point-like limit the external particles would be geodesic lines and in interaction regions move under Kähler force.

2. In the general case the dimension $D(X)$ of X satisfies $D(X) \leq 2$. One can have $D(X) = 2$ if space-time surface carries vanishing induced Kähler form: these surfaces are special case of minimal surface extremals for the twistor lift of Kähler action [K13] [L41].

   There are also other kinds of preferred extremals. Cosmic string solutions are of form $X^2 \times S^2 \subset M^4 \times CP_2$, where X^2 is minimal surface - string world sheet and S^2 is geodesic sphere of CP_2. CP_2 has two non-equivalent geodesic spheres. The first one has vanishing induced Kähler form and second is homologically non-trivial (non-contractible) and carries Kähler magnetic flux.

   One has also more general preferred extremals $X^2 \times Y^2$, where Y^2 is complex sub-manifold of CP_2 obtained by replacing S^2 with a sphere with $g \geq 1$ handles. These flux tubes are infinitely thin but one can deform them in M^4 directions to get magnetic flux tubes of finite thickness, which are key players in TGD inspired quantum biology.

3. The proposal is that simple modifications of these extremals exist as preferred extremals. One can "kick" Y^2 in rotational rigid body motion in CP_2 such that there are separate rotations in temporal and spatial directions of X^2. The surface X would be 2-D projection of $U(1) \times U(1)$ to X^2. Symmetry breaking can occur and reduce the projection esentially to that for $U(1) \subset U(1) \times U(1)$, and one obtains a unique waggle run along flux tube. Note that this ansatz works also for the M^4 deformations of cosmic strings.

   Surfaces X at string world sheets X^2 or equal to them would thus serve as representations for the points of F.

What about the details of the waggle dance?

1. Additional information such as waggling can be coded by the dynamics of the modified $X^2 \times Y^2$ with rotating Y^2 deformed in M^4 degrees of freedom. X has one time-like direction so that the two waggle runs must correspond to two distinct points of F related by a symmetry realized as a reflection with respect to the line connecting the hive to the food source (the two waggle runs give rise to a V shape with edges representing the horizontal projection of the line to the food source).

   The necessity of the crucial phase transition from waggle dance to circle dance (special case of waggle dance) follows actually without any assumption about the model for the proposed coding of position information about food source.

2. The temporal duration assignable to X defines naturally the duration of the waggle dance in turn coding for the distance of the food source and identifiable as TGD counterpart for the parameter α of Shipman.

3. Waggle run involves two important frequencies: vibration frequency f_v of wings and waggle frequency f_w: these frequencies could correspond to the two conserved Hamiltonians - essentially frequencies (f_1, f_2) associated with the waggle run.

In the sequel I will summarize some basic facts about honeybee dance, sum up what I understand from the work of Shipman, and discuss the TGD based model and compare it with Shipman's work. The TGD inspired model is inspired by the twistor lift of TGD giving special status for the twistor space of CP_2 as flag manifold $F = SU(3)/U(1) \times U(1)$, by the general vision provided by TGD about living matter, by the TGD based model for qualia, by the basic knowledge about honeybee dance - in particular the intriguing observation the two basic frequencies associated with dance correspond to cyclotron frequencies - , and by the interpretation of the findings of Shipman.

Before continuing it is appropriate to list references to Shipman's work. Work related to Toda lattices can be found at [A11, A12]. There are also articles in arXiv (see `http://tinyurl.com/y998f9v6`, `http://tinyurl.com/yapgjprt`, and `http://tinyurl.com/y7a47f39`). The work related to honeybee dance can be found in the articles [A13, A9].

11.2 Some empirical facts

The background for TGD based proposal concerning the dance of honeybee relies on some key empirical facts and the attempt to understand the intriguing findings of Barbara Shipman in TGD framework.

There are articles in ScienceDirect discussing waggle dance from the perspective of neuroscience (see `http://tinyurl.com/ycuhjybt`). For instance, "Dance Language" by Dyer and "Learning Theory and Behaviour" by Marco and Menzel are warmly recommended.

The beginning of the article of Dyer gives some idea about the importance of the decoding of waggle dance by Frisch.

> *Anyone who has watched bees dance for food, and is aware of the function of this behavior, cannot help but be amazed. Karl von Frisch's decoding of the dance language is certainly one of the great discoveries in modern biology. This is not only because of the inherent fascination that the dance holds for curious human observers. Even more important is the extent to which von Frisch's discovery laid the foundation for the study of deep questions about animal behavior. When we consider the role that the dance language has played in the study of vision, olfaction, audition, learning, circadian rhythms, decision making, social organization, and behavioral evolution, it is easy to see why von Frisch regarded the dance language as a 'magic well' of discovery. Furthermore, with advances in neuroscience, genomics, and evolutionary theory, it seems clear that the value of the dance as a model system will continue for many years to come.*

From this it is clear that waggle dance involves multi-sensory communications including vision, hearing, and olfaction. There are several questions to be answered. What information does the dance convey? How the dancer gathers this information? How the audience extracts this information from the dance? The basic puzzle is how an insect with so small cognitive capacity (no cortex nor limbic brain) is able to carry out this feat?

Swarm intelligence is proposed as an answer: this would not involve consciousness. I would be surprised if deep learning were not proposed as a solution. But is this enough? Should one consider bee as part of larger conscious entity - the hive - just like one regards single neuron as part of brain? And what about cognition: should one have genuine theory of consciousness describing also cognition: the formulation of TGD as adelic physics indeed provides a theory of cognition [L70] [L69].

11.2.1 Basic facts about the dance

The dance of the honeybee occurs at the vertical face of the honeycomb and codes the information about the distance and direction of the food source. Von Frisch discovered the choreographic syntax and interpretation of the dance and published the results of his work in his 1967 book "*Dance language and Orientation of Bees*" [J175].

The pattern of the dance is that of figure eight above certain critical distance to the food source and that of a circle below this distance.

1. The angle of the figure eight pattern with respect to the vertical codes the angle between the direction of the food source and the horizontal projection of Sun. For instance, when the food source is in the direction of Sun, figure eight pattern is vertical. The dancer waggles and produces buzzing sound during the first phase of the dance and then walks to the original position along the other circle of the figure eight. After that the dancer waggles again but now along the second circle of the figure eight so that the waggling phases of the dance form the pattern of a figure V in the middle of the figure 8. The buzzing sound produced by the wings of the dancer makes it possible for the audience to locate the dancer (dance occurs in darkness). The opening angle of the figure V codes the distance to the food source for distances above some critical distance.

2. Below the critical distance the pattern changes to a circle. Now the waggling parts of the dance correspond to two disjoint straight line portions located at the opposite sides of the hexagon.

Besides waggle dance and circle dance as special case of waggle dance there are also other forms of honeybee dance such as tremble dance and grooming dance.

One can find summary about more quantitative empirical facts related to the waggle dance in Wikipedia (see `http://tinyurl.com/c7pljpw`). The following represents some facts relevant to the updated TGD inspired model are listed.

1. Waggle dance involves 100 or more circuits. The duration of the straight portion, waggle run, depends on distance: according to Wikipedia 1 second corresponds to 1 km. This might make sense at long enough distances but for short distances in the range 10-20 m this would mean millisecond time scale and this cannot make sense.

2. The dance language codes positional information about the food source (this need not be the only information: also information about the quality of the nectar might be represented). The direction of the food source relative to Sun is coded to the direction of relative to the direction of gravity (vertical direction). The polar angle θ_S with respect to the direction of Sun is mapped to polar angle $\theta_{gr} = \theta_S$ with respect to the vertical direction defined by gravitational force. The atzimutal angle ϕ with respect to the projection of the solar direction to the horizontal plane is represented as such.

   The distance d of the food source is coded to the duration, call it T - of the waggle period and also to the number of wagtail movements during single waggle run (this is trivially true if the wagtail movements occur with same frequency f_w always). Also the vibration frequency f_v of wings correlates with d. One has $f_w \simeq 13$ Hz and $f_v \in [200, 300]$ Hz.

   Remark: These frequencies are not too far from cyclotron frequencies $f(Ca^{2+}) = 15$ Hz and $f(p) = 300$ Hz in endogenous magnetic field $B_{end} = 0.2$ Gauss explaining the quantal effects of ELF radiation on vertebrate brain [J57] [K94, K95].

3. What is remarkable that the orientation information - that is the values of θ and ϕ - is automatically updated to take into account the motion of the Sun. In brain as a computer paradigm this would require quite impressive computation taking into account the size of the brain of honeybee (no cortex and no limbic brain). Even humans are unable to perform this feat. Deep learning paradigm might help but personally I remain skeptic.

11.2.2 How forager bee could collect the position information?

Honeybee dance mediates information about both the direction and distance of the food source. In neuroscience approach identifying brain as a computer this information would be stored by computation. The proposal is that the foraging bee utilizes solar compass. The information about the direction in the plane of Earth would be stored by using the information extracted from the polarization of the sunlight. The cloud free regions can provide this information even in cloudy day.

It has been proposed that the information about the distance of food source is coded by the net motion of the visual features of environment along retina during the flight. Experimentation

has shown that it is the projected distance to the food source (rather than absolute distance) which is coded in this manner.

During flight bee develops positive electromagnetic charge, call it Q, to its abdomen. The charge is due to moving and rubbing together of the body parts. Also Q serves as a measure for the distance of the food source (see http://tinyurl.com/y8vcqc7n and http://tinyurl.com/ycn32wrk).

Interestingly, the pollen in flowers is negatively charged relative to environment and sticks to positively charged bees. The electric field of flow changes for 100 seconds after the visit of bee to prevent from futile visits. Bees also detect the electric field created by flower possessing negative charge relative to environment. Bees also detect electric oscillations.

11.2.3 Communications in other sensory modalities

Dance language is not purely visual. There are also communications in sensory modalities other than vision. Dancing bee produces and releases hydrocarbons: two alkanes, tricosane and pentacosane, and two alkenes, (Z)-9-tricosene and (Z)-9-pentacosene, onto their abdomens and into the air. This makes possible communication by olfaction.

Also acoustic and electromagnetic communications are involved.

1. During dance sounds with frequencies f_v in the range 250-300 Hz are emitted from the vibrations of the wings. Flight sounds are in the same frequency range. It is reported (see http://tinyurl.com/y8qklrhx) that there is a preferred value of f_v around 265 Hz. Honeybees also prefer rhythmic sounds. These preferences allow to detect the sounds produced by honeybee dance in dark and noisy environment.

2. The value of f_v correlates with the distance of the food source decreasing with the distance (see http://tinyurl.com/ya4kq8b8). In the example discussed in the article f_v decreases from 315 Hz to 207 Hz at interval 50-1600 m. Also the duration of the wag run and the number of wagtail movements during the run increase with the distance.

   This vibration mediates auditory information. Acoustic oscillations can be however transformed to electromagnetic vibrations in the body of honeybee since living systems are piezo electrets. The antennae of bees are sensitive to em radiation at ELF frequencies.

3. The frequency f_w of lateral swinging of the body of dancer is reported to be 13 Hz (see http://tinyurl.com/ycsmlxt7). This frequency is below the consciously audible range in the case of humans but also now the transformation to electromagnetic oscillations is possible. During waggle run electric fields are emitted and a natural expectation is that the frequencies f_v and f_w define important electromagnetic frequencies.

What is intriguing is that f_w is in EEG range. As already observed, f_v and f_w could correspond to cyclotron frequencies of proton and Ca^{2+} in a magnetic field near to the endogenous magnetic field $B_{end} = .2$ Gauss needed to explain the quantal effects of ELF em fields in vertebrate brain.

Could radiation with frequencies in EEG range be important also in beehive? For years ago I asked the crazy question whether beehive could have the analog of EEG communicating information from beehive to its MB and making possible the control of beehive by MB using cyclotron radiation. The condition that cyclotron frequencies for MB are identical with some relevant frequencies of biological body is essential for resonance making possible communication and control.

11.3 The findings of Shipman

A popular article describing the findings of Barbara Shipman [A10, A13, A9] related to honeybee dance can be found at web (see http://tinyurl.com/96kzbw). These are however difficult to find. There are also articles about Toda lattices [A11, A12], which she studied in her thesis (see http://tinyurl.com/yde7h6q4).

The basic notions used by Shipman relate to the theory of symplectic manifolds M with symmetry group G. The notion of flag manifold is in an essential role. Moment(um) map to the co-adjoint g^* of the Lie algebra g having symplectic structure is involved. Also projections to the Cartan algebra $h \subset g$ and its image in M and to the co-adjoint h^* of the Cartan algebra of G are involved. These notions are standard.

What about the particle dynamics having curves as orbits? This question one cannot be answered firmly without access to the work of Shipman but I failed to find the work of Shipman in web anymore. The natural guess is however that the orbits correspond to actions inf M of one-parameter subgroups of G parameterized by g, which for symmetric spaces such as CP_2 correspond to geodesic lines. The subset of M spanned by the orbits assignable to the elements of $h \subset g$ is therefore a natural object.

Shipman studies in her thesis "Convex polytopes and duality in the geometry of the full Kostant-Toda lattice") (see `http://tinyurl.com/yde7h6q4`) the dynamics of Toda lattices. These systems are completely integrable systems and Shipman uses generalized flag manifolds for this purpose. The groups involved are non-compact and have non-trivial Borel sub-groups (consisting of matrices with vanishing lower diagonal). I have briefly summarized the ideas related to Toda lattice in [K50].

It however seems that in the applications to honeybee dance one can study $SU(3)$, which is compact. For $SU(3)$ the Borel sub-group would formally reduce to $U(1) \times U(1)$ consisting of diagonal matrices.

Momentum map seems to be very general and allows very general dynamics. What is needed is that one can assign to each point of the orbit values of Hamiltonians $H_i = \mu(X_i)$ defined as contractions of vector fields X^i with the 1-form μ. The Hamiltonians of Cartan algebra commute with respect to Poisson bracket and therefore it is natural to consider the orbits for which these Hamiltonians are constant in Hamiltonian dynamics having G as symmetries. It would however seem that co-adjoint orbit (it would not reduce to a point for non-Hamiltonian dynamics) and its Cartan projection are always well-defined: even when the dynamics itself is not Hamiltonian and Hamiltonians are not conserved.

11.3.1 Dance of the honeybee

The following piece of text is summary of Shipman's findings that I wrote as I proposed g the TGD inspired model for honeybee dance in [K50]. It must be emphasized that the model to be discussed differs from this model introduced for more than twenty years ago. I cannot guarantee that Shipman would agree with all what I claim.

What Barbara Shipman found [A10] was that the images of certain curves of 6-dimensional flag manifold under the so called momentum map reproduce the dancing pattern of the honeybee if the six initial values determining the curve are chosen suitably. Only two of these parameters code the information about the food source. The article about the model of honeybee dance is not published yet but on the basis of short abstract [A10] it seems that the curves in question are solution curves associated with a completely integrable system known as a full Kostant-Toda lattice studied by Barbara Shipman [A11, A12].

The solutions of the $2(n-1)$ equations of motion associated with this model can be mapped to the solutions of certain completely integrable Hamiltonian system in the flag manifold $F_n = SL(n,C)/B$, where $SL(n,C)$ is the space of complex matrices with unit determinant and B is the space of upper triangular matrices with unit determinant. F_n is in turn isomorphic with $SU(n)/U(1)^{n-1}$ and this implies a connection with the quantum measurement theory of color charges in $n = 3$ case.

The dance of honeybee should somehow map the some curve of the flag manifold to a planar curve representing the dancing pattern. $SU(n)$ acts as Hamiltonian transformations of the flag manifold but not as symmetries of Kostant-Toda lattice (see `http://tinyurl.com/ybds7us2`): in particular, the Cartan algebra generators define Hamiltonians $H_I(x)$ and $H_Y(x)$ in F_3. The so called momentum map associating to the point x of the flag manifold F_3 the point $(H_I(x), H_Y(x))$ characterizing the values of the isospin and hypercharge Hamiltonians at the point x. The image of F_3 under this map is hexagonal region of plane and the image of Kostant-Toda orbit under this map is identified as the dancing pattern of the honeybee. It is obvious that $SU(3)$ cannot act as

symmetries of the Kostant-Toda system since in this case Hamiltonians would be constant along the solution curves and momentum map would map every orbit to single point.

To summarize the result concisely:

1. If the orbit of 3-surface in the flag manifold is characterized by Hamiltonian equations related to the so called Kostant-Toda lattice, which is a completely integrable system,

2. if the hexagonal planar region defined by the image of the momentum map corresponds to the "dance floor" and

3. if the orbit of the bee corresponds to the image of the orbit of flag manifold under the momentum momentum map,

one can understand the basic aspects of the waggle dance.

One can indeed understand the dance of honeybee as a representation for the information content of thought of the honeybee. What forces one to take the model seriously is that it reproduces also the dependence of the dancing pattern on bee community and predicts correctly the spectacular change of the V shaped dancing pattern to a union two disjoint lines on the opposite boundaries of the hexagon like region.

Remark: The recent TGD inspired model to be discussed deviates from this picture since the intersection X of Shipman's projection with space-time surface defines the parquette for $D(X) = 2$ and also the dance for $D(X) = 1$.

11.3.2 Basic mathematical notions

It is appropriate to introduce the basic mathematical notions used by Shipman although the TGD based model is formulated without using these notions explicitly: the dance parquette is identified as the surface $X \subset X^4$ defined as the intersection of X^4 with the orbit of $U(1) \times U(1)$ in CP_2. For $D(X) = 1$ dance parquette reduces to dance pattern. For given orbit $U(1) \times U(1)$ the Hamiltonians associated with $u(1) \times u(1)$ Lie-algebra generators are constant.

1. The definition of the moment(um) map can be found from Wikipedia. One considers manifold M with symplectic structure and allowing group G as isometries. Any element of Lie-algebra g of G can be represented as a vector field X of M giving rise to orbits by exponential map. If X is symplectic transformation, the one parameter group associated with X is represented as orbit in M obeying Hamiltonian dynamics defined by the conserved Hamiltonian $H(X)$ assignable to X.

   At any point of M can map $X(x)$ to the dual g^* of g (co-adjoint of g) by contracting it with symplectic form J defining the symplectic structure. Momentum map gives just the Hamiltonian $H(X)$ associated with X. One starts from the formula

   $$d\langle \mu, X \rangle = dH(X)$$

   for the contraction between 1-form μ and vector field X. Clearly, the Hamiltonians are defined only modulo additive constant. Along the orbit of the flow defined by X $H(X)$ is constant since one has Hamiltonian flow

   $$\frac{dY}{dt} = \{H, Y\}$$

   applied to $Y = X$. Also the Hamiltonians associated with Lie-algebra generators commuting with X are constant along the orbits of X.

   One can define momentum map as one-form μ by requiring that the value of μ at point x of M for any X equals to Hamiltonian $H(X)$ at this point:

   $$H(X(x)) = \langle \mu(x), X(x) \rangle \quad .$$

Since the number of components of μ is the dimension $D(M)$ of M and g is $D(g)$-dimensional, this gives $D(M)$ equations for $D(N) > D(M)$ variables so that solutions exist. The condition that the Poisson brackets of Hamiltonians represent the Lie-algebra gives additional conditions allowing to fix μ.

2. Momentum map allows to assign to the orbits of the dynamical system obeying Hamiltonian dynamics conserved Hamiltonians and for completely integrable systems such as Toda lattice these conserved Hamiltonian fix the solution completely.

3. The Cartan sub-algebra h of g determines maximal number of commuting conserved quantities quantum mechanically and one can assign to the image of the classical system in g^* its projection to h^*. In TGD framework one can however argue that this does not provide an interesting representation of the waggle dance since a stationary position of the bee at dancing parquette would code for the position information.

   Rather, it would seem that the dual of this representation in which point of h^* determines the direction and magnitude of the momentum/velocity of the bee is more appropriate. One can also indeed h as a union of orbits of generators of h in M. Waggle run would correspond to one particular point of h. The Hamiltonians associated with vector fields of h would be constant at this surface.

4. The projection of flag manifold to the image of h in flag manifold $F = SU(3)/U(1) \times U(1)$ or any manifold M, say CP_2 with symplectic $SU(3)$ action would determine the 2-D dance parquette for $G = SU(3)$. At these 2-surfaces orbits would be parameterized by constant values of Hamiltonians defining color hypercharge and isospin. The choices of the subgroup $U(1) \times U(1)$ are parameterized by F and at each surface. As already noticed, one must consider the intersection of this set with space-time surface in TGD framework.

   One could say that the points of F representing the choices of quantization axes for color quantum numbers are represented by 2-D Lagrangian surface in CP_2 in TGD framework. This would realize quantum classical correspondence realizing the quantization axis as a dynamical pattern. As noticed, the projection to space-time surface need not be 2-D.

5. The projection map of $F = G/H$ to h^* defines so called momentum polytope having dimension of h (see `http://tinyurl.com/ycxddqz5`). In the case of $SU(3)$ polytope is 2-D hexagon. The fact that beehive has the structure of hexagonal lattice is taken by Shipman as an accident but one can ask whether this is really so.

11.4 TGD based model

The purpose of honeybee dance is to represent symbolically a behavioral pattern leading to a desired goal, a kind of a program. In ZEO behavioral patterns are fundamental whereas time=constant snapshots of dynamics are fundamental in standard positive energy ontology (PEO). ZEO is extremely restrictive: the preferred extremals of the action principle satisfy infinite number of additional gauge conditions reducing the effective number of space-time dimensions to 2 corresponding to the strong form of holography.

Number theoretic approach [L70, L69] forces even stronger form of holography: in which finite measurement resolution is a key aspect of dynamics reduces the locus of initial values to a set of discrete space-time points providing a cognitive representation for the system at space-time level [L61]. This picture conforms with the computationalistic idea that that finite number of numbers fixes the time evolution as an analog of computer program [L59].

The idea that forager bee would perform complex neuronal computations to store the data about the path to the food source looks to me somewhat questionable. At least these computations involved cannot be conscious. AI enthusiast would propose deep learning as a formation of associations leading to the miraculous ability of the bee to remember the path and represent it by dance pattern. This option looks more promising.

To me a more plausible view to consider is that the positional information is stored automatically to the MB of honeybee. This brings in the radical possibility that the forager bee actually generates temporary flux tube connections with the food source and has a permanent contact with

Sun and Earth via gravitational flux tubes. This would store the information to the MB of the bee and the updating would be automatic.

11.4.1 Some ideas of TGD and TGD inspired neuroscience and quantum biology

One should be able to model honeybee dance without introducing any adhoc assumptions. In particular, the dance itself should emerge at space-time level from the fundamental dynamics of TGD. Central notions are ZEO and magnetic body (MB) carrying dark matter as $h_{eff} = n \times h$ phases of ordinary matter. This hierarchy has first principle description in terms of adelic physics [L70, L69].

Zero energy ontology

TGD inspired theory of consciousness and quantum biology rely on few key ideas and notions. Zero energy ontology (ZEO) is of them. ZEO leads to an extension of quantum measurement theory to a theory of consciousness [L72]. The notion of causal diamond (CD) plays a key role in ZEO. ZEO implies that time=constant snapshots as counterparts of physical states are replaced by preferred time evolutions as 3-surfaces (analogs of Bohr orbits) connecting the 3-surfaces at the opposite light-like boundaries of CD analogous. Zero energy states states can be regarded as events with initial and final states at opposite boundaries of CD and classically represented as 3-surfaces.

Field equations in the twistor lift of TGD [K126, L71, K13] can be regarded as a generalization of the dynamics of geodesic motion coupled to Kähler force obtained by replacing 1-D curve with 4-D orbit X^4 of 3-surface. The preferred extremals can be divided to two kinds of regions. Regions of first kind represent external particles for which Kähler 4-force vanishes and which are minimal surfaces as analogs of light-like geodesics. Regions of second kind are interaction regions inside CDs where the Kähler 4-force is non-vanishing. Following biologists and neuroscientists one could speak about a generalization of the notion of behavioral pattern or biological function. Computer scientist would talk about programs.

In ZEO the act of free will would be analogous to a replacement of a deterministic program with a new one [L59]. ZEO is actually forced by the acceptance of the fact that we have free will, which must be consistent with the determinism of field equations. At quantum level, classical program as preferred extremal is replaced with a quantum superposition of classical programs, which in some resolution cannot be distinguished from each other.

The notion of magnetic body

The basic distinction between TGD and Maxwell's electrodynamics and gauge theories is that in TGD Universe any system has a field identity as separate space-time sheets, topological field quanta. They correspond to magnetic flux sheets or tubes and also to electric field has topological quanta. This follows from the notion of the induced gauge field. In Maxwell's theory fields of different systems interfere, in TGD they correspond to separate space-time sheets but particle experiences the sum of the forces caused by them since it touches these space-time sheets.

This modification forces the replacement

organism + environment $\rightarrow$ *MB + organism + environment.*

MB receives sensory input from biological body (BB) and controls it. Sensory input to MB can be in terms of generalized Josephson radiation from cell membrane acting as generalized Josephson junction and coding nerve pulse patterns to frequency modulations. The control by MB can be realized in terms of cyclotron radiation to DNA (accompanied by what I call dark DNA [L42]).

Hierarchy of Planck constants

The hierarchy $h_{eff} = n \times h$, $n = 1, 2, 3, ..$ of Planck constants gives rise to a hierarchy of dark matters. $h_{eff} = n \times h$ labels the onion like layers of MB. The size scale of give layer is by uncertainty principle of order of cyclotron wavelength $\lambda \propto m/eB$ and thus proportional to particle mass m. The value of Planck constant determines the hierarchy level: n can be identified as the dimension of the algebraic extension of rationals defining the adele [L70], and measures the complexity of the

algebraic extension associated with the dynamics at the basic level, and therefore serves as a kind of IQ. Evolution corresponds to a gradual and unavoidable increase of $h_{eff}/h = n$ in statistical sense.

1. At the atomic level the value of n seems to be $n = 6$ rather than $n = 1$ [L65, L46]. For valence bonds the value of n is already larger and increases along the rows of the periodic table being largest for the molecules containing atoms towards the right end of the period: biologically important atoms C, N, O, S, P are examples associated with valence bonds with large n.

2. For protons at hydrogen bonds the value of n is much higher than for electrons of valence bonds and the generation of hydrogen bonds could be seen as a crucial aspect of bio-chemistry. Metabolic energy is measured as the difference of the energy of bond for ordinary value of h_{eff} from the real one and one can say that metabolic energy provides for the system ability to increase its negentropy. Metabolic energy increases h_{eff} resources: this is why we must eat.

An important additional hypothesis generalizes the notion of gravitational Planck constant due to Nottale [E1].

1. The hypothesis [K31, K32, K33, K34, K90] states that at the flux tubes mediating gravitational interactions (propagation of gravitons) one has

$$\hbar_{eff} = n\hbar = \hbar_{gr} = \frac{GMm}{v_0} \quad ,$$

where M and m are the masses associated with the ends of the flux tube and $v_0 < c$ has dimensions of velocity. This formula holds true if Mm/v_0 exceeds Planck mass squared and implies that the coupling parameter GMm in perturbation series is replaced with $v_0/c < 1$ so that one achieves convergence.

2. For large values of M the value of h_{gr} can be very large, which means that long range gravitational interaction can give rise to systems with very high cognitive resources. This hypothesis generalizes also to other interactions in rather obvious manner and the phase transition increasing the value of h_{eff} leads to dark phase in which perturbation theory converges (the value of the coupling strength $\alpha \propto 1/\hbar_{eff}$ is reduced).

3. The value of M depends on the state of the network defined by the flux tubes mediating gravitational interaction. At the limit of ordinary quantum gravity M would be mass of elementary particle. There is however entire dynamical fractal hierarchy of gravitational flux tubes completely analogous to those postulated flux tube hierarchies in neural system and in endocrine system. For instance, the fountain effect of superfluidity could correspond to a situation involving large value of h_{gr}. In living matter the mass of large neuron is of order Planck mass and defines kind of critical mass in the sense that gravitational interaction between two large neurons could correspond to h_{gr}.

4. $h_{eff} = h_{gr}$ hypothesis implies that cyclotron energies do not depend on the mass m of the charged particle and are therefore universal. The proposal is that the energy scale of bio-photons, which is in visible and UV appropriate for molecular transitions, corresponds to the energies of dark cyclotron photons, which can transform to bio-photons [K15]. The spectrum of the values of "endogenous" magnetic field B_{end} with nominal value $B_{end} = .2$ Gauss would corresponds to the energy range of bio-photons. Cyclotron photons would play central role in the control of biological body by MB based on resonance mechanism. Also the communications from biological body to MB would involve resonance mechanism.

Flag manifold qualia

TGD inspired theory of consciousness leads to a proposal concerning the identification of qualia [K50]. The original proposal was based on standard ontology and the sensory qualia were identified in terms of changes of quantum numbers in state function reduction: the problem of the

interpretation is that the outcome of the reduction is random and qualia could be defined only in statistical sense.

The recent view is based on the vision about self as a generalized Zeno effect [L72]. In ZEO qualia would correspond to quantum numbers measured repeatedly during the Zeno period having also interpretation as so called weak measurement.

1. One can distinguish between non-geometric qualia like colors, tastes, and odours, and geometric qualia representing geometric information such as angles and distances. Flag manifold qualia would be universal geometric qualia. In the model for the honeybee dance [K50] the point of 6-D flag manifold F would represent positional information about the food source and waggle dance would represent a point f of F (or an orbit inside the 2-surface of CP_2 representing f) as a dynamical pattern.

2. F has symplectic structure and this encourages the question whether flag manifold qualia could be divided to position type qualia and momentum type qualia. The symplectic structure of F forces to ask whether only degrees of freedom which correspond to mutually commuting Hamiltonians are representable. If so then the representations of qualia at space-time level could correspond to 2-surfaces for which Hamiltonians assignable to $U(1) \times U(1)$ are constant. Motion in this plane dictated by the values of these Hamiltonians as momenta would provide the representation of the geometric qualia at the level of CP_2.

3. The natural proposal is that the surface $X \subset X^4$ obtained as intersection of space-time surface and the orbit of $U(1) \times U(1)$ in CP_2 and depending on the dimension $D(X)$ analogous to string world sheet, curve, or even point corresponds to a kind of dance parquettes or dance itself.

4. In the case of M^4 twistor lift forces to introduce the geometric variant of twistor space as $M^4 \times CP_2$ and also generalization of Kähler structure and symplectic structure. The counterpart of $U(1) \times U(1)$ consists of translations in time-like plane and the point of the twistor space correspond to a choice of time axis (energy quantization axis) and quantization axis of spin.

   In fact, octonionic approach to TGD reducing the dynamics of TGD to algebraic geometry forces to introduce preferred time axis and spatial axis: they correspond to octonionic real unit and preferred imaginary unit [L61]. The 6-D twistor space $M^4 \times S^2$ labelling the choice of these axes would code for geometric information, and also now one would have a representation in terms of the intersection of space-time surface with this plane.

These arguments suggest that flag manifold qualia are something very fundamental and gives support for the discovery of Shipman. Honeybee dance would provide also support for the coherence of long range classical color gauge fields predicted by TGD.

11.4.2 Waggle and vibration frequencies as clues

The basic vision is that MB uses biological body (BB) as a motor instrument and sensory receptor. Control and communication mechanisms are based on resonance mechanism requiring that the changes of energies for some transitions are same at the level of MB and BB: this givesvery powerful constraints on prebiotic scenarios and allows to understand why just certain molecules were chosen as bio-molecules [L66, L80]. Cyclotron frequencies are in a special role and one expects that the resonant frequencies at the level of biological body correspond to cyclotron frequencies. Large value of h_{eff} guarantees that low frequency quanta have energies about thermal energy and therefore effective.

The fundamental dynamics would be that of magnetic flux tubes. Bee could simply move along a flux tube carrying dark ions. A more ore detailed model will be discussed later. The orbits at the image Y of $U(1) \times U(1)$ in CP_2 are labelled by two momenta, essentially frequencies since angle variables are in question. Could the frequencies (f_1, f_2) have counterparts in honeybee dance? There are indeed two key frequencies involved: waggle frequency f_w and vibration frequency f_v for the wings of the bee: could the identification $(f_w, f_v) = (f_1, f_2)$ make sense?

Some of the cyclotron frequencies involved should correspond to f_w and f_v.

1. The vibration frequency f_v for the wings of the bee varies in the range 200-300 Hz roughly. For $B_{end} = .2$ Gauss, which explains Blackman's findings about the quantal effects of ELF radiation [J57], the cyclotron frequency of Ca^{2+} would be $f(Ca^{2+}) = 15$ Hz (or its multiple corresponding to higher cyclotron transitions).

   300 Hz would correspond to protons cyclotron frequency for B_{end}. For $f_c(p) = 200$ Hz the value of B would be $B = 2B_{end}/3$. f_v could correspond also to electromagnetic frequency since acoustic signals are transformed to electric signals in living matter, which consists of piezo electrets.

2. The observed waggle frequency f_w is around 13 Hz and suggests that B_{end} is scaled down by factor 13/15 in this case. This scaling down reduces f_v to 250 Hz. The preferred value of f_v is reported to be around 265 Hz (see `http://tinyurl.com/y8qklrhx`) .

3. The average value of f_v is reported to decrease with the distance from 315 Hz at 50 m to 207 Hz at 1600 m (see `http://tinyurl.com/ya4kq8b8`). Therefore also the value of B_{end} should decrease with the distance. Interestingly, the lower bound $f_v = 200$ Hz corresponds to lower bound $f_w = 10$ Hz in alpha band and in the case of humans defines the lowest frequencies correlating directly with conscious experience. Alpha band indeed dominates in the transition from awake state to sleep.

4. These observations support the view that f_w and f_v allow interpretation as cyclotron frequencies, and force to ask whether proton and Ca^{2+} cyclotron frequencies are in key role in the communications between the dancer and the audience. It is indeed known that the dancer generates electric oscillations and the bees can detect them by their antennae. Proton and Ca^{2+} are also in a key role in the function of cells and neurons.

One cannot avoid the question whether beehive could have EEG or at least alpha band. Bees should not have EEG if the usual neuroscience interpretation for EEG frequencies as being produced by cortex is correct but in TGD one cannot be certain about this.

11.4.3 What should one understand?

One can try to understand the basic topology of the dance by starting from the interpretation for the information coded by it. This does require introduction any specific model for how the information is represented.

1. Why the waggle pattern transforms from two parallel lines for large distances to V shape at shorter distances and finally to two disjoint pieces of circle dance? A possible answer is that the angle between the edge of V and its diagonal represents the angle between the direction of the food source and its projection in horizontal direction. For long distances the angle is small so that the lines are nearly parallel.

   For short distances the angle becomes large. At criticality the upper edge of V becomes vertical and the dancing pattern must change since other wise the direction to the source is interpreted to opposite from the real one. Waggle periods must be in a direction parallel to the direction of food sources to code for the direction of the food source. Waggle period becomes short since it codes for a short distance.

2. Why two waggle runs - left and right run - as mirror images of each other with respect to the diagonal of V are needed. If waggle direction is actually the direction along the surface of Earth to the food source, waggle run and its mirror images are necessary for coding the information about the diagonal of V defining the direction to the food source.

   Suppose that the position information about the source is represented by a point of F.

1. How the coordinates of the point of F characterizing choices of $U(1) \times U(1)$ code for the position information? The intersections X of the orbits of $U(1) \times U(1)$ in CP_2 with the space-time surface have in the generic case $D(X) \leq 2$ and should code the position information. X can (and must) have one time-like direction. For $D(X) = 1$ this gives just single waggle run. The temporal length T of X codes defining the duration of the waggle codes for the distance of the food source.

2. The parameter α introduced by Shipman correlates with distance and could code it. Since the duration of the waggle run correlates with the distance, a possible interpretation of α as temporal duration T assignable to X. Also the value of the charge Q generated during the flight and proportional to the duration of the flight is roughly proportional to the distance and thus T and α.

3. Waggle frequency f_w is additional dynamical parameter related to the motion of the dancer. According to Wikipedia the higher the value of f_w is, the more excited the bee is. This would suggests that f_w varies. Waggling and f_w would relate to the dynamics of space-time surface involved (flux tube perhaps) in M^4 degrees of freedom rather than to the rather simple dynamics of geodesic motion in CP_2. Oscillating string is what comes in mind as approximation to the dynamics of the flux tube.

4. Vibration frequency f_v for wings is a further additional parameter. Also f_v would to the dynamics of X if the flux tube controls the motion of the bee. Cyclotron frequency hypothesis implies that the ratio f_v/f_w of waggle frequency and vibration frequency is constant equal to the mass number of Ca divided by two $f_v/f_w = A/2 = 20$.

   If $(f_w, f_v) = (f_1, f_2)$ identification makes sense then also (f_w, f_v) would be coded by the point of F.

   Remark: Amusingly, the same number 20 appears in the model for life like properties of a simple system of plastic balls in Argon gas: now the ratio of atomic weight of Argon and proton ($A(Ar) = 20$) gives it [L66] (see `http://tinyurl.com/y8wexfqo`). An explanation for the decrease of the f_v and (possibly of f_w too) with the distance of the food source would be needed. Could the long distance to the food source imply that the dancer is less excited? This would require the decrease of the value of B_{end} to which f_w and f_v are proportional with distance. The value of B_{end} could correspond to the magnetic field at the flux tube.

5. It seems that one can understand what happens to the position information at the criticality. One should also understand how the change of the dancing pattern is represented at the level of F and X. Why the intersections of $U(1) \times U(1)$ with space-time surface get short? Is this simply due to the fact that the temporal length of X is determined directly by the length of the path to the source.

How the angle between Sun and target could be updated automatically?

1. In neuroscience approach identifying brain as a computer this information would be stored by computation. Deep learning algorithms would be proposed by AI people. Standard physics mechanism for storing the information about the direction angles are proposed. Foraging bee would utilize solar compass. The information about directions in plane of Earth would be stored by using the information coming the polarization of the sunlight.

2. Automatic updating of the direction S of Sun and the direction L of the food source relative to it should be understood. This requires computation and learning in neuroscience approach. I do not know enough about deep learning to articulate precisely why I do not believe this option.

   A more radical option is that MB of bee stores this information into its own geometry? The proposal has been that MB explains the third person perspective of consciousness: this would explain also OBEs [K98, K121]. Could the MB provide a representation for the dynamics of the bee and its environment including the Sun? If MB contains flux tube S in the direction of Sun defining a pointer of sundial so to say, a temporary flux tube L in the direction of food source, and a temporary flux tube H along projection of L parallel to Earth, this is guaranteed and updating takes place automatically.

3. How the temporary flux tubes would generated? In TGD inspired theory of consciousness flux tubes serve as a correlate for attention. Dancer has directed its attention to the food source and has become connected bya flux tube it. Could this bond be preserved so that the bee would be connected by flux tubes to the target? To be precise, these temporary flux tubes would be actually by pairs of flux tubes generated as flux tube loops from bee and food

source reconnect. One could also imagine kind of miniature variant of this representation if this sounds too non-local.

4. The flux tubes S in the direction of Sun would be naturally gravitational flux tubes possibly carrying dark matter with $h_{eff} = h_{gr}$. The mass M appearing in h_{gr} could be some fraction of solar mass. The angle between L and H a would code the information needed to realize the V shape. Same would apply to the gravitational flux tubes E of Earth. Earlier work suggests that a fraction 10^{-4} of Earths mass of the gravitational flux of Earth is at dark flux tubes $h_{eff} = h_{gr}$.

   These flux tubes would provide a cognitive representation for the direction S of Sun, for the line L connecting the hive to the food source, and for the projection H of L along the surface of Earth. The MB of bee should have also gravitational flux tubes of Earth and since they are orthogonal to H: could these two kinds of gravitational flux tubes make possible the representation of H as edge of V? H and L would be behave like rigid body whereas S would be like a pointer of sundial.

5. Does the rotation of the reference direction from L to E mean rigid body rotation for the MB (and body) of the dancer? Do solar flux tubes become flux tubes inside the vertical flux tubes? If so, the first part of waggle run would take place along the flux tube to target along H turned by $\pi/2 - \theta$. The second part of waggle run would take place along its mirror image with respect to rotated L.

Consider now the role of $h_{eff}/h = n$ having two widely different ranges of values.

1. The cyclotron energies of p and Ca^{2+} are extremely small for the ordinary value of Planck constant. This was one of the reasons motivating to the introduction of the hierarchy of Planck constants $h_{eff}/h = n$ [K44, K31, K32, K33, K34]. The hypothesis $h_{eff} = h_{gr}$ implies that the cyclotron energies do not depend on the mass m of the particle and are in the range of energies of bio-photons (visible and UV). Also the gravitational Compton lengths of particles are independent of m. Also this encourages the consideration of the possibility that the MB of bee has flux tubes carrying gravitational flux tubes from Sun. The values are roughly of the order of 10^{14} if EEG photons have energies in visible and UV.

   The directions of gravitational flux tubes to Sun and Earth define two preferred stationary directions. It seems natural to assign to them gravitational Planck constants $h_{E,gr}$ and $h_{S,gr}$.

2. Relatively small values of n are assignable to electrons of valence bonds and of aromatic cycles [L65]. $n < n_{max} = 100$ is a rough estimate. Thus they are much smaller than the values of $n = h_{gr}/h$ assignable to dark protons at magnetic flux tubes of say hydrogen bonds and assignable to gravitational fields. The model for valence bonds based on TGD predicts that n increases along the row of the periodic table and the molecules appearing as nutrients have the highest values of n associated with their valence bonds.

   $h_{eff}/h = n$ serves as a kind of measure for IQ of the system. More precisely, the recent interpretation is that n expresses the ability of the system to generate negentropy. I have proposed that chemical senses might detect the value of n. For instance, the higher the value of n, the more pleasant the odour. Aromatic compounds with aromatic cycles would have dark electrons at the flux tubes assignable to the cycles and therefore would have value of n larger than the usual.

   Could the average value $\langle n \rangle$ measure the quality of the nectar? Could the dancer communicate the value of $\langle n \rangle$. Could be be more excited if the average value of n is large. This should be reflected in the value of f_w via the value of B_{end} if f_w really measures how excited the bee is.

11.4.4 Concrete model for the coding of the information about waggle dance at MB

Magnetic flux tubes forming part of MB serve as controllers of BB in TGD inspired quantum biology. This suggests that it could be possible to build a concrete model for the control of waggle dance in terms of magnetic flux tubes.

1. The simplest flux tubes are infinitely thin and thus their orbits have 2-D M^4 projection. I call them cosmic strings. They are space-time surface of form $X^4 = X^2 \times S^2 \subset M^4 \times CP_2$, where X^2 is minimal surface - string world sheet - and S^2 is geodesic sphere of CP_2. CP_2 has two non-equivalent geodesic spheres. The first one has vanishing induced Kähler form and second is homologically non-trivial (non-contractible) and carries Kähler magnetic flux.

2. One has also more general preferred extremals $X^2 \times Y^2$, where Y^2 is complex sub-manifold of CP_2 obtained by replacing S^2 with a sphere with $g \geq 0$ handles.

3. One can deform these extremals in M^4 directions to get magnetic flux tubes, which are key players in TGD inspired quantum biology.

All geodesic circles of $Y^2 = S^2$ give rise to X with $D(X) = 1$ but the space-time projection is space-like and corresponds to single point in X^2. How could one get time-like X as a projection of $U(1) \times U(1)$ orbits? The idea comes from the dynamics of rigid body generalized to that for the complex surface $Y^2 \subset CP_2$.

1. Think Y^2 as a rigid body in CP_2 and "kick" it into a rotational motion. This extremely simple motion might produce a preferred extremal. The idea can be illustrated for a geodesic circle S^1 of ordinary sphere. One can "kick" S^1 to a rotational motion around any axis defined by a line from origin to a point of S^2. This motion describes geodesic circle as the image of a Cartan group $SO(2) \subset SO(3)$.

2. For infinitely thin flux tubes the space-time is effectively the string world sheet $X^2 \subset M^4$. X should define surface at X^2. For a rotating Y^2 the orientation of Y^2 in CP_2 depends on the time coordinate t of of X^2. One would have a geodesic motion corresponding to $U(1) \subset U(1) \times U(1) \subset SU(3)$.

3. One can also imagine the dependence of the orientation of Y^2 on the space-like coordinate x of Y^2: there would be "rotation" also in the x direction! The orientation of rotating Y^2 would depend on two string coordinates. Given $(t, x) \in X^2$ would correspond to a point $(\Phi, \Psi) \in U(1) \times U(1)$ and string world sheet itself to $U(1) \times U(1) \in F$! String world sheet would represent flag manifold qualia.

4. This picture is not yet realistic enough. One must have magnetic flux tubes with M^4 projection, which is not infinitely thin. They are obtained for the deformations $X^2 \times S^2$ solutions in M^4 directions increasing the dimension of M^4-projection so that it is 4-D. $D(X) \geq 1$ is however needed to explain honeybee dance.

5. Also for the realistic flux tubes one obtains the rotation by allowing rotation in the additional two directions. A reasonable first guess is that the rotation is everywhere in fixed $U(1) \times U(1)$: this would correspond to a global choice of quantization axes for color quantum numbers.

   Can one identify unique string world sheet X^2 now? What I call fermionic string world sheets are fundamental in TGD. They connect the orbits of partonic 2-surfaces carrying fermion numbers at their ends are indeed realized at the orbits of magnetic flux tubes. This brings in mind strong form of holography (SH) implied by strong form of general coordinate invariance in TGD. Maybe honeybee dance is in certain sense a holographic representation?

6. The temporal size scale T of X would correspond to the duration of the dance and would thus code for the distance to the food source. Hence T must be more or less equivalent with the parameter α of Shipman. The electromagnetic charge Q generated during the flight of forager correlates also with the distance (1 second corresponds to 1 km) and also corresponds to T.

   T would naturally correspond to a finite size scale for CD assignable to the conscious self assignable to the honeybee dance.

7. It is quite possible that the full symmetry breaks down, and the intersection with X^4 gives only single geodesic in the torus $U(1) \times U(1)$. It is characterized by winding numbers (m, n). Waggle run involves two important frequencies: vibration frequency f_v of wings and waggle

frequency f_w: these frequencies could correspond to the two conserved Hamiltonians assigning two-momentum to the waggle orbit. These momenta would be equivalent with frequencies. If (f_w, f_v) corresponds to the pair (f_1, f_2) of rotation frequencies at torus $U(1) \times U(1)$ for the rigid body motion one would have $m/n = 20 = f_v/f_w$. The same frequency ratio appears in the system of plastic balls exhibiting life like properties [L66]. Could the dynamics of preferred extremals favor this value of m/n and give Ca^{2+} its unique role in biology and neuroscience?

11.4.5 Summary

The basic vision behind TGD view is that flag manifold coordinates represent geometric qualia and honeybee dance represents them. The choice of the subgroup $U(1) \times U(1)$ representing point of flag manifold is represented at space-time level. In TGD framework geodesic dynamics coupled to Kähler force is the physically attractive first guess since it would be 1-D idealization of the dynamics of classical TGD, which is obtained from this dynamics by replacing point-like particle with 3-surfaces. This dynamics follows from the twistor lift of TGD by dimensional reduction occurring dynamically. At the point-like limit it gives geodesic motion coupled to Kähler force and allowing $SU(3)$ charges as conserved charged. If one requires that also action $\int j \cdot A$ is invariant the symmetries reduce to $U(1) \times U(1)$ characterizing particular choice of Kähler function of CP_2 (it does not depend on coordinates (Φ, Ψ) assignable to $U(1) \times U(1)$).

The classical dynamics of TGD could explain how the map from the dual of $u(1) \times u(1)$ algebra to the space-time level - the beehive - is realized.

1. The orbits for completely integrable systems are parameterized by the conditions that maximal number of commuting Hamiltonians are constant. TGD is integrable theory and what suggests itself is that the Hamiltonians (P_Φ, P_Ψ) assignable to the phase angle coordinates (Φ, Ψ) parameterizing $U(1) \times U(1)$ orbit in CP_2 are constants at the projection X of the $U(1) \times U(1)$ orbit to X^4 the dimension $D(X)$ satisfies $D(X) \leq 2$. For $D(X) > 0$ the representation is dynamica.

   Space-time sheet could allows $D(X) > 0$ only for very few values of the momentum (P_1, P_2): the projections of other points of F would be discrete. One parameter subgroup of $U(1) \times (1)$ (torus orbit) would define the line H and its mirror image along magnetic flux tube. The edges of V would be obtained by π rotation from each other.

   Waggle run would correspond to time-like line and its spatial projection would represent the orientation angles (θ, ϕ) of the food source as those associated with with the diagonal of V. The temporal size T of X would determine the duration of waggle run and therefore the distance to the source. The electromagnetic charge Q generated to the abdomen of the bee during the flight is proportional to T of the waggle run and codes for the length of the path.

2. The natural parameterization of the situation is in terms of Darboux coordinates for CP_2 for which Kähler potential is given by $A = P_k dQ^k$. Using standard complex coordinates ξ_i for CP_2 [L2], one can choose Q_i to be phase angles of ξ^i: $Q_1 = \Phi$, $Q_2 = \Psi$. These coordinates are cyclic coordinates not appearing in Kähler function of CP_2 and they correspond to $U(1) \times U(1)$ isometries of CP_2. They are constants of motion also for the geodesic dynamics coupled to Kähler form. Conservation laws would correspond to the constancy of the corresponding Hamiltonians P_i. The orbit at X (or equal to it) would be therefore surfaces $P_i = constant$.

   The ratio $v = P_1/P_2$ would define the velocity $v = d\Psi/d\Phi$. The interpretation of P_i as frequencies is natural - hence the notation $P_i = \omega_i$ is more appropriate and an interesting possibility is that these frequencies could serve as a measure for the eagerness of the bee. An interesting possibility is that the frequencies f_v and f_w correspond to f_i. This would give $v \simeq 1/20$.

   X is intersection of HY with X^4. In so called Chladni mechanism [L44] for which self-organization patterns for charged particles correspond to the nodes of electromagnetic field so that the force vanishes. The situation would be exactly the same now but em field would be replaced by the induced Kähler form.

3. This picture would allow to understand why the two waggle runs become parallel at large distances and why they form V shape at smaller distances. Also the criticality could be understood. At criticality the second branch of V would become vertical and the geometry of the dance orbit would change so that waggle periods would be parallel to Earth and at opposite sides of the circle to code the information about the direction of the food source.

4. The waggle pattern characterized by the frequency f_w represents information related to the dynamics in M^4 degrees of freedom allowing perhaps only very limited number of continuous orbits. Also vibrational frequency f_v would represent additional information. The interpretation as cyclotron frequencies for Ca^{2+} and proton makes sense. These frequencies could correspond to the conserved momenta or equivalently frequencies associated with Ψ and Φ.

5. The rotation of the frame defined by the direction of Sun to that defined by the direction of local gravitation would correspond to a rotation of the MB of the bee. Here the permanent dark gravitational flux tubes would play a key role in defining the frame.

Needless to say, the proposed representation is very general and perhaps provide a universal manner to represent geometric information. Flag manifold qualia might be universal manner to represent geometric information. In the case of M^4 twistor lift forces to introduce the geometric variant of twistor space as $M^4 \times CP_2$ and also generalization of Kähler structure and symplectic structure. Now the counterpart of $U(1) \times U(1)$ consists of time translations and translations in some spatial direction and point of the twistor space correspond to a choice of time axis (energy quantization axis) and quantization axes of spin.

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Part III

TIME AND CONSCIOUSNESS

Chapter 12

Time and Consciousness

12.1 Introduction

The identification of moments of consciousness as quantum jumps between quantum histories suggests that our common sense picture about the time evolution of universe might be badly misguided by the restrictions posed by the basic features of our conscious experience. What one can do is to try to develop the most general picture about the cosmology of consciousness consistent with our own conscious experiences and try to identify our position in this picture. Already in its recent form TGD inspired theory of consciousness can give quite restrictive constraints on this Grand Scenario.

The understanding of how psychological time and its arrow emerge has been perhaps the most longstanding problem of quantum TGD and TGD inspired theory of consciousness. By quantum classical correspondence the arrow of subjective time should be mapped to the arrow of geometric time at the level of conscious experience. In similar way the asymmetry between subjective future and past should be correspond to an asymmetry between geometric future and past. What this means at the level of details has been far from clear and I have proposed many partial answers to the question about the arrow of geometric time.

For instance: the geometric future inside light-cone contains much more room than geometric past so that the space-time region about which the contents of conscious experience are about tends to diffuse to the direction of the geometric future defined by light-cone proper time; perhaps the flow of geometric time corresponds to a wave front of intentional action identifiable as a phase transition changing intentions identified as p-adic space-time sheets transformed to real space-time sheets; maybe the space-time sheet assignable to self topologically condensed to a larger space-time sheet shifts in quantum jumps to the direction of geometric future some average temporal distance perhaps defined by CP_2 length scale. All these proposals have provided only partial answers, have led to paradoxes, and failed to give a firm quantitative grasp about the situation.

Also the original wrong view about the correspondence of real and p-adic numbers has generated a lot of confusion. The natural belief of topologist would be that p-adic space-time sheets are mapped to their real counterparts by a continuous map (some variant of what I called canonical identification making sense in p-adic thermodynamics). This map did not however respect symmetries and was inconsistent with field equations. Finally I was able to accept the natural belief of algebraist: reals and various p-adic number fields must be glued to together along rationals and common algebraic numbers to achieve generalization of the number concept and also that of embedding space. What was difficult to accept was the highly non-intuitive implication that most points of p-adic space-time sheets are at spatial and temporal infinity in real (but not in p-adic) sense so that cognition and intentionality would be literally cosmic phenomena and only cognitive representations would be realized in a finite space-time volume in real sense (causal diamond) in terms of intersections of real and p-adic space-time sheets consisting of rational and some algebraic points.

The development visions about zero energy ontology (ZEO) and about hierarchy of Planck constants labelling a fractal hierarchy of quantum criticalities and dark matters have been instrumental in developing the recent phenomenology of consciousness and time.

I have tried to tidy up the chapters so that they would not contain too many mammoth bones. Since I can use only a finite amount of time to documentation purposes, I have not been completely successful and this chapter as also others might contain statements which represent earlier archeological strata. I hope that reader could forgive this. Benevolent reader might even take these chapters as documents about how ideas have developed.

12.1.1 The Concepts Of Self, Time, And Subjective Memory

The notion of self has developed gradually to its recent form. Consider first the original proposal and its evolution before the discovery of zero energy ontology (ZEO).

1. I identified self as a subsystem able to remain unentangled during quantum jumps consisting of unitary processes U defining what I called "informational time evolutions" followed by a state function reduction which in zero energy ontology includes also state preparation occurring for the negative energy part of the state (zero energy state corresponds to physical event in positive energy ontology with negative and positive energy parts of the state being identified as the counterparts of the initial and final states of the event). The obvious counter argument is of course that un-entangled states are not stable.

2. Bound state entanglement is stable against state function reduction so that consciousness would be lost the bound state entanglement is generated. This would stop the sequence of state function reductions initiated after the U-process.

3. The notion of number theoretic entropy allows to assign entanglement negentropy to algebraic entanglement probabilities so that NMP favors the generation of entanglement in this kind of situation. This encourages the hypothesis that subsystem does not lose consciousness if it generates algebraic entanglement with environment. This would correspond to the fusion to the sea of consciousness in the spiritual terminology. Algebraic entanglement is possible in the intersection of real and p-adic worlds which in turn encourages the proposal that living matter corresponds to this intersection, and is therefore a critical phenomenon in number-theoretical sense so that evolution involves in an essential way the generation of algebraic entanglement.

   It turned out that consistency with quantum measurement theory requires that density matrix for the reduced state is projector and thus proportional to unit matrix. Unitary entanglement - typically associated with quantum computers - gives rise to projector as density matrix in the case of two entangled systems. This only generalizes the standard quantum measurement theory in that the reduced density matrix an be a higher-dimensional projector.

4. One can say that self is a subsystem behaving like its own sub-Universe (with respect to NMP). What this really means quantitatively is far from obvious.

The precise definition of self however remained a longstanding problem and I have been even ready to identify self with quantum jump. Also the understanding of the relationship between experienced time and geometric time has been a longstanding challenge. Zero energy ontology allows what looks like the final solution of the problems.

1. Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. The zero energy state is a superposition of the zero energy states associated with the CDs with only second boundary at fixed light-cone boundary. Hence the distance between the tips of CDs in the superposition varies.

2. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary. This explains how the experience of subjective time and its arrow emerges. The average distance between the tips of CDs increases and self experiences flow of time. These repeated state function reductions correspond to unitary process. Self dies when the first reduction to opposite boundary of CD occurs and creates new self. The lifetime of self is the increase of average distance between the tips of CDs in superposition. The first quantum jump to

the opposite boundary corresponds to the act of free will or wake-up of new self. In particle physics time scales this first corresponds to the quantum measurement.

The hypothesis that the experiences of self associated with the quantum jumps occurred after the "wake-up" sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore self becomes extended object with respect to subjective time and has a well defined "personal history". If temporal binding of experiences involves kind of averaging, quantum statistical determinism makes the total experience defined by the heap of the experiences associated with individual quantum jumps reliable. Subjective memory associated with sensory mental images has duration of about .1 seconds from the temporal resolution of sensory experience: it is quite possible that our self has much longer duration. The subjectotemporal sequences of sub-selves make possible to remember the digits of a phone number.

The identification of the fundamental volume of attention as a causal diamond (CD) provides answers to more detailed questions. This identification means also that at the level of embedding space causal diamond of embedding space (or their superposition) serves as the correlate of self whereas at space-time level space-time surface (or their superposition) serves as a correlate of self.

Subsystem X possessing self behaves essentially as a separate sub-Universe with respect to NMP. An attractive hypothesis is that the experience of self is abstraction in the sense that the experiences of sub-selves X_{ij} of X_i are abstracted to average experience $\langle X_{ij} \rangle$. This implies that the experiences of sub-sub-...selves of X are effectively unconscious to X. This self hierarchy is infinite and has entire Universe, God at the top. Temporal binding with averaging implies that experiences of individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles.

12.1.2 Negeentropy Maximization Principle And Ethics

Negentropic entanglement corresponds to a density matrix, which is higher-dimensional projection operator. Number theoretic entanglement negentropy for a prime appearing as a factor of the dimension of the density matrix is indeed positive. Negentropic entanglement could be seen as a quantum physical correlate for love, understanding, and various states of consciousness with positive coloring.

NMP states that the entanglement entropy is reduced in the first state function reduction to the opposite boundary of CD. The subsequent reductions do not change the part of the state at this boundary so that negentropy is not changed. The negentropy for sub-CDs associated with the mental images of self can however increase by repeated state function reductions to the opposite boundary of sub-CD.

NMP allows too variants.

1. The strong variant of NMP implies that entanglement entropy of the state at opposite boundary of CD is not only reduced in state function reduction but also the entanglement negentropy of the resulting state at opposite boundary of CD cannot be lower than it was at original boundary of CD. One can wonder whether this leaves any free will and whether only good deeds, which would not be deeds since no selection is involved, are possible.

2. Second variant of NMP allows reduction to any sub-space of the space defined by a projection matrix appearing in the density matrix. Self can thus choose between good and evil. In this case, entanglement entropy would be always reduced in state function reduction but the entanglement negentropy of the state at the opposite boundary of CD need not be higher than that at the original boundary.

In religious view these options correspond to God which allows only good deeds and to God that allows the sinner to choose between Evil and Good.

12.1.3 Cosmology Of Consciousness

The idea about cosmology of consciousness is inspired by the prediction of the infinite self hierarchy and by quantum-classical correspondence principle [K73]. The expectation is that the fractal structure of the many-sheeted space-time should directly reflect the general structure for the cosmology

of consciousness. For instance, the p-adic evolution of consciousness should have its counterpart at the space-time level. Indeed, there are good reasons to believe that 4-surfaces have decomposition into real regions and p-adic regions and that one can assign to each real region a finite prime p characterizing the effective p-adic topology of the real space-time region (or of light-like 3-surface or partonic 2-surface) and the p-adic topology which the real region is near criticality to transform to. In zero energy ontology this transformation indeed makes sense. Just like configuration space is conjecture to have a decomposition into regions D_P labelled by infinite p-adic primes P, the space-time surface decomposes into real regions labelled by finite primes appearing in the decomposition of P.

Fractality suggests that there are conscious universes within conscious universes and the nested structure of the topological condensate suggests that experiences of universes involve kind of abstractions about the experiences of the sub-universes they contain. The prediction of infinite hierarchy of selves and summation hypothesis for the experiences of selves is in accordance with this expectation.

Mind-like space-time sheets were introduced originally as space-time sheets of finite temporal duration or alternatively as space-time sheets for which the classical determinism in the standard sense of the word fails. In zero energy ontology all space-time sheets have finite temporal scale and zero energy states associated with them have mind-like aspects. For instance, the positive and negative energy parts of the fermionic state define a quantum representation for an abstraction for the Boolean statement $A \to B$ with various instances of a and b appearing in the superposition.

Since mind like space-time sheets have a bounded time duration, one cannot assign to a quantum jump a single value of the geometric time. Rather, our psychological time would be associated with one of the infinitely many irreducible sub-experiences associated with mind like space-time sheets and the values of the psychological time range from zero to infinity. Since selves contain sub-selves with various values of psychological time, experiences are actually multitime experiences with respect to both geometric and subjective time. The entire 4-dimensional space-time is a living system: both the geometric future and past are living and participate in each moment of consciousness. Selves have increasingly longer geometric and subjective memories and that at the limit of entire universe selves have infinitely long subjective memory.

12.1.4 Four-Dimensional Brain

The hypothesis that entire space-time surface is populated by mind like space-time sheets realized in concrete way in zero energy ontology in terms of causal diamonds (CDs) representing systems participating in every moment of consciousness, means also dramatically new way to understand brain. For instance, the problem of memory trivializes. Geometric memory provides simulations and expectations for what happened and will happen whereas subjective memory has interpretation as immediate short term memory. The most plausible interpretation of long term memories is as geometric memories represented by multitime snapshots. This hypothesis explains the practically unlimited capacity of autobiographical memory and also other basic aspects of long term memories and avoids the counter arguments against the neural net models of long term memory.

The paradigm of four-dimensional brain (and body!) forces to reconsider the basic dogma of neuroscience stating that sensory consciousness is associated with brain only and explains nicely the results of Libet's experiments. A concrete model of the long term memory is based on quantum mirror mechanism: experience long term memory means looking at a quantum mirror at a distance of say light years. The attribute "quantum" means that there is no need to code information to a classical signal, just time like entanglement made possible by the classical nondeterminism of Kähler action and by p-adic nondeterminism is enough.

In ZEO self-organization is 4-D. It is 4-D pattern (time evolution of say magnetic body) which evolves quantum jump by quantum jump to the asymptotic pattern. This has profound implications for understanding of say morphogenesis and emergence of behavioral patterns.

12.1.5 Evidence For TGD Based Time Concept

The new concept of time follows from the quantum jump between quantum histories concept so that tests for the latter are indirect tests for the former. Perhaps the strongest support for the new concept of time comes from the requirement of the internal consistency of the world view.

The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and mathematically rather ugly, irreversible "real" world, seem to exist simultaneously. Quantum jumps between quantum histories concept solves the paradox and one can understand dissipative world as an effective description forming "almost" envelope for the sequence of reversible worlds understood as entire time evolutions.

Quantum jumps between quantum histories concept explains the peculiar time delays of consciousness revealed in the experiments of Libet and Kornhuber relating to active and passive roles of consciousness [J87, J44] and the causal anomalies revealed by the experiments of Radin and Bierman [J46, J47, J67]. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

A further implication is quantum theory of self-organization. Self-organization means the organization of selves leading to fixed point patterns analogous to those generated in Benard flow. This means that dissipation serves as a Darwinian selector of both genes and memes. Dissipation is present also at the elementary particle level and leads to the selection of the p-adic effective topologies of elementary particle space-time sheets. Black-hole elementary particle analogy suggests that the allowed p-adic primes are given the p-adic length scale hypothesis $p \simeq 2^k$, k power of prime.

ZEO brings in an even more radical new aspect. What evolves in quantum self-organization is not a superposition of 3-surfaces but a superposition of 4-D time evolutions represented by preferred extremals of Kähler action connecting two space-like 3-surfaces at the opposite boundaries of CD evolves. These space-time surfaces represent 4-D patterns, behaviours rather than 3-D states of say brain. Entire quantum history of space-time approaches in self-organization to an asymptotic quantum history. This view has very powerful implications - consider only the modelling of morphogenesis and learning.

A further new aspect of self-organization relates to the hierarchy of Planck constants and NMP. The basic prediction is that the value of Planck constant $h_{eff} = n \times h$ labelling an infinite hierarchy of critical systems tends to increase spontaneously (criticality is reduced as some conformal gauge degrees of freedom having conformal structure become physical), and that living systems tend to stay at criticality (homeostasis and metabolism) and therefore oppose this process. One can indeed understand this in terms of NMP.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

12.2 TGD Based Concept Of Time

TGD based notion of time involves several new aspects.

1. Quantum jump as occurring between entire quantum histories rather than time=constant snapshots of a single history is certainly the most decisive new element. The necessity to differentiate between subjective and geometric time is immediate implication of this identification.

   The basic challenges could be formulated as questions. What is the precise identification of self and how does self relate to quantum jump? How does the experienced flow of time emerge? How does this flow correlate with the increase of the value of geometric time around which the contents of consciousness experiences are located? How the arrow of time emerges?

2. The classical non-determinism of Kähler action is a fundamental ingredient: without it time would be lost in the sense that the contents of our conscious experience would not be localized with respect to geometric time and one could not understand the emergence of psychological time and its arrow. Non-determinism leads to the notions of ZEO (ZEO) and causal diamond (CD) defining the embedding space correlate of self.

3. As discussed in the introduction, ZEO eventually led to the identification of self as a sequence of state function reductions to a fixed (call it passive) boundary of causal diamond (CD) and leave the part of zero energy state at it unchanged.

   (a) In standard quantum measurement theory the repeated state function reductions have no effect on the quantum state. In ZEO the boundary of CD at which reductions take place (call it active) can change. This occurs in elementary particle time scales in every quantum measurement and the sequences of state function reductions at passive boundary are short. In ZEO they the sequences of state function reductions to a fixed boundary give rise to the experienced flow of time and self.

   (b) The experienced flow of time corresponds to the increase of the average distance between the tips of CDs appearing in quantum superposition of CDs. The arrow of subjective time can correspond to both directions of geometric time and changes when the first quantum jump to the opposite boundary of CD - eventually forced by NMP to occur - takes place.

   Self dies when a reduction to the opposite boundary of CD eventually forced by Negentropy Maximization Principle (NMP) occurs and creates new self at it.

   (c) A further new element is related to the change of the arrow of geometric time occurring when the first state function reduction to the opposite boundary of CD occurs and induces a dramatic change of the state. The interpretation is as an act of volition. The change of the arrow of geometric time makes also possible classical communications with geometric past, which leads to a new view about memory. The new view about time leads also to the notion of four-dimensional brain implying a new manner to see what long term memories are, and the vision about space-time as a four-dimensional organism.

   (d) CD serves as embedding space correlate of self - kind of 4-D perceptive field - and space-time surface inside CD as space-time correlate of consciousness. Our conscious experience is about 4-D space-region - or rather about changes in the superposition of these region occurring during repeated reductions at the passive boundary of CD. Naturally the change occurs at active boundary of CD whereas the passive boundary remains unchanged and corresponds to system remaining un-entangled as long as self "lives".

4. TGD Universe is postulated to be quantum critical. Classical non-determinism leads to the realization of quantum criticality of TGD Universe as an infinite hierarchy of critical systems labelled by the values of Planck constant $h_{eff} = n \times h$. TGD Universe is like a hill at the top of hill at the top of hill... The increase of Planck constant corresponds to a reduction of criticality and tends to occur spontaneously: it is however governed by NMP.

   Living systems can be seen as systems trying to stay at criticality (homeostasis and metabolism). During single sequence of reductions at passive boundary of CD its CD size would increase linearly by integer shifts but neither h_{eff} nor negentropic entanglement in the scale of CD would increase.

   The flow of time defined by the sequence of the first reductions at opposite boundary of CD would naturally correspond to average increase of h_{eff} and by NMP generation of or at least possibiity of generatio of negentropic entanglement. This depends on whether NMP only allows reduction to a higher- than 1- dimensional space assignable to the projector part appearing in the density matrix or whether NMP forces. My personal experiences about real world suggests that the first option is more realistic. This does not however mean that wisdom can be gained only by dying. The values of h_{eff} of sub-CDs associated with mental images would increase and mental images of self would get wiser and this could postpone the first state function reduction at the opposite boundary of CD for self.

   This view looks like the exact opposite of the standard view inspired by second law but is not in conflict with it since the two notions of negentropy are different.

12.2.1 The Three Non-Determinisms

TGD Universe is characterized by a "holy trinity" of non-determinisms. The first non-determinism is associated with quantum jumps between quantum histories and is what makes possible subjective existence and consciousness. One achieve determinism by giving up the assumption that initial values at fixed time define the time evolution and replaces 3-dimensional sections of space-time surface with what I have called "mind-like" space-time sheets. The attempt to realize this picture geometrically led to zero energy ontology. Second non-determinism is classical non-determinism of Kähler action and is to symbolic representations and perhaps also with macroscopic volition. The third non-determinism is inherent to all p-adic field equations and might correspond to the non-determinism of imagination and thus makes possible cognition and intentionality. There is no conscious experience associated with classical nor with p-adic non-determinism as dualist might think. These three non-determinisms have turned out to be basic building bricks of TGD inspired theory of consciousness.

The original identification of the geometric correlates of selves was as mind like space-time sheets. In ZEO all real space-time sheets satisfy the criterion for "mind-likeness" and therefore serve as correlates for selves. Therefire the notion of "mind-likeness" becomes reduntant.

12.2.2 Some Aspects Of Classical Non-Determinism

The general view about the classical non-determinism of Kähler action and its role in TGD and TGD inspired theory of consciousness has developed gradually and still does so. The newest developments relate to the application of quantum gravitational hologram principle in TGD framework. What has been however clear for a long time is that TGD inspired theory of consciousness falls or stands with the classical non-determinism.

Vacuum extremals

Any 4-surface which belongs to $M^4_+ \times Y^2$, where Y^2 is so called Legendre manifold of CP_2 representable as

$$P_i = \nabla_i f(Q_1, Q_2), \quad i = 1, 2 \ ,$$

where f is arbitrary function and (P_i, Q_i) are some canonical coordinates of CP_2, is vacuum extremal of Kähler action. For these vacuum extremals the signature of the induced metric can be either Minkowskian or Euclidian. There are also vacuum extremals with Euclidian signature of the induced metric. The so called CP_2 type vacuum extremals have light like random curve as light cone projection. These extremals are isometric with CP_2 so that the signature of the induced metric is Euclidian. These extremals provide a model for elementary particle.

Only the non-vacuum deformations of the vacuum extremals are physical. The remnants of the huge vacuum non-determinism are expected to give rise to the non-determinism required by symbolic representations of conscious experience at the level of space-time dynamics giving rise to language as a special case. Of course, classical nondeterminism of the Kähler action might also relate to the nondeterminism of volition. It seems that the CP_2 type extremals representing cognitive neutrino pairs are crucial for our cognitive consciousness and its transformation to symbolic representations.

"Mind-like" space-time sheets as deformations of vacuum extremals

The original proposal that "mind-like" space-time sheets and "matter-like" space-time sheets differ in the sense that the first ones are non-deterministic and consist of a collection of 3-surfaces with time-like separations whereas the latter are deterministic or at least have infinite size in time direction by standard conservation laws. In zero energy ontology "mind-like"ness in this sense holds true quite generally.

Physical intuition suggests that the gluing vacuum extremals to a material space-time sheet $X^3(Y^3)$ by # (topological sum) contacts, an interaction results and deforms vacuum extremal slightly and that in some cases this leads to a new preferred extremal with a slightly larger value of Kähler function and hence a larger value of the vacuum functional making the 3-surface more

probable. These deformed vacuum extremals are expected to be still non-deterministic although the non-determinism should be reduced considerably. Via their interactions with the environment, ("mind-like") space-time sheets provide sensory and symbolic representations for some aspects of the surrounding world. Hence they are quite generally natural geometric counterparts of selves. For instance, the time evolution of our body would correspond to this kind of deformed vacuum space-time sheet with a finite time duration. The space-time surfaces $X_i^4(Y^3)$ are expected to be very nearly identical outside the time-interval characterizing the size of the mind like space-time sheet: this in turn implies time localization for the non-determinism of quantum jump and therefore for the contents of conscious experiences associated with the mind like space-time sheet.

In ZEO "mind-like" space-times sheets correspond to a collection of 3-surfaces belonging to boundaries of causal diamond (CD) and its sub-CDs corresponding to the classical correlate for radiative corrections. Generalized causality makes it possible to avoid paradoxical situation: assuming that space-time surface $X^4(Y^3)$ is preferred extremal of the Kähler action for Y^3 one might always find a new 4-surface giving rise to a smaller Kähler action by gluing suitable vacuum extremal to $X^4(Y^3)$.

Massless extremals as quantum gravitational holograms

Massless extremals (MEs) belong to the fundamental solutions of field equations. It has become also clear that they play the role of quantum gravitational holograms. The hologram principle of quantum gravitational theories roughly states that the quantum theory in space-time with boundary reduces to a conformal quantum field theory at the boundary. If Kähler action were deterministic, precisely this would happen. The construction of WCW geometry relies crucially on the assumption that the complications due to the non-determinism of Kähler action does not radically modify the construction based on the assumption of a complete determinism.

It has indeed turned out that the basic construction in which everything reduces to the light like boundary of M_+^4 (moment of big bang) acting as a hologram in quantum gravitational sense and defining conformal quantum theory, generalizes. This construction survives as a template in a more general construction in which also the light like boundaries of MEs having always light like M_+^4 projection are taken into account besides δM_+^4 as surfaces at which initial values can be fixed arbitrarily. This brings in also time absent in a strictly deterministic theory. Thus the quantum gravitational hologram defined by δM_+^4 is replaced by a fractal structure formed by δM_+^4 and Russian doll hierarchy of the light like boundaries of MEs inside MEs. The super-canonical and super-conformal invariances of the light like boundaries indeed generalize in an elegant manner thanks to the basic properties of MEs.

The "light like selves" defined by the boundaries of MEs cold be fundamental in TGD inspired theory of consciousness. The super-symplectic quantum states associated with these boundaries are genuine quantum gravitational states defined by WCW functionals, whose dependence on the bosonic fiber degrees of freedom of WCW does not reduce to a mere vacuum functional given by the exponent of Kähler action. This means that these states do not possess any quantum field theoretic counterparts. They are state functionals in the world of worlds (WCW), so to say, and therefore should represent highest level in the hierarchy of quantum control in living systems. Thus it is the higher abstraction level of quantum gravitational states which connects conscious intelligence and quantum gravitation.

12.2.3 Quantum Jump As Moment Of Consciousness

Quantum jump between quantum histories identified as moment of consciousness was originally believed to be something irreducible and structureless. Gradually the view about quantum jump has however become more and more structured and a connection with the standard quantum measurement theory emerged. In what sense quantum jumps remains irreducible is that one cannot build any dynamical model for the non-deterministic steps appearing in quantum jump.

The general structure of quantum jump

It seems that TGD involves "holy trinity" of dynamics.

1. The dynamics defined by the preferred extremals of Kähler action corresponds to the dynamics of material existence, with matter defined as "res extensa", 3-surfaces. What preferred extremals really are has been a long standing open question. The recent formulation of the quantum theory using Kähler-Dirac action leads to the proposal that the preferred extremals are critical in the sense that they allow an infinite number of deformations for which the second variation vanishes. At the level of Kähler action this corresponds to the vanishing of classical Noether charges for a sub-algebra of super-symplectic algebra isomorphic with the entire algebra. This serves as space-time counterpart for quantum criticality of TGD Universe fixing the fundamental variational principle uniquely.

2. The dynamics defined by the sequence of state function reductions at fixed boundary of CD defining the life span of self at given level of hierarchy. This time evolution is a discrete counterpart of the ordinary Schrödinger time evolution $U \equiv U(-t,)$, $t \to \infty$ and can be regarded as "informational" time development occurring at the level of objective existence. It is un-necessary and in fact impossible to assign real Schrödinger time evolution with U. U defines the S-matrix of the theory. These reductions define the dynamics of sensory perception (passive aspects of consciousness) during which external world is regarded as unchanged in standard framework. Now the part of zero energy state at the fixed boundary of CD remains unchanged and un-entangled.

3. The dynamics of state function reductions at opposite boundary of CD defines the dynamics of volition (active aspects of consciousness).

Quantum jump was originally regarded as something totally irreducible. Gradually the structure of the complex formed by state function reductions and unitary process has revealed itself and led to the understanding how one can understand basic aspects of conscious experience in terms of this structure. Let us start with the original picture.

1. The first step in quantum jump was identified as "informational time development"

$$\Psi_i \to U\Psi_i \ ,$$

where U is the counterpart of the unitary process of Penrose. The resulting state is a completely entangled multiverse state, the entire sub-universe corresponding to a given CD being in a holistic state of "oneness".

In the recent picture Universe is replaced with CD and "informational time development" corresponds to a sequence of state function reductions keeping second boundary of CDand-states associated with it fixed. Repeated measurement having no effect on quantum state is the analog in standard quantum measurement theory. Self corresponds to this sequence.

Two subsequent reductions at same boundary of CD have unitary process between them tending to increase the size CD. The challenge is to identify the unitary process U. Self experiences the flow of time, which suggests that the unitary operator followed by localization in the moduli spaces of CDs corresponds to an integer shift for the tip of the active boundary of CD. No state function reduction can occur at the active boundary of CD during this period.

2. Next comes the TGD counterpart of state function in the ordinary sense of the word:

$$U\Psi_i \to \Psi_f^0 \ .$$

According to the recent view, the state function reduction in this sense corresponds to the state function at the opposite boundary of cD and leads to a change of the arrow of geometric time. Old self dies and new self is born. In this transition also the value of h_{eff} is expected to increase. This reduction is preceded by a scaling of by the integer ratio $h_{eff}(f)/h_{eff}(i)$ and realized as a unitary exponential of conformal scaling operator. Thus both Poincare and conformal time developments are realized.

3. The state function reduction for given CD is followed by a cascade of self measurements for sub-CDs in quantum fluctuating degrees of freedom

$$\Psi_f^0 \to .... \to \Psi_f \ ,$$

whose dynamics is governed by the Negentropy Maximization Principle (NMP). For a generic entanglement probabilities this process leads to bound states or negentropically entangled states. This process can be regarded as an analysis or even decay process. If entanglement probabilities define projection operator, the state function reduction leads or can laed to a negentropically entangled state: this depends on what form of NMP one assumes. Entanglement coefficients correspond to unitary matrix in this case.

Quantum measurement theory involves also the correlation between quantum degrees of freedom and classical degrees of freedom (the position of the pointer of the measurement apparatus correlates with the outcome of the measurement).

1. The assumption that localization occurs in zero modes of the WCW would pose very important consistency condition: there is one-one correlation between the quantum numbers in quantum fluctuating degrees of freedom in some state basis and the values of the zero modes. This in fact has interpretation in terms of holography: classical degrees of freedom in space-time interior correlate with fermionic degrees of freedom assignable to string world sheets and partonic 2-surfaces. This together with the fact that zero modes are effectively classical variables, implies that the localization in zero modes corresponds to a state function reduction.

2. Measurement theory requires an entanglement between zero modes and quantum jumps of the physical state. The addition of a measurement interaction term to the Kähler-Dirac action coupling to four-momentum and color quantum numbers of the state and also to more general conserved quantum numbers allows an explicit realization of this coupling and induces the addition of an analogous measurement interaction term to Kähler action [K139]. This term implies the entanglement of the quantum numbers of the physical states with zero modes.

A good metaphor for quantum jump is as Djinn leaving the bottle (informational time development), fulfilling the wish (quantum jump involving choice) and returning to, possibly new, bottle (localization in zero modes and subsequent state preparation process). One could formally regard each quantum jump as a quantum computation with duration defined by the life-time of corresponding self (the increase of the average temporal distance between the tips of CD in superposition of CDs) followed by halting meaning reduction to the opposite boundary of CD. Quantum jump to the opposite boundary could also be seen as an act of volition (or giving rise to experience of volition at some level of self hierarchy).

Is the complete localization in zero modes really necessary?

The detailed inspection of what happens in state function reductions forces to consider the possibility that state function reduction involves always a complete localization in zero modes. This was indeed the original proposal. It however seems that a localization modulo finite measurement resolution might be a more realistic assumption. Certainly it is enough to explain why the perceived Universe looks classical.

1. QFT picture strongly suggests that sub-system must be defined as a tensor factor of the space of WCW spinors at given point Y^3 of WCW . This suggests that subsystem should be defined as a function of Y^3 and should be a local concept. An important consequence of this definition is that entanglement entropy gives information about space-time geometry.

2. WCW spinor field can be formally expressed as superposition of quantum states localized into the reduced configuration space consisting of 3-surfaces belonging to light cone boundary. Hence WCW spinor field can be formally written as

$$\sum_{Y^3} C(Y^3)(n,N)|n\rangle|N\rangle$$

for any subsystem-complement decomposition defined in Y^3. Clearly, WCW coordinates appear in the role of additional indices with respect to which entanglement coefficients are diagonal. The requirement that final state is pure state would suggest that quantum jump reducing entanglement must involve complete localization of the WCW spinor field to some Y^3 plus further quantum jump reducing entanglement in Y^3. Complete localization in WCW is however not physically acceptable option since the action of various gauge symmetries on quantum states does not commute with the complete localization operation. In particular, the requirement that physical states belong to the representations of Super Virasoro and super-symplectic algebras, is not consistent with this requirement.

3. WCW has fiber space structure. WCW metric is non-vanishing only in the fiber degrees of freedom and since the propagator for small fluctuations equals to the contravariant metric, fiber degrees of freedom correspond to genuine quantum fluctuations. WCW metric vanishes in zero modes, which can be identified as fundamental order parameters in the spirit of Haken's theory of self organization. The requirement that various local symmetries act as gauge symmetries, provides good reasons to expect that *entanglement coefficients in the fiber degrees of freedom are gauge invariants and depend on the zero modes parametrically.* The one-one correlation between quantum numbers of the state assignable to fiber degrees of freedom and classical variables identified as zero modes would encourage the assumption the a complete localization occurs in zero modes. A weaker condition is that localization occurs only modulo a finite measurement resolution.

4. The original argument was that the non-existence of metric based volume element in zero modes forces the wave functions in zero modes to have a discrete locus. There however exists a symplectic measure defined by the symplectic form in zero modes. It does not however allow a complexification to Kähler form as it does in quantum fluctuating degrees of freedom. This symplectic from could define a hierarchy of integration measures coming as restrictions of $J \wedge J ... \wedge J$ with n factors to $2n$-dimensional sub-manifolds. Under some additional conditions- maybe the homological non-triviality of J and the orientability of the sub-manifold are enough, this measure would define a positive definite inner product and one would have a hierarchy finite-dimensional sub-spaces of zero modes. The maxima of Kähler function with respect to zero modes replace naturally the continuum with a discrete set of points and define the counterpart of the spin glass energy landscape consisting of the minima of free energy. Effective finite-dimensionality and even effective discreteness would be achieved.

5. The time development by quantum jumps in zero modes is effectively classical: Universe is apparently hopping around in the space of the zero modes. This looks very attractive physically since zero modes characterize the size, shape and classical Kähler fields associated with 3-surface. Therefore each quantum jump gives very precise conscious geometric information about space-time geometry and about WCW in zero modes. This also means that Haken's classical theory of self-organization generalizes almost as such to TGD context. The probability for localization to given point of zero mode space is given by the reduced probability density Q defined by the integral of the probability density R defined by WCW spinor field over fiber degrees of freedom. The local maxima of Q with respect to zero modes appear as attractors for the time development by quantum jumps. Dissipative time development could be regarded as a sequence of quantum jumps leading to this kind of local maximum.

6. Effective localization in zero modes is completely analogous to spontaneous symmetry breaking in which scalar field attains vacuum expectation value with the difference that the number of degrees of freedom is infinite unlike in typical models of symmetry breaking. Thus the general structure of the WCW spinor field together with TGD based quantum jump concept automatically implies spontaneous symmetry breaking in its TGD version (note however that particle massivation results from both p-adic thermodynamics and coupling to Higgs like field of purely geometric origin in TGD framework). TGD Universe is superposition of parallel

classical universes (3-surfaces). Therefore quantum entangled state can can be regarded as a superposition of parallel entangled states, one for each 3-surface. Formally entanglement coefficients can be regarded as coefficients containing the WCW coordinates of 3-surfaces as additional index. The analogy with the spin glass also supports the localization in the zero modes.

7. Effective localization in the zero modes provides simple explanation for why the universe of conscious experience looks classical: moment of consciousness makes it classical. It also explains why the physics treating space-time as a fixed arena of dynamics has been so successful. As already found, a further important consequence is first principle description of the state function reduction.

12.2.4 The Notion Of Self

Self is by definition a sub-system able to remain unentangled in subsequent quantum jumps. The original belief was that this characterizes the notion of self completely. Only bound state entanglement is stable in quantum jump and selves correspond to regions of the space-time surface having local topology in a given number field (real or p-adic number fields labelled by primes).

Originally p-adic regions were interpreted as physical (non-conscious) correlates for imagination and cognition whereas real regions correspond to matter and sensory perception. The original belief was that the transformation of p-adic space-time sheets to real ones in quantum jump would correspond to the realization of intention as action. It is now clear that this hypothesis is both un-necessary and difficult to realize mathematically. Rather, TGD Universe is adele meaning that both embedding space, space-time, and WCW are adelic structure containing real sector and various p-adic sectors as correlates of cognition.

The unitary operator U could in principle generate entanglement also between p-adic and real regions (rational entanglement coefficients make sense in any number field), which is destroyed in the state function reduction step. This might be crucial for the generation of cognitive maps assigning to the states of matter (say reading of physical measurement apparatus) cognitive states (say mental image about the reading of the measurement apparatus). In the intersection of realities and p-adicities it how does not make sense to distinguish between p-adic and real and the recent view is that string world sheets carrying fermions serving as correlates of Boolean cognition are in this intersection consisting of string world sheets for which the parameters of equations defining them are in some algebraic extension of rationals. One cannot speak about real and p-adic fermions - just fermions.

Assumptions about the structure of conscious experience of self

One makes some structural assumptions about the contents of consciousness of self.

1. The contents of consciousness of self are determined as the average over the quantum jumps occurred after it was created (the real or p-adic space-time region corresponding to self appeared in quantum jump). Selves can have sub-selves and self experiences them as mental images. Self can represent a mental image of a higher level self. Self experiences only the average of its sub-sub-selves. Thus statistical averaging is involved in both subjecto-temporal sense and spatially and is of central importance in the theory of qualia. This suggests that the foundations of, not only quantum measurement theory, but also statistical physics, reduce to the theory of consciousness. Quantum entanglement between sub-selves means fusion of mental images. The simplest assumption is that entangling self loses its consciousness.

2. The sharing of mental images by quantum entanglement is purely TGD based prediction. What happens is rather paradoxical: the sub-selves of unentangled selves bound state entangle so that the resulting fused mental image is shared by both selves. This is not possible if one applies the standard notion of quantum mechanical sub-system as a tensor factor. The p-adic hierarchy of space-time sheets forces to generalize the notion of sub-system (note that also real space-time sheets are characterized by p-adic prime determining the size scale).

   Smaller space-time sheets glued to larger space-time sheets are glued to it by wormhole contacts having size of order CP_2 length and having Euclidian signature of the induced metric.

This implies the presence of elementary particle horizons at which metric around wormhole contacts changes its signature from Minkowskian to Euclidian. At these 3-dimensional surfaces the induced metric is degenerate so that these surfaces are effectively 2-dimensional and allow conformal invariance crucial for the construction of the quantum theory. The analogy with black hole horizon is obvious.

This allows a situation in which two systems correspond to disjoint surfaces but smaller space-time sheets glued to them are connected by magnetic flux tubes serving as correlates for entanglement. Therefore intuitively selves entangled in given length scale can have subselves, which are entangled.

3. Thus many-sheeted space-time and the notion of length scale resolution forces to postulate a hierarchy of systems labelled by p-adic primes and to allow entanglement between subsystems of unentangled systems. In terms of length scale thinking of quantum field theories, one can say that the entanglement between sub-systems is not visible in the p-adic length and time scales of the systems themselves.

   The mathematical description for this length scale dependent view about sub-systems relies on inclusions of hyper-finite factors of type II_1 (HFFs) [K138].

The notion of length scale resolution and self

The rough definition of self is as a subsystem able to remain unentangled during sequential quantum jumps. Self would lose consciousness when it entangles. What this statement really means is far from obvious and I have proposed several interpretations. the following picture represents the recent views.

1. The idea that even slightest entanglement leads to a loss of consciousness does not sound realistic. This suggests that entanglement should be defined only modulo finite measurement resolution. System would be conscious only provided that its entanglement entropy with the external world is below the value defined by the measurement resolution. For hyper-finite factors of type II_1 the notion of finite measurement resolution is unavoidable. The concrete interpretation at space-time level would be that space-time sheets (sub-selves) topologically condensed at larger space-time sheets (selves) can be connected by flux tubes to form an entangled state. The selves represented by the larger space-time sheets would remain unentangled in the resolution applying to the systems themselves (flux tubes would be invisible in this resolution). This invisible entanglement would however give rise to a sharing and fusion of mental images implying what might be called stereo consciousness.

2. How the notion measurement resolution should be defined is far from obvious. p-Adication approach suggests that finite measurement resolution boils down to a pinary cutoff for the p-adic entanglement entropy represented as a series in powers of p. This pinary cutoff should have also space-time correlate. For hyper-finite factors of type II_1 and type III_1 emerging naturally in quantum TGD entanglement entropy is always defined only modulo finite measurement resolution, which can be characterized in terms of inclusions of hyper-finite factors [K138]. The included factor defines the measurement resolution in the sense that its action creates states not distinguishable from the original in the resolution used. There should exist a connection between the two approaches.

3. A further complication is due to the fact that also the p-adic variants of Shannon entropy obtained by replacing the logarithm of probability with the logarithm of the p-adic norm of probability make sense if entanglement probabilities are rational or have values in some algebraic extension of rationals. The fact that number theoretic entanglement entropy can be negative is especially attractive from the point of view of consciousness theory and also quantum computation since entanglement indeed carries information. There is also a temptation to identify evolution as the emergence of increasingly complex systems having negative entanglement entropy. The generation of negative entanglement entropy might correspond to a kind of enlightenment experience - fusion to a sea of consciousness - instead of a loss of consciousness.

4. This forces to reconsider the original vision that everything is conscious but consciousness can be lost as the system entangles in U process. U process generates highly entangled states and the sub-sequent state function reduction (possibly modulo measurement resolution) repeatedly decomposes the Universe (or CD) into unentangled pairs of subsystems. The process stops for any subsystem for which all subsystem pairs have either bound state entanglement or negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). If the bound state entanglement is entropic, the entangled subsystems lose consciousness. If the entanglement beween the subsystems in negentropic the process stops but subsystems remain conscious. Mystics might associate the entropic entanglement to what they calls attachment and negentropic entanglement to a relationship which they might characterize as love.

NMP and self

NMP and self

The development of the view about Negentropy Maximization Principle (NMP) [K73] has meant also development of the notion of self.

(a) The original formulation of NMP was in positive energy ontology and made same predictions as standard quantum measurement theory. The only new element was that the density matrix of sub-system defines a fundamental observable and the system goes to its eigenstate in state function reduction.

(b) p-Adic physics led to the realization that for rational and even algebraic entanglement probabilities it is possible to define number theoretic entanglement negentropy satisfying the same basic axioms as the ordinary Shannon entropy but having negative values and therefore having interpretation as information. NMP would force the generation of negentropic entanglement and stabilize it. Negentropic entanglement resources of the Universe - one might call them Akashic records- would steadily increase.

(c) It turned out that the consistency with the quantum measurement theory demands that the density matrix for the final state is projector as also in the standard quantum measurement theory but can project also to a higher-dimensional space. This additional condition allows also to identify negentropic entanglement uniquely: without this restriction one could not really say whether this is the case since rationals form dense set of reals.

(d) The next step was to realize that this form of NMP is not realistic. NMP would force the Universe to be the best possible one, and this does not seem to be the case. Also ethically responsible free will would be very restricted since self would be forced always to do the best deed that is increase maximally the negentropy serving as information resources of the Universe. This led to the notion of weak form of NMP. Instead of maximal negentropy corresponding to n-dimensional projector self can choose also lower-dimensional sub-spaces and 1-D sub-space corresponds to the vanishing entanglement and negentropy assumed in standard quantum measurement theory.

Weak form of NMP suggests how to understand the notions of Good and Evil. Various choices in the state function reduction correspond to Boolean algebra, which suggests an interpretation in terms of what might be called emotional intelligence [K133]. Also it turns out that one can understand how p-adic length scale hypothesis - actually its generalization - emerges from NMOP [K137].

(a) One can start from ordinary quantum entanglement. It corresponds to a superposition of pairs of states. Second state corresponds to the internal state of the self and second state to a state of external world or biological body of self. In negentropic quantum entanglement each is replaced with a pair of sub-spaces of state spaces of self and

external world. The dimension of the sub-space depends on the which pair is in question. In state function reduction one of these pairs is selected and deed is done. How to make some of these deeds good and some bad?

(b) Obviously the value of $h_{eff}/h = n$ gives the criterion in the case that weak form of NMP holds true. Recall that weak form of NMP allows only the possibility to generate negentropic entanglement but does not force it. NMP is like God allowing the possibility to do good but not forcing good deeds.

Self can choose any sub-space of the subspace defined by n-dimensional projector and 1-D subspace corresponds to the standard quantum measurement. For $n = 1$ the state function reduction leads to vanishing negentropy, and separation of self and the target of the action. Negentropy does not increase in this action and self is isolated from the target: kind of price for sin.

For the maximal dimension of this sub-space the negentropy gain is maximal. This deed would be good and by the proposed criterion the negentropic entanglement corresponds to love or more neutrally, positively colored conscious experience. Interestingly, there are $2^n - 1$ possible choices which is almost the dimension of Boolean algebra consisting of n independent bits. The excluded option corresponds to 0-dimensional sub-space - empty set in set theoretic realization of Boolean algebra. This could relate directly to fermionic oscillator operators defining basis of Boolean algebra- here Fock vacuum would be the excluded state. The deed in this sense would be a choice of how loving the attention towards system of external world is.

(c) A map between between the different choices of k-dimensional sub-space to k-fermion states is suggestive. The realization of logic in terms of emotions of different degrees of positivity would be mapped to many-fermion states - perhaps zero energy states with vanishing total fermion number. State function reductions to k-dimensional spaces would be mapped to k-fermion states: quantum jumps to quantum states!

The problem brings in mind quantum classical correspondence in quantum measurement theory. The direction of the pointer of the measurement apparatus (in very metaphoral sense) corresponds to the outcome of state function reduction, which is now 1-d subspace. For ordinary measurement the pointer has n positions. Now it must have $2^n - 1$ positions. To the discrete space of n pointer positions one must assign fermionic Clifford algebra of second quantized fermionic oscillator operators. The hierarchy of Planck constants and dark matter suggests the realization. Replace the pointer with its space-time n-sheeted covering and consider zero energy energy states made of pairs of k-fermion states at the sheets of the n-sheeted covering? Dark matter would be therefore necessary for cognition. The role of fermions would be to "mark" the k space-time sheets in the covering.

ZEO and self

Zero energy ontology brings in additional aspects to the notin of self. Zero energy states correspond to entangled pairs of positive and negative energy states located at the opposite light-like boundaries of a given causal diamond (CD) defined as the intersection of future and past directed light-cones. Strictly speaking a Cartesian product of CD with CP_2 is in question. CDs form a fractal hierarchy. In the ordinary ontology zero energy state corresponds to a physical event. The time-like entanglement between positive and negative energy states defines M-matrix generalizing the notion of S-matrix. Time-like entanglement must be fundamental also from the point of view of consciousness as a reduction of quantum state to a state with well defined values of observables for the initial (positive energy) and final (negative energy) states.

The most important input from ZEO is that state function reductions can occur to both boundaries of CD. The natural identification of self is as a sequence of state functions occurring at fixed boundary of CD leaving the state at it invariant but affecting the opposite position of opposite boundary. This if one has superposition of CDs with zero energy states

associated with them and of unitary process generates quantum superposition of CDs in the moduli space of CDs and if the unitary process is followed by a localization in this moduli space. The first quantum jump to opposite boundary corresponds to a state function reduction in ordinary sense and has interpretation as volitional act. Self dies and reincarnates at the opposite boundary of CD.

In this picture one can assign to self a definite age as the increase of the proper time distance between the tips of CD. Also the experience of time flow can be understood. In each death of self a reversal of geometric time occurs. This conforms with the old proposal of Fantappie that the notion of syntropy makes sense in living systems [J121],

Space-time correlates of self

The identification of the space-time correlates of selves is not so obvious as one might think. One can imagine three options. The space-time correlates of selves are space-time sheets or CDs or somehow combinations of these two.

1. If space-time sheets serve as correlates for selves, the space-time correlate for the entanglement is the presence of magnetic flux tubes connecting the space-time sheets serving as correlates for selves. The entanglement which corresponds to join along boundaries bonds associated with sub-selves (smaller space-time sheets topologically condensed at the space-time sheet representing self) is below the measurement resolution assignable to self. In this kind of situation selves remain conscious whereas sub-selves loose consciousness for positive entanglement entropy and fuse to form single stereo mental image of self. For negative entanglement entropy sub-selves would remain conscious.

2. In zero energy ontology [K29] one is forced to ask whether the correlates of self should be identified also at the level of embedding space rather than only at the level of space-time sheets so that a given CD would serve as a correlate for self. This identification leads to a beautiful argument for how the arrow of subjective time, the flow of subjective time, and the localization of the contents of conscious experience around a narrow time interval takes place [K10]. There is no reason for why CDs should not be allowed to overlap and this overlap would be a natural correlate for the sharing and fusion of mental images. Both of these identifications look natural and one can argue that the geometric correlates of self exist at both embedding space and space-time level.

3. If both space-time sheets and CDs serve as correlates for selves, the magnetic flux tube contacts could connect space-time sheets associated with the two. CDs and would belong to their intersection. One can also require that the CDs are at the same p-adic level of hierarchy. In other words, CDs correspond to the same value of p-adic prime near a power of two meaning that the temporal distance between the tips of CDs is same octave of CP_2 time for the standard value of Planck constant. The hierarchy of Planck constants [K44] means an additional complication in this picture but does not bring in anything essentially new.

Since self behaves effectively like a separate autonomous universe, an attractive hypothesis is that the typical decomposition of self-organized system to almost autonomous subsystems corresponds to the decomposition of universe to selves. This means very close connection between self-organization theory and theory of consciousness.

Dark matter hierarchy and self

The notion of dark matter hierarchy has dramatically improve the understanding of the notion of self and together with NMP [K73] allows to even answer questions concerning Good and Evil and Life and Death [K133].

1. The idea about hierarchy of Planck constants emerged from anomalies of biology and the strange finding that planetary orbits could be regarded as Bohr orbits but with a gigantic value of Planck constant. This lead to the vision that dark matter corresponds to ordinary particles but with non-standard value of Planck constant and to a generalization of the 8-D

embedding space to a book like structure with pages partially characterized by the value of Planck constant. Using the intuition provided by the inclusions of HFFs one ends up to a prediction for the spectrum of Planck constants. This inspires the proposal that dark matter could be in quantum Hall like phase localized at light-like 3-surfaces with macroscopic size and behaving in many respects like black hole horizons.

2. The physical interpretation for the hierarchy of Planck constants would be in terms of a hierarchy of quantum criticalities concretizing the vision about quantum criticality of TGD Universe. TGD Universe would be like a hill at the top of a hill at .... The larger the Planck constant the larger the size scale of the hill. Criticality involves crucially the notion of conformal gauge symmetry. The conformal symmetries correspond to some sub-algebra of the full algebra isomorphic to it acting as gauge symmetries and with conformal weights coming as n-multiples of those for the full symmetry algebra. $h_{eff} = n \times h$ would label the levels of the hierarchy. This hierarchy would correspond directly to the hierarchy of measurement resolutions and to hierarchy of HFFs. Also now one obtains infinite hierarchies of symmetry breakings and the identification with the hierarchies of inclusions of HFFs is compelling. Hence various hierarchies reflect the same underlying phenomenon.

3. The phase transitions reducing criticality would take place spontaneously unlike opposite phase transitions. This vision is especially powerful in biology, where homeostasis could be seen as mechanisms preventing the reduction of criticality but at expense of metabolic energy. The basic goal of living system would be staying at criticality. Eastern philosophies would formulate this fight for staying at criticality using the notions of ego and Karmic cycle. In the phase transition increasing $h_{eff} = n \times h$ part of gauge degrees of freedom assignable to a sub-algebra of the full super-symplectic algebra are transformed to physical ones and this implies better measurement resolution. The new HFF contains the previous one as a sub-factor. Evolution understood as increase of h_{eff} forced by Negentropy Maximization Principle as also interpretation improvement of measurement/cognitive resolution.

Dark matter hierarchy turns out to be crucial for the deeper understanding of the notion of self. In particular, the evolution of mental images as sequences of births and deaths of sub-selves correspond to state function reductions at opposite boundary of CD. These reductions are forced by NMP and can be said to occur spontaneously. The value of h_{eff} increases in these state function reductions while it remains constant during the sequence of state function reductions at fixed boundary defining self. Quantum criticality is reduced in these phase transitions and self has to fight to stay at fixed level of criticality. Self achieves this by the use of metabolic energy and homeostasis. As long self stays at criticality - that is alive- it's sub-selves can evolve by deaths and re-incarnations.

Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

12.2.5 Four Views About How The Arrow Of Psychological Time Could Emerge

The notion of quantum jump implies a new view about time. Experienced/subjective time corresponds to a sequence of sub-quantum jumps and cannot be identified with the geometric time defined as the fourth space-time coordinate. This is of course obvious for anyone: consider only the reversibility of geometric time contra irreversibility of experienced time, and the fact that both geometric past and future exist whereas only subjective past exists. The fact that the contents of conscious experience is about 4-D rather than 3-D space-time region, motivates the notions of 4-D brain, body, and even society. In particular, conscious existence continues after biological death since 4-D body and brain continue to exist.

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self has been problematic. I have explained the most feasible solution to both problems already in the introduction and describe in the following other approaches which all rely on the same basic idea: the future for a point inside future light-cone has more room than past so that particle diffusing inside the light-cone gradually drifts to future.

1. First trial

The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

1. Why this drifting?
2. If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).
3. It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second trial

Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

3. Third trial

The third explanation for the arrow of psychological time considered earlier looks rather elegant but the explanation based on superpositions of CDs and state function reductions occurring at either boundary of CD looks more attractive.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D embedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima

of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in embedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfven wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self?

4. The recent view

As mentioned in the beginning, ZEO forces a generalization of quantum measurement theory explaining how the flow and arrow of time emerge. ZEO also reduces the notion of self to observer identified as the sequence of state function reductions to a fixed boundary of CD, whose size (or possibly average quantum size) increases during the sequence of reductions. There is also strong temptation to identify the sequence of reductions at fixed boundary of CD as sequence of unitary evolutions inducing shift of the integer n characterizing the size of CD.

The first state function to the opposite boundary of CD would correspond to a scaling scaling of CD size by the integer $m = n_f/n_i$ defined by the integers h_{eff}/h for scaled up CD and the original one. A sequence of transitions reducing quantum criticality would be in question and all big ideas of quantum TGD would find each other in the picture. Minimization of assumptions and maximization of predictive power selects this model as the most plausible one.

12.2.6 What Really Distinguishes Between Future And Past?

Our knowledge about geometric future is very uncertain as compared to that about geometric past. Hence we usually use words like plan/hunch/hope/... in the case of geometric future and speak about memories in the case of geometric past. We also regard geometric past as something absolutely stable. Why cannot we "remember" geometric future as reliably as the geometric past?

Is it that geometric future is highly unstable as compared to the geometric past? Why this should be the case? Or could it be that it does not really exist?

ZEO provides again the most convincing explanation for the asymmetry between future and past. The low unchanging boundary of CD corresponds to the most remote geometric past and is completely stable during the sequence of state function reductions defining self. The active, changing boundary of CD (or superposition of them), which corresponds to "sensory now" is replaced with a new one in every reduction. The geometric past corresponds to the regions of CD "below" it. This asymmetry between future and past explains why remembering future is difficult if note even impossible for given self.

The fact is however that we can make predictions about our future. One can indeed consider a loop-hole making possible to predict future to some extent. As self dies and new self wakes up at opposite boundary of corresponding CD the arrow of time changes and past becomes future. This self has memories about what corresponds to the future of the original self. If this information is preserved when the original self wakes up and is accessible to it, this self can pre-cognize its future to some degree. An attractive idea is that during sleep the sub-self representing "wake-up me" dies and is replaced with a new one. During sleep the new self would recall information about its geometric past and this information would be partially accessible to the original sub-self after wake-up.

12.2.7 Two Views About Flow Of Time

One can consider two alternative views about how the subjectively experienced flow of time emerges.

1. The first view would identify the flow of time with life cycle of period and essentially with sensory perception defining the passive aspects of consciousness. This view is consistent with the ZEO based about self and looks rather feasible. One can wonder how repeated state function reduction give rise to the increase of the average size of CD (possibly in superposition of CDs). Why the entire zero energy state and CD do not remain unchanged in state function reduction? What is the unitary process defining the dynamics of dispersion in the moduli space of CDs? One must admit that this aspect is not well-understood yet and more detailed view about what the sequences of state function reductions really means.

2. Second view that I have considered assigns the flow of time with active aspects of consciousness.

   (a) The acts of volition would give rise to an experience about flow of time. The proposal is that in ZEO act of volition corresponds to the first state function reduction at the opposite boundary of some sub-CD. Some self in the hierarchy dies in this process and NMP forces it to occur although it does not fix the outcome.

   Time mirror mechanism for motor action assumes that the phase transition gives rise to negative energy space-time sheets representing propagation of signals to geometric past, where they induce neuronal activities. From Libet's experiments relating to neuronal correlates of volition the time scale involved is a fraction of second but an infinite hierarchy of time scales is implied by fractality. Perhaps the most logical interpretation is that state function reduction sequences with opposite arrows of time correspond to sensory perception and motor action from the point of view of a higher level self with larger CD.

   (b) Skeptic can argue that the act of volition in this sense is only a choice between alternative outcomes of state function reduction rather than a realization of intention as action creating something genuinely new: a new real space-time sheet from p-adic space-time sheet. One can however argue that genuine volitional acts are realizations of intentions. The reason is that NMP defines the goal of the dynamics and means that total quantum randomness does not prevail anymore.

   One can also argue that there is no actual choices between good and evil. This is certainly not the case if weak form of NMP which only allows the reduction to any

subspace of the subspace with the dimension of the projection operator appearing in density matrix.

These view can be understood as mutually consistent ways to understand the flow of time. The first flow would be pseudo-continuous and correspond to translation in time and second one would occur in discontinuous steps and correspond a scaling of CD. These time developments corresponds to time evolutions in ordinary QFT and in conformal field theory respectively.

Consider first how the smooth flow of subjective time during the life cycle of self emerges.

1. One can argue that the value of h_{eff} associated with a given self cannot increase during the lifetime of self since this would scale up also the size of the passive boundary of CD and thus also the sizes of 3-surfaces there. The explanation for the flow of geometric time however demands that the size of CDs in the superposition increases.

   This requires a linear increase in which CD size increases by integer rather than being scaled by integer: shift instead of scaling. This criterion would suggests that the increase of the size of CD is below scaling by factor two - below a more flexible option is considered - and relate the lifetime of self to the size scale of CD.

2. The basic mathematical challenge is to formulate the transition amplitudes between different CDs. Is the transition amplitude essentially an overlap of fermionic lines associated with the two CDs? In Yangian approach the transition amplitude would reduce to an overlap integral associated with the string world sheets belonging to both CDs. This would favor the increase of the size of CD. It is not clear whether it makes sense to assume a localization to single CD to take place at every step localizing only its active boundary. Certainly state function reduction in the degrees of freedom associated with this boundary of CD cannot occur since this would reverse the direction of time.

   The time evolution during the single step keeping passive boundary of CD corresponds to a shift for the integer specifying the size scale of CD. Can one interpret this shift as a fractional scaling $n \to n(1 + \Delta n/n)$ or does this shift correspond to translation by representable in terms of Poincare energy as Noether charge? The latter option looks more natural. This time evolution would be the one usually studied in quantum field theories.

3. Interesting questions relate to the constraints coming from number theoretical universality forced by adelization. Could the increase of h_{eff} correspond to the increase of p-adic prime characterizing the system? What about p-adic counterpart of unitary evolution: the existence of the exponential $exp(iP_0t)$ requires that t has p-adic norm below some upper bound. This could give an upper bound to the life time of self as a real number since the p-adic counterpart of life-time would be below this upper bound.

What happens in the first reduction to the opposite boundary of CD changing the arrow of time?

1. The reduction should be forced by NMP and involve scaling of h_{eff} generating negentropic entanglement. Thus the scaling of h_{eff} and reduction of quantum criticality would be possible only in the first reduction to the opposite boundary - biological death. Life cycle would end when the transition increasing h_{eff} would occur and at least tend increase negentropic entanglement. The tendency of living system to stay at criticality using metabolism and homeostasis would translate to the urge to maximize the life span, which looks indeed natural.

2. At the level of sub-selves this scalings can occur for self and would correspond to mental images with are born and die. Also motor action would correspond to a transition changing the arrow of time for a mental image representing the intention and will to perform the motor action.

3. One can argue that the increase of h_{eff} giving also rise to an increase in negentropy becomes unavoidable eventually. This criticality could mean that the size scale of CD becomes integer multiple of the original one.

For instance, when the size scale of personal CD approaches to a value which is twice that of the original one, the situation is expected become highly critical for $h_{eff} \to 2 \times h_{eff}$ transition. Could it be possible to avoid this phase transition so that the biological death could correspond to $h_{eff} \to n \times h_{eff}$, $n > 2$? The manner to avoid the phase transition would be by the generation of negentropic entanglement at the level of mental images and by the corresponding phase transitions for them - can one see spiritual thoughts as a way to live longer?

4. In the first reduction to the opposite boundary the negentropy increases and also the value of h_{eff} presumably does (by NMP). Does this mean that self can gain wisdom only by dying! The intuitive idea is that aging is accompanied by increase of wisdom of some kind. But *if* one assigns negentropic entanglement with the passive boundary, negentropy associated with the length scale of CD remains unchanged.

   There is however a loophole. For the sub-selves associated with sub-CDs the situation is different. Given mental image of self/sub-self can live several life-cycles meaning that it generates (or can generate) negentropic entanglement. Mental images of self get wiser even if self does not! The refusal of self to grow spiritually would make possible for sub-selves to grow spiritually: one cannot cheat NMP!

5. The scaling of CD inducing the increase of $h_{eff} = n \times h$ occurring spontaneously represented as an exponential of scaling generator - call it L_0 - seems to be precede the first reduction. I have already considered conditions on this dynamics. Note that translations are replaced with scalings by integer valued ratios $m = n_f/n_i$, which predicts that periodicity is replaced by periodicity with respect to the logarithm of ordinary embedding space time. A unique signature of dynamics of consciousness, which I have proposed as an explanation for the hyperbolic decay law for the emission of bio-photons.

6. The scaling of CD inducing the increase of $h_{eff} = n \times h$ occurring spontaneously is naturally represented as an exponential of scaling generator - call it L_0. Translations are replaced with scalings by integer valued ratios $m = n_f/n_i$, which predicts that periodicity is replaced by periodicity with respect to the logarithm of ordinary embedding space time. A unique signature of dynamics of consciousness, which I have proposed as an explanation for the hyperbolic decay law for the emission of bio-photons.

7. The phase transitions increasing $h_{eff}/h = n$ can be said to begin from some prime value $n = p$ - the smallest prime power appearing in n: one could even say that the basic label for the sequences of breakings of super-symplectic symmetries are labelled by primes. This strongly suggests a connection with p-adicity.

These two views are consistent with each other. The first view corresponds to a flow of time as shifts in the integer characterizing the size of CD and corresponds to the flow of time experienced by self during its life-cycle. The second view corresponds to time evolution as a sequence of state function reductions at opposite boundary involving scalings of h_{eff} by integer. The tick for this clock would be a phase transition reducing quantum criticality. Self experiences this time flow as sequence of mental images which live and die.

12.3 Intention, Cognition, And Time

Intentions involved time in an essential manner and this led to the idea that p-adic-to-real quantum jumps could correspond to a realization of intentions as actions. It however seems that this hypothesis posing strong additional mathematical challenges is not needed if one accepts adelic approach in which real space-time time and its p-adic variants are all present and quantum physics is adelic. I have already earlier developed the first formulation of p-adic space-time surface in [K140] and the ideas related to the adelic vision in [K86, K84, K9].

The recent view involving strong form of holography would provide dramatically simplified view about how these representations are formed as continuations of representations of strings world sheets and partonic 2-surfaces in the intersection of real and p-adic variants of WCW ("World of

Classical Worlds") in the sense that the parameters characterizing these representations are in the algebraic numbers in the algebraic extension of p-adic numbers involved.

12.3.1 What Intentions Are?

One of the earlier ideas about the flow of subjective time was that it corresponds to a phase transition front representing a transformation of intentions to actions and propagating towards the geometric future quantum jump by quantum jump. The assumption about this front is unnecessary in the recent view inspired by ZEO.

Intentions should relate to active aspects of conscious experience. The question is what the quantum physical correlates of intentions are and what happens in the transformation of intention to action.

1. The old proposal that p-adic-to-real transition could correspond to the realization of intention as action. One can even consider the possibility that the sequence of state function reductions decomposes to pairs real-to-padic and p-adic-to-real transitons. This picture does not explain why and how intention gradually evolves stronger and stronger, and is finally realized. The identification of p-adic space-time sheets as correlates of cognition is however natural.

2. The newer proposal, which might be called adelic, is that real and p-adic space-time sheets form a larger sensory-cognitive structure: cognitive and sensory aspects would be simultaneously present. Real and p-adic space-time surfaces would form single coherent whole which could be called adelic space-time. All p-adic manifolds could be present and define kind of chart maps about real preferred extremals so that they would not be independent entities as for the first option. The first objection is that the assignment of fermions separately to the every factor of adelic space-time does not make sense. This objection is circumvented if fermions belong to the intersection of realities and p-adicities.

   This makes sense if string world sheets carrying the induced spinor fields define seats of cognitive representations in the intersection of reality and p-adicities. Cognition would be still associated with the p-adic space-time sheets and sensory experience with real ones. What can sensed and cognized would reside in the intersection.

   Intention would be however something different for the adelic option. The intention to perform quantum jump at the opposite boundary would develop during the sequence of state function reductions at fixed boundary and eventually NMP would force the transformation of intention to action as first state function reduction at opposite boundary. NMP would guarantee that the urge to do something develops so strong that eventually something is done.

   Intention involves two aspects. The plan for achieving something which corresponds to cognition and the will to achieve something which corresponds to emotional state. These aspects could correspond to p-adic and real aspects of intentionality.

12.3.2 P-Adic Physics As Physics Of Only Cognition?

There are two views about p-adic-real correspondence corresponding to two views about p-adic physics. According to the first view p-adic physics defines correlates for both cognition whereas second view states that it provides correlates for cognition only.

1. Option A: The older view is that p-adic -to-real transitions realize intentions as actions and opposite transitions generate cognitive representations. Quantum state would be either real or p-adic. This option raises hard mathematical challenges since scattering amplitudes between different number fields are needed and the needed mathematics might not exist at all.

2. Option B: Second view is that cognition and sensory aspects of experience are simultaneously present at all levels and means that real space-time surface and their real counterparts form a larger structure in the spirit of what might be called Adelic TGD. p-Adic space-time charts could be present for all primes. It is of course necessary to understand why it is possible to assign definite prime to a given elementary particle.

This option could be developed by generalizing the existing mathematics of adeles by replacing number in given number field with a space-time surface in the embedding space corresponding that number field. Therefore this option looks more promising. For this option also the development of intention can be also understood. The condition that the scattering amplitudes are in the intersection of reality and p-adicities is very powerful condition on the scattering amplitudes and would reduce the realization of number theoretical universality and p-adicization to that for string world sheets and partonic 2-surfaces.

For instance, the difficult problem of defining p-adic analogs of topological invariant would trivialie since these invariants (say genus) have algebraic representation for 2-D geometries. 2-dimensionality of cognitive representation would be perhaps basically due to the close correspondence between algebra and topology in dimension $D = 2$.

Most of the following considerations apply in both cases.

12.3.3 Some Questions To Ponder

The following questions are part of the list of question that one must ponder.

Do cognitive representations reside in the intersection of reality and p-adicities?

The idea that cognitive representation reside in the intersection of reality and various p-adicities is one of the key ideas of TGD inspired theory of consciousness.

1. All quantum states have vanishing total quantum numbers in ZEO, which now forms the basis of quantum TGD [K28]. In principle conservation laws do not pose any constraints on possibly occurring real–p-adic transitions (Option A) if they occur between zero energy states.

   On the other hand, there are good hopes about the definition of p-adic variants of conserved quantities by algebraic continuation since the stringy quantal Noether charges make sense in all number fields if string world sheets are in the real–p-adic intersection. This continuation is indeed needed if quantum states have adelic structure (Option B). In accordance with this quantum classical correspondence (QCC) demands that the classical conserved quantities in the Cartan algebra of symmetries are equal to the eigenvalues of the quantal charges.

2. The starting point is the interpretation of fermions as correlates for Boolean cognition and p-adic space-time sheets space-time correlates for cognitions [K119]. Induced spinor fields are localized at string world sheets, which suggests that string world sheets and partonic 2-surfaces define cognitive representations in the intersection of realities and p-adicities. The space-time adele would have a book-like structure with the back of the book defined by string world sheets.

3. At the level of partonic 2-surfaces common rational points (or more generally common points in algebraic extension of rationals) correspond to the real–p-adic intersection. It is natural to identify the set of these points as the intersection of string world sheets and partonic 2-surfaces at the boundaries of CDs. These points would also correspond to the ends of strings connecting partonic 2-surfaces and the ends of fermion lines at the orbits of partonic 2-surfaces (at these surfaces the signature of the induced 4-metric changes). This would give a direct connection with fermions and Boolean cognition.

   (a) For option A the interpretation is simple. The larger the number of points is, the higher the probability for the transitions to occur. This because the transition amplitude must involve the sum of amplitudes determined by data from the common points.

   (b) For option B the number of common points measures the goodness of the particular cognitive representation but does not tell anything about the probability of any quantum transition. It however allows to discriminate between different p-adic primes using the precision of the cognitive representation as a criterion. For instance, the non-determinism of Kähler action could resemble p-adic non-determinism for some algebraic

extension of p-adic number field for some value of p. Also the entanglement assignable to density matrix which is n-dimensional projector would be negentropic only if the p-adic prime defining the number theoretic entropy is divisor of n. Therefore also entangled quantum state would give a strong suggestion about the value of the optimal p-adic cognitive representation as that associated with the largest power of p appearing in n.

Could cognitive resolution fix the measurement resolution?

For p-adic numbers the algebraic extension used (roots of unity fix the resolution in angle degrees of freredom and pinary cutoffs fix the resolution in "radial" variables which are naturally positive. Could the character of quantum state or perhaps quantum transition fix measurement resolution uniquely?

1. If transitions (state function reductions) can occur only between different number fields (Option A), discretization is un-avoidable and unique if maximal. For real-real transitions the discretization would be motivated only by finite measurement resolution and need be neither necessary nor unique. Discretization is required and unique also if one requires adelic structure for the state space (Option B). Therefore both options A and B are allowed by this criterion.

2. For both options cognition and intention (if p-adic) would be one half of existence and sensory perception and motor actions would be second half of existence at fundamental level. The first half would correspond to sensory experience and motor action as time reversals of each other. This would be true even at the level of elementary particles, which would explain the amazing success of p-adic mass calculations.

3. For option A the state function reduction sequence would correspond to a formation of p-adic maps about real maps and real maps about p-adic maps: real $\rightarrow$ p-adic $\rightarrow$ real $\rightarrow$ ..... For option B it would correspond the sequence adelic $\rightarrow$ adelic $\rightarrow$ adelic $\rightarrow$ .....

4. For both options p-adic and real physics would be unified to single coherent whole at the fundamental level but the adelic option would be much simpler. This kind of unification is highly suggestive - consider only the success of p-adic mass calculations - but I have not really seriously considered what it could mean.

What selects the preferred p-adic prime?

What determines the p-adic prime or preferred p-adic prime assignable to the system considered? Is it unique? Can it change?

1. An attractive hypothesis is that the most favorable p-adic prime is a factor of the integer n defining the dimension of the $n \times n$ density matrix associated with the flux tubes/fermionic strings connecting partonic 2-surfaces: the presence of fermionic strings already implies at least two partonic 2-surfaces. During the sequence of reductions at same boundary of CD n receives additional factors so that p cannot change. If wormhole contacts behave as magnetic monopoles there must be at least two of them connected by monopole flux tubes. This would give a connection with negentropic entanglement and for $h_{eff}/h = n$ to quantum criticality, dark matterm and hierarchy of inclusions of HFFs.

2. Second possibility is that the classical non-determinism making itself visible via super-symplectic invariance acting as broken conformal gauge invariance has same character as p-adic non-determinism for some value of p-adic prime. This would mean that p-adic space-time surfaces would be especially good representations of real space-time sheets. At the lowest level of hierarchy this would mean large number of common points. At higher levels large number of common parameter values in the algebraic extension of rationals in question.

How finite measurement resolution relates to hyper-finite factors?

The connection with hyper-finite factors suggests itself.

1. Negentropic entanglement can be said to be stabilized by finite cognitive resolution if hyper-finite factors are associated with the hierarchy of Planck constants and cognitive resolutions. For HFFs the projection to single ray of state space in state function reduction is replaced with a projection to an infinite-dimensional sub-space whose von Neumann dimension is not larger than one.

2. This raises interesting question. Could infinite integers constructible from infinite primes correspond to these infinite dimensions so that prime p would appear as a factor of this kind of infinite integer? One can say that for inclusions of hyperfinite factors the ratio of dimensions for including and included factors is quantum dimension which is algebraic number expressible in terms of quantum phase $q = exp(i2\pi/n)$. Could n correspond to the integer ratio $n = n_f/n_i$ for the integers characterizing the sub-algebra of super-symplectic algebra acting as gauge transformations?

12.3.4 Generalizing The Notion Of P-Adic Space-Time Surface

The notion of p-adic manifold [K140] is an attempt to formulate p-adic space-time surfaces identified as preferred extremal of p-adic variants of p-adic field equations as cognitive charts of real space-time sheets. Here the essential point is that p-adic variants of field equations make sense: this is due to the fact that induced metric and induced gauge fields make sense (differential geometry exists p-adically unlike global geometry involving notions of lengths, area, etc does not exist: in particular the notion of angle and conformal invariance make sense).

The second key element is finite resolution so that p-adic chart map is not unique. Same applies to the real counterpart of p-adic extremal and having representation as space-time correlate for an intention realized as action.

The discretization of the entire space-time surface proposed in the formulation of p-adic manifold concept [K140] looks too naïve an approach. It is plausible that one has an abstraction hierarchy for discretizations at various abstraction levels.

1. The simplest discretization would occur at space-time level only at partonic 2-surfaces in terms of string ends identified as algebraic points in the extension of p-adics used. For the boundaries of string world sheets at the orbits of partonic 2-surface one would have discretization for the parameters defining the boundary curve. By field equations this curve is actually a segment of light-like geodesic line and characterized by initial light-like 8-velocity, which should be therefore a number in algebraic extension of rationals. The string world sheets should have similar parameterization in terms of algebraic numbers.

   By conformal invariance the finite-dimensional conformal moduli spaces and topological invariants would characterize string world sheets and partonic 2-surfaces. The p-adic variant of Teichmueller parameters was indeed introduced in p-adic mass calculations and corresponds to the dominating contribution to the particle mass [K66, K27].

2. What might be called co-dimension 2 rule for discretization suggests itself. Partonic 2-surface would be replaced with the ends of fermion lines at it or equivalently: with the ends of space-like strings connecting partonic 2-surfaces at it. 3-D partonic orbit would be replaced with the fermion lines at it. 4-D space-time surface would be replaced with 2-D string world sheets. Number theoretically this would mean that one has always commutative tangent space. Physically the condition that em charge is well-defined for the spinor modes would demand co-dimension 2 rule.

3. This rule would reduce the real-p-adic correspondence at space-time level to construction of real and p-adic space-time surfaces as pairs to that for string world sheets and partonic 2-surfaces determining algebraically the corresponding space-time surfaces as preferred extremals of Kähler action. Strong form of holography indeed leads to the vision that these geometric objects can be extended to 4-D space-time surface representing preferred extremals.

4. In accordance with the generalization of AdS/CFT correspondence to TGD framework cognitive representations for physics would involve only partonic 2-surfaces and string world sheets. This would tell more about cognition rather than Universe. The 2-D objects in question would be in the intersection of reality and p-adicities and define cognitive representations of 4-D physics. Both classical and quantum physics would be adelic.

5. Space-time surfaces would not be unique but possess a degeneracy corresponding to a subalgebra of the super-symplectic algebra isomorphic to itandacting as conformal gauge symmetries giving rise to n conformal gauge invariance classes. The conformal weights for the sub-algebra would be n-multiples of those for the entire algebra and n would correspond to the effective Planck constant $h_{eff}/h = n$. The hierarchy of quantum criticalities labelled by n would correspond to a hierarchy of cognitive resolutions defining measurement resolutions.

Clearly, very many big ideas behind TGD and TGD inspired theory of consciousness would have this picture as a Boolean intersection.

12.3.5 Number Theoretic Universality For Cognitive Representations

Number theoretic universality is one of the key principles of quantum TGD [K83]. In the following this principle is discussed in the light of the newest results about quantum TGD.

1. By number theoretic universality p-adic zero energy states should be formally similar to their real counterparts for option B. For option A the states between which real–p-adic transitions are highly probable would be similar. The states would have as basic building bricks the elements of the Yangian of the super-symplectic algebra associated with these strings which one can hope to be algebraically universal.

2. Finite measurement resolution demands that all scattering amplitudes representing zero energy states involve discretization. In purely p-adic context this is unavoidable because the notion of integral is highly problematic. Residue integral is p-adically well-defined if one can deal with π.

   p-Adic integral can be defined as the algebraic continuation of real integral made possible by the notion of p-adic manifold and this works at least in the real–p-adic intersection. String world sheets would belong to the intersection if they are cognitive representations as the interpretation of fermions as correlates of Boolean cognition suggests. In this case there are excellent hopes that all real integrals can be continued to various p-adic sectors (which can involve algebraic extensions of p-adic number fields). Quantum TGD would be adelic. There are of course potential problems with transcendentals like powers of π.

3. Discrete Fourier analysis allows to define integration in angle degrees of freedom represented in terms of algebraic extension involving roots of unity. In purely p-adic context the notion of angle does not make sense but trigonometric functions make sense: the reason is that only the local aspect of geometry generalize characterized by metric generalize. The global aspects such as line length involving integral do not. One can however introduce algebraic extensions of p-adic numbers containing roots of unity and this gives rise to a realistic notion of trigonometric function. One can also define the counterpart of integration as discrete Fourier analysis in discretized angle degrees of freedom.

4. Maybe the 2-dimensionality of cognition has something to do with the fact that quaternions and octonions do not have p-adic counterpart (the p-adic norm squared of quaternion/octonion can vanish). I have earlier proposed that life and cognitive representations resides in real-p-adic intersection. Stringy description of TGD could be seen as number theoretically universal cognitive representation of 4-D physics. The best that the limitations of cognition allow to obtain. This hypothesis would also guarantee that various conserved quantal charges make sense both in real and p-adic sense as p-adic mass calculations demand.

12.3.6 Why P-Adic Intentionality Does Not Reduce To Quantum Randomness?

The basic argument against quantal free will is that quantum non-determinism is basically randomness of a particular kind so that one can apply statistical determinism to predict the behavior for an ensemble of systems. The crucial question is whether also intentionality in the proposed sense reduces to randomness so that statistical determinism applies. One can imagine several mutually consistent approaches to the problem.

1. The notion of randomness is based on the notion of probability, and it could happen that the notion of probability simply does not make sense at all for a system exhibiting an intentional behavior or that the probabilities do not exist in the real sense but only as p-adic probabilities. Thus abnormal statistics might serve as a signature of an intentional system.

2. Intentionality involves free will and unpredictability in short time scales but predictability in long time scales. This could serve as a signature of an intentional system. Quantum-classical correspondence states that the dynamics of space-time surface mimics quantum dynamics and therefore also the dynamics of consciousness and intentionality. If so the behavioral patterns of an intentional system characterized by p-adic prime p should obey p-adic topology, which is a strong and testable prediction.

3. Zero Energy Ontology and the notion of negentropic entanglement provide a further perspective to the problem. Intentionality means goal directed behavior. NMP implies that the increase of negentropy is the universal goal. Universe builds negentropic entanglement servings as kind of Akashic records. One could therefore say that it is NMP that intends and wants. The outcome of the state function reduction at the opposite boundary of CD is forced by NMP and the plan for making it and the will to do do it should characterize the contents of consciousness associated with the self defined by a sequences of state function reductions at given boundary of CD. NMP also implies that the outcome of state function reduction is not random since entanglement negentropy is preserved or even increases. Of course, negentropic entanglement can be transferred between different systems.

p-Adic topology for time series as a signature of intentionality

Intentional behavior means that there is unpredictability in short time scales but predictability in long time scales because system can realize its long term plans and use its partially free will to cope with the changing challenges of the everyday life.

p-Adic topology could realize this idea.

1. The rational values of real and p-adic embedding space coordinates correspond to the same points of the generalized embedding space (essentially union of real and p-adic embedding spaces for various values of p with common rational points identified).

2. The points, which are p-adically close to each other can have arbitrarily long real distance since the points x and $x+kp^n$, $k \in \{0, p-1\}$, become arbitrarily near to each other p-adically and arbitrarily far way in real sense as n increases for the p-adic topology characterized by prime p.

Thus p-adic long range fractal correlations could simply result from p-adic continuity. The local unpredictability would be mimicked by a discontinuous behavior in the real topology resulting from the fact that time values close to each other in the real sense are far from each other in p-adic sense.

p-Adic non-determinism means that integration constants of p-adic differential equations having by definition vanishing derivatives, are functions of the pinary cutoffs x_N defined as $x = \sum_k x_k p^k \to x_N = \sum_{k<N} x_k p^k$ of the arguments of the function. Since the rational values of real and p-adic coordinates correspond to same points of embedding space, this means that p-adic non-determinism realizes intentionality by fixing the solution of field equations at a finite number of points below some real time (length) scale defined by N. The choice of these pseudo constants would characterize p-adic intentionality, the future plan of the system relatively stable against

quantum jumps and the range of intentional action would be finite, which could explain why the young person in the geometry youth now cannot make choices affecting dramatically the geometric now decades later.

There is an analogous non-determinism also in the real sector due to the dramatic failure of the complete non-determinism of the basic action principle determining the dynamics of space-time surfaces. This non-determinism justifies the characterization of the real space-time sheets by a p-adic primes.

Consider now a situation in which some observables of might -be intentional system are measured as a function of time. Suppose that measurements are carried out at moments $t_n = n\Delta T$, $\Delta T = T/N_m$, where T is the duration of the experiment and N_m is the number of measurements.

1. With respect to the real topology the behavior of the system would look random in short time scales with violent discontinuities independently how precise the time resolution is made: fluctuations would actually become more violent with the improving time resolution.

2. p-Adic fractality would predict long range correlations over arbitrarily long time scales p^n in this kind of situation. Time values t and $t + rp^k\Delta T$ would be near to each other p-adically so that the values of the observables measured at these time values would be near to each other. Long range temporal correlations would thus quantify the ideas that will is not completely free and that intentionality implies an approximate predictability in long time scales. The fact that p-adic pseudo constants allow intentional free will only below some time and length scales, justifies the idea that our life is in long time scales determined by what might be called fate although we can make freely decisions in short time scales. The stability of the p-adic pseudo constants and pinary cutoff N in quantum jumps would also mean that the realization of p-adic intentions occurring subjectively now in my geometric childhood would not have dramatic implications in the geometric now.

3. p-Adic fractality would also mean that similar behavioral time patterns could repeat themselves as temporally scaled-up versions. Person would react in a similar manner in different time scales, say in stressing situation lasting for few minutes or many years. What is used to call as personality might have something to do with these fractal behavioral patterns. There is indeed statistical evidence for the possibility to predict much about the life cycle of a person from the behavioral patterns in childhood. The child who wants all now tends to become an adult who does the same. Some aspects of personality would perhaps represent something not invariant under time translations but under p-adic time scalings.

How statistical behavior could exhibit intentionality?

Consider an ensemble of consisting of N_m measurements of some observables of a system during a fixed time interval T occurring at equally spaced moments of time $t_n = n \times \Delta T$, $\Delta T = T/N_m$. Classify the measurements by some equivalence relation so that there are I possible outcomes and estimate the probabilities for the outcomes as rational numbers $p_i = n_i/N_m$, $\sum n_i = N_m$. When N_m becomes large one should obtain estimates for the probabilities of various instances labelled by $i = 1, ..., I$. The standard frequency interpretation of probability theory relies on the assumption is that these estimates converge in real topology so that the estimates $p(i, N_m + k) = n_i/N_m + k$, $k << N_m$ and $p(i, N_m) = n_i/N_m$ do not differ much for large values of N_m.

It is however quite possible that $p(N_m)$ converges in some p-adic topology which would mean that in the real topology the estimates would fluctuate wildly without any convergence, in a typically fractal manner. The estimates for probabilities would however converge p-adically in which case the system would be intentional and characterized by some p-adic prime p. The quantum-classical correspondence suggests that the sequence of N_m measurements performed for an intentional system during time interval T can be modelled as a sequence of measurements performed for a p-adic space-time sheet serving as its correlate. With this assumption one can immediately conclude that the estimates for the probabilities do not converge since various observables are continuous functions with respect to p-adic rather than real topology and ΔT does not approach zero at the limit $N_m \to \infty$ but fluctuates wildly. Only for N_m and $N_m + kp^n$ p-adic continuity guarantees that probabilities estimated in this manner are near each other.

It must be emphasized that the notion of p-adic probability based on frequency interpretation satisfies the Kolmogorov axioms as demonstrated by [A7] [A7]. The notion of resolution $\Delta T = T/N_m$ defining what $N_m \to \infty$ limit really means is an absolutely essential additional element. If one defines $N_m \to N_m + 1$ as an addition of one additional measurement to existing sequence of measurements, the frequencies convergence to ordinary real probabilities with a given resolution since only one of the numbers n_i changes in $N_m \to N_m + 1$. The notion of resolution makes sense also in spatial degrees of freedom.

The notion of resolution is unavoidable already in quantum field theories in order to reduce degrees of freedom which are not directly experimentally detectable since the that measurement resolution is always finite. The notion of renormalization group realizes mathematically the notion of finite resolution [B18]. Thus resolution dependent statistics is not anything new. What is new is p-adicity and the long range correlations reducing to the p-adic continuity because of different concept of nearness. Note also that p-adically small structures have real sizes which are astrophysical so that cognition is naturally an astrophysical phenomenon in accordance with the notions of magnetic body and ME.

These considerations suggests how one could try to demonstrate p-adic intentionality experimentally.

1. One might hope of demonstrating that intentional systems behave apparently randomly in short time scales but that there are long range temporal correlations in time scales $t_n = p^n \Delta T$, $\Delta T = T/N_m$. Wild fluctuation of the probability estimates as function of N_m is a direct signature of intentionality. The approximate invariance of the frequencies under the transformations $N_m \to N_m + p^n \Delta T$ in turn allow to identify the value p. This approach could be used to prove the presence of the p-adic intentionality even at the molecular level or at level of say solar and planetary magnetospheres by studying the temporal behavior of the fluctuations of magnetic fields. For instance, it is known that solar magnetic field has what might be called memory [E3], which should not be there if it were really random. For tornadoes the presence of short range chaos and long range order in at at least spatial degrees of freedom is obvious. Period doubling in the systems approaching chaos could be a signature for the appearance of 2-adic intentionality in increasingly longer time scales. Also $1/f$ noise, not really understood in standard physics framework, might be related to intentionality.

2. One could also test the number theoretic information measures suggested by the p-adic approach using preferred resolutions defined by $N_m = kp^n$. Number theoretic information measures make sense for rational valued probabilities, and are obtained from Shannon entropy by replacing ordinary logarithm with the p-adic logarithm $Log_p(x) = log(|x|_p) = log(p^k) = klog(p)$ to get $S_p = -\sum_n p_n Log_p(p_n)$. The number theoretic entropies can have also negative values in which case one can say that the ensemble contains genuine information.

How the p-adic primes involved with intentionality and ordinary physics are related?

In real physics the p-adic primes involved are very large, for instance, $p = 2^{127} - 1$ for electron. These large primes however labels real space-time sheets and characterize their fractality and *effective* p-adic topology. p-Adic length scale hypothesis in its basic form predicts that primary and n-ary length/time scales correspond to powers of $\sqrt{2}$ of the fundamental p-adic length/time scales so that 2-adic fractality would indeed be realized in this sense. Besides the basic units for time and length also their integer multiples can take the role of the basic unit, this of course in accordance with the very notion of fractality.

Small primes would characterize p-adic space-time sheets serving as correlates of intentions. It seems that only relatively small values p, $p = 2$ being the simplest guess, are realized as far as intentionality is considered. The octaves in music realize 2-adic fractality and it might not be an accident that binary mathematics is mathematics of computation.

12.4 Some Other Aspects Of Consciousness In Relation To Time

The new view about time implies has quite far reaching implications. The notion of 4-dimensional body is the basic concept involved. One can understand long term memories as communications with the geometric past. Sensory perceptions can be seen as memories of magnetic body about the state of the material body in a time scale of a fraction of second. Also some other unexpected symmetries are predicted. Long term memory and precognition seem to be aspects of one and a same phenomenon. The same applies to psychokinesis and retro PK. In fact, both sensory perception, motor action, and memory can be seen as being based on the same mechanism if one accepts that personal magnetic body corresponds to "me". Libet's findings about active and passive aspects of consciousness provide empirical support for the notion of magnetic body.

12.4.1 Passive And Active Aspects Of Consciousness

The division of the aspects of conscious experience to active and passive ones is not so obvious as one might think. Sensory experiencing is more like building a piece of artwork than passive receival of the sensory input and active processes like healing could be rather passive receival of negative energy MEs from the patient so that the healee gets in this manner only metabolic energy and does the healing herself. It is also far from obvious whether precognition is passive experiencing of the geometric future or psychokinesis actively affecting it.

The fundamental identification for the active and passive aspects could be in terms of terms of the arrow of time for the sub-self in question. Sequences of state function reduction at the opposite boundaries of sub-CD would correspond to sensory perception and motor action respectively. Which is which would depend on the arrow of time for the CD containing the sub-CD.

A precise theoretical dichotomy, at least apparently analogous to active-passive dichotomy, however exists if one accepts that MEs provide the basic mechanism of remote viewing and intentional action. Negative energy MEs can induce mere entanglement making sharing of mental images possible. This would naturally correspond to the passive aspects of consciousness as far as the receiver of negative energy MEs is considered. The generation of negative energy MEs makes possible remote metabolism at the end of system generating the negative energy ME. The receiver of the negative energy ME, say precognizer would be the passive counterpart whereas its sender, say an area of left cortex suffering from under-nutrition as might be in the case of synesthesia, would be the active counterpart. One must be however cautious here. It is not at all clear whether one can talk about sender/receiver of the negative energy ME since entanglement is completely symmetric process. In the sequel it is assumed that the notion of sucking of negative energy does not make sense.

Low frequency MEs can also contain also high frequency MEs inside them and positive energy MEs of this kind are especially natural for the realization of active aspects of consciousness. Positive energy MEs could directly provide energy to the receiver. They can also induce bridges along which various particles leak between space-time sheets so that basic metabolic activities are induced and controlled remotely.

12.4.2 Sensory Perception, Motor Action, And Time

TGD view about sensory perception differs dramatically from that of the standard neuroscience in that sensory organs are carriers of basic sensory representations and the magnetic body rather than body or brain is the experiencer with which we can identify ourselves. Magnetic body is also the intentional agent and both motor action, sensory perception, and long term memory which all involve also intentional elements, are based on the time mirror mechanism (see **Fig. ??** in the appendix of this book). Intentions are represented by p-adic MEs generated at the magnetic body. p-Adic ME is then transformed to a desire about a particular action and represented as a negative energy ME propagating to the direction of the geometric past. Actions are realized as responses to the negative energy MEs as various kinds of neural activities and as a generation of positive energy MEs. A more realistic model involves an entire sequence of this kind of steps proceeding like a sequence of sub-program calls downwards along the hierarchy of the magnetic bodies down to the level of CNS. A good metaphor is obtained by regarding magnetic bodies as bosses in the

hierarchy of some organization and CNS as the lowest level ultimately realizing the desire of the big boss.

Sensory organs as seats of qualia

According to the music metaphor, sensory organs are responsible for the music whereas brain writes it into notes by building symbolic and cognitive representations communicated to the magnetic body. Back projection to the sensory organs is an essential aspect of this process and is discussed in [K50]. Sensory perception at the level of magnetic body involves the generation of negative energy MEs entangling with sensory organs involving possibly also brain as an intermediate entangler.

The assumption that sensory organs are carriers of the sensory representations entangling with symbolic representations realized at the level of cortex does not mean any revolution of neuroscience, just adding something what is perhaps lacking [K50].

Neuronal/symbolic level would do its best to symbolically represent what occurs naturally at the level of qualia. Color constancy could be understood as a basic characteristic of color qualia represented symbolically at the neuronal level. Center-surround opponency for the conjugate colors is the neural counterpart for the contrast phenomenon in which the boundary for a region of the perceptive field with a given color carries the conjugate color (black-white opponency associated with the luminance is only a special case of this). The contrast phenomenon at the level of visual qualia could derive from the vanishing of the net color quantum numbers for the electrodes of the retinal color capacitors.

The basic prediction is the presence of the back projection at least in the sensory modalities in which hallucinations are possible. MEs with MEs mechanism is the most natural candidate for realizing the back projection, negative/positive energy MEs would realize the back projection based on quantum/classical communications, and the capacitor model of the sensory receptor can be applied to model photoreceptors and retina. This picture integrates nicely with the various speculations about the role of the ciliary micro-tubules in vision. The obvious question is how the presence and character of the back projection reflects itself in the structure of the sensory pathways and sensory organs.

Basic facts about how gastrulation and neurulation proceed during the development of the embryo, lead to testable hypothesis about the character of the back projection for various sensory modalities. According to the hypothesis, one can speak about "brain senses" and "skin senses" according to whether the back projection is based on quantum or classical communications.

How motor action differs from sensory perception?

There is a deep similarity between sensory perception and motor action in TGD framework, the basic difference being that classical signals propagate in different direction in CNS and in geometric time. Motor action is initiated by the magnetic body by the sending of negative energy to motor organs by generating negative energy MEs, and proceeds by similar processes backwards in the geometric time to the level of brain and magnetic body, very much like an instruction of a boss at the top of organization to the lower levels of hierarchy and induces lower level instructions. The analogy with computer program calls (quantum communications, desires) and their executions (classical signals, actions) is also obvious. Also classical signals from the magnetic body to the body and brain are possible.

Analogous picture applies to sensory perception with motor organs replaced by sensory organs except that the fundamental communications occur to geometric future from biological body to magnetic body via a hierarchy of EEGs. There is however also an active building of sensory percepts by feedback from the magnetic body which selects between quantum superposed alternative percepts already at the level of sensory organs.

Sensory *resp.* motor imagination differ from sensory perception *resp.* motor action only in that the magnetic body entangles with some higher level of CNS. Therefore there is no danger that imagined motor action would become real or that imagined sensory perception would be experienced as real. This picture is in accordance with the idea of quantum credit card implying maximal flexibility, and with respect to the geometric time would mean that motor actions are only apparently initiated from the brain.

12.4.3 Long Term Memories And Time

TGD based model of long term memory requires no storage of memories of past to the brain of the geometric now. The memories are in the geometric past as dynamical self organization patterns and subject to changes.

1. In the case of active memory recall the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

2. In the case of episodal memories active precisely targeted memory recall might be difficult since the entanglement with a correct mental image seems to require good luck. In principle it is possible to select the distance T to the geometric past where the memory comes from by selecting the fundamental frequency of ME. There are huge amounts of information, which is useless unless the person is an artist. Ironically, the loss of cognitive abilities would be compensated by episodal memories providing mental powers making an idiot a genius able to tell whether a given number is prime and to perform extremely complex calculations. A mild variant of the idiot savant phenomenon can be induced artificially by trascranial magnetic stimulation even in ordinary persons [J122]. The miraculous memory feats of synesthetes and idiot savants, and also sensory memories and strange abilities induced by electric and transcranial magnetic stimulation could involve the entanglement of the stimulated brain areas rather than that of magnetic body with sensory representations with brain areas taking the role of sucker of positive energy. In this kind of situation the starving magnetic body could send negative energy sensory MEs to a more distant geometric past and experience episodal memories instead of the sensory input.

3. Classically communicated memories are symbolic and thus the amount of information is minimized. They are also reliable since it is enough for the brain of the geometric past to share the desire to remember. If the desire is communicated to a wide temporal range in geometric past, some self of the geometric past is able to communicate the answer. Context sensitivity is the drawback of this memory mode. Memes defined as sequences of memes defined by sequences of 21 DNA triplets might define what might be called universal language helping to overcome the context sensitivity [K52].

4. Brains could also generate automatically classical signals about often needed declarative memories to the geometric past at various lengths of magnetic flux tubes. The memory recall would require only the tuning to receive the classical signal. This would require an organization of brain analogous to sensory areas so that a particular neuron group is tuned to receive signals from a particular distance to geometric past. One can also imagine a situation in which the communication of the memory from the past occurs as repeated communications over shorter time interval, somewhat like ordinary communications using radio stations receiving and re-sending the message. For instance, classical communications could circulate around the magnetic loops associated with the personal magnetic body or that of Earth's magnetic field much like neural signals in neural circuits. This would make the memory retrieval more reliable. The automatic classical communications could be also involved with the communications by active memory recall. The extreme situation would be the transfer of information from the geometric past like a news about some event in a population via communications between individuals. This mechanism would also establish the memory representation along the entire life span.

Do declarative memories and intentional action involve communications with geometric past?

Communications with geometric past using time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig.** 24 in the appendix of this book) in which phase conjugate photons propagating to the geometric past are reflected back as ordinary photons (typically

dark photons with energies above thermal threshold) make possible realization of declarative memories in the brain of the geometric past [K101].

This mechanism makes also possible realization of intentional actions as a process proceeding from longer to shorter time scales and inducing the desired action already in geometric past. This kind of realization would make living systems extremely flexible and able to react instantaneously to the changes in the environment. This model explains Libet's puzzling finding that neural activity seems to precede volition [J44].

Also a mechanism of remote metabolism ("quantum credit card") based on sending of negative energy signals to geometric past becomes possible [K59]: this signal could also serve as a mere control signal inducing much larger positive energy flow from the geometric past. For instance, population inverted system in the geometric past could allow this kind of mechanism. Remote metabolism could also have technological implications.

Episodal memories as time-like entanglement

Time-like entanglement explains episodal memories as sharing of mental images with the brain of geometric past [K101]. An essential element is the notion of magnetic body which serves as an intentional agent "looking" the brain of geometric past by allowing phase conjugate dark photons with negative energies to reflect from it as ordinary photons. The findings of Libet about time delays related to the passive aspects of consciousness [J87] support the view that the part of the magnetic body corresponding to EEG time scale has same size scale as Earth's magnetosphere. The unavoidable conclusion would be that our field/magnetic bodies contain layers with astrophysical sizes.

p-Adic length scale hierarchy and number theoretically preferred hierarchy of values of Planck constants, when combined with the condition that the frequencies f of photons involved with the communications in time scale T satisfy the condition $f \sim 1/T$ and have energies above thermal energy, lead to rather stringent predictions for the time scales of long term memory. The model for the hierarchy of EEGs relies on the assumption that these time scales come as powers $n = 2^{11k}$, $k = 0, 1, 2,$, and predicts that the time scale corresponding to the duration of human life cycle is ~ 50 years and corresponds to $k = 7$ (amusingly, this corresponds to the highest level in chakra hierarchy).

Basic model for memory recall

For the time-mirror model of long term memory the ULF dark MEs must be generated both at the personal magnetic body and in the brain.

1. At the personal magnetic body cyclotron phase transition would give rise to negative energy neutral MEs sucking energy from the biological body of the geometric past. This radiation would be reflected back to the geometric future as positive energy neutral MEs. The response would depend on the state of the brain. Motor action would differ from memory recall only in that it would involve negative energy W MEs inducing exotic ionization at both ends and leading to a physiological outcome. The entanglement via W MEs could induce direct sensory memories relying on sharing and fusion of mental images.

2. The ULF radiation representing the response to the memory recall would correspond to Josephson radiation giving rise to a scaled up dark EEG in the relevant time scale characterized by the level of the dark matter hierarchy. The de-coherence of higher level dark photons to single ordinary EEG dark photon or their decay to EEG dark photons is probably involved with the memory call and would transform the response from the geometric past to ordinary cognitive and emotional input at personal magnetic body.

The time span of long term memories as signature for the level of dark matter hierarchy

Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of.1 seconds [K36], and EEG frequencies correspond at this level dark photon energies above the

thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [K37]. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K65, K37]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

How to achieve precisely time-targeted communication to and from geometric past?

Negative energy MEs are ideal candidates for sending a signal to the geometric past and inducing entanglement and sharing of the mental image representing the desire to remember. The magnetic flux tubes of the personal magnetic body with sizes measured in light years in turn can act as wave guides along which the negative energy curvilinear MEs propagate along or are parallel to. Also negative energy em MEs are possible since negative energy MEs interact very weakly with the external world in any case. Also the positive energy MEs sent to the direction of the geometric future as a response and representing classically communicated declarative memories would propagate along magnetic flux tubes. The same magnetic flux tube could be used for both communications.

One can consider several variants about how long terms memories are realized as communications between geometric now and geometric past.

1. Mirror model

The original idea was that MEs could be reflected at the ends or kinks of a magnetic flux tube serving as kind of mirrors. The outcome was the mirror model of long term memory in which the signal from the geometric past represented by ME is reflected at the end of the magnetic flux tube of astrophysical size. In the similar manner also the negative energy ME would be reflected. The model was still based on the idea that "me" is the physical body or brain. The basic objections are that there is no convincing identification of the mirrors and there is no guarantee that the mirrored ME returns to the original brain.

2. Loop model

One can also consider the possibility that closed magnetic flux tubes associated with the personal magnetic body could function as wave guides for curvilinear MEs, so that MEs would automatically return to the brain if they propagate while attached to the boundary of a closed magnetic flux tube. Also this model is still based on idea that the size of the personal magnetic body is not much larger than Earth's size so that one can idealize "me" as brain, at least in the length scale defined by the time span of the long term memories. Furthermore, despite the fundamental similarity between motor action, sensory perception, and memory, the mechanism of long term memory would differ from the mechanism of motor action and sensory perception. A further serious objection is that MEs parallel to the closed magnetic flux tubes and representing closed topological light rays might not be allowed as solutions of the field equations.

3. Brain and body as time like mirror

If one takes completely seriously idea about "me" as the magnetic body with size at least of order light lifetime which can be regarded as single quantum coherent structure, one ends up to a

variant of the model a). First of all, the whole magnetic body becomes the experiencer and classical communications need not be spatially precisely targeted. Secondly, brain and body serve as time like mirrors in the sense space-like reflection is replaced with both spatial and temporal reflection. Negative energy ME characterized by frequency and wave vector is replaced with time reflected positive energy ME: $(-E, -k) \to (E, k)$ in the reflection. Ideal reflection changes only the sign of the normal component of 3-momentum. If this is the case also now then also the magnitude of energy would be conserved so that the classically communicated memory would be automatically communicated to a correct temporal position in the geometric future.

If the transverse area S of flux tube codes for the temporal distance T to the geometric past by its transverse area ($T \propto S$) and thus by cyclotron frequency scale, the mechanism of long term memory becomes precisely identical with that of sensory perception and motor action. The desire to remember is communicated quantally from the magnetic body to brain along flux tube, and the reply arrives as a classical communication along same flux tube at the fundamental frequency and the reply communicated classically generates cyclotron transitions at the receiver's end at a correct temporal distance in future. In light of the fractality of consciousness, this model is certainly the unique one and is certainly consistent with the field equations.

The memory mental image communicated classically should reach the temporal position of the 4-D brain, which communicated the desire to remember. High precision communication is not absolutely necessary although it is favored by metabolic considerations: it is enough that the memory is communicated to a time interval containing the temporal position wherefrom the desire to remember was communicated. Memory could even diffuse like an interesting news in a 4-D society formed by mental images in brains at different times.

If MEs are amplified by Alfven wave resonance (closed magnetic flux tubes or flux tubes with ends), the wave length of ME should correspond to the length of the magnetic flux tube involved. If negative and positive energy MEs are associated with same magnetic flux tubes and the thickness of the magnetic flux tube varies as $S \propto L$, cyclotron transitions occur automatically at a correct temporal and spatial position of the flux tube and the sender of the memory recall receives the answer. In this case however memory is communicated to some time interval in geometric future.

If temporally selective communication is required, the frequency associated with ME must correspond to the same time value for the negative and positive energy MEs involved. A relative precision of $\Delta f/f \simeq 10^{-9}$ is required if the time span of the memory is 10 years and precision about.1 seconds (sensory memories). Of course, the needed precision could be much lower already because the time span of short term memories is of the order of minute. The active loss of memories could result from the refusal or inability of the "mes" of the geometric past to communicate memories or of the "me" of now to generate memory recalls. Later a model of time like reflection which could conserve the frequency with this precision will be discussed.

Second solution to the problem is to have several copies of the memory mental image so that the probability to hit one of them is high. Very probably brain applies this trick. This would explain why the standard model for long term memories seems to work reasonably well.

4. Variants of the time-mirror model

One can consider several variants of the time-mirror model.

1. For the simplest model the MEs involved are mor or less linear structures. For classical communications with light velocity the lengths $L = cT$ of the flux tubes would be measured in light years for a typical time span T of long term memory. If the memory recall originates simultaneously from various points of the magnetic body, the reply to the memory recall is received simultaneously by different part of the personal magnetic body in the approximation that the response at the biological body is instantaneous (so that also the received response emerges instantaneously). For EEG phase velocities L would be of the order of the size of the magnetic body of Earth for typical values of T so that the declarative memory could be communicated also to the magnetic Mother Gaia responsible for the third person aspects of the memory.

2. What is intriguing that for a typical EEG phase velocity v the distance $L_B = vT$ travelled during T corresponds to a wave length $\lambda = L_B = c/f_{high}$ of EEG wave propagating with light velocity. This brings strongly in mind the scaling law of homeopathy and its generalizations

[K53], and suggests that the boundary ME corresponds to EEG wave with EEG phase velocity v. This numerical coincidence encourages to consider also time like reflection in which energy is not conserved. The scaling law of homeopathy suggests that low frequency negative energy ME could transform in the reflection to high frequency positive energy ME:

$$f_{low} \to f_{high} \quad .$$

This transformation could be interpreted in terms of the Alfven resonance condition $f_{high} = c/L_B$ for a ME propagating in the flux loop of length L_B (recall however the objection against closed topological light rays).

3. Positive energy EEG MEs could propagate with light velocity along the closed loops of personal magnetic body of Earth's magnetic field and return again and again to brain very much like neural signals circulate in neural circuits. This would provide a way to refresh often needed memories. The main theme of [K64] was indeed the fractal correspondence between the structures of the brain and magnetosphere.

4. Fractality suggests that magnetic loops of all possible sizes are involved with classical communications by boundary MEs, even the magnetic loops of the material body serving as templates for neural circuits. The requirement that frequencies are identical for these fractally scaled magnetic circuits could be seen as an entrainment phenomenon. This would predict ultra-slow neural signals serving as correlates for the classical communications of long term memories at brain level. It is indeed known that Ca_{++} have extremely wide velocity spectrum [A40].

The model based on W MEs as induces of motor actions explains these velocities explains these velocities differently. Classical W field depends on the light like longitudinal coordinate and single transversal coordinate. One expects that the maxima for the intensity of W field are the loci around which physiological effects concentrate. These maxima in general propagate in the transversal direction. This velocity could correspond to the velocity of the physiological wave.

12.4.4 Remote Mental Interactions And Time

If the notion of magnetic body is taken completely seriously, sooner or later comes the realization that not only motor action, sensory perception, and memory, but also various forms of remote mental interactions could be based on essentially the same mechanism. Motor action and memory recall certainly involve the active aspect but so does sensory perception via direction of attention and selection between percepts.

Magnetic bodies are the intentional agents, and accompany even "non-living" targets. The intention of the magnetic body to achieve something is transformed first to a negative energy ME representing the communication of the desire to achieve something to the geometric past by sharing of mental images. Already the sharing of mental images might be enough, as In the case of remote viewing of the geometric past, in special case long term memory. Then the receiver of the negative energy ME, be it lower level magnetic body or material body, tries to realize the desire and generates classical signals. These signals could be also positive energy MEs and could propagate back to the magnetic body as in case of declarative memory recall. They could also propagate to another magnetic body, which would mean that mind-mind interactions are involved.

This unified view means that the distinction between active and passive aspects of remote mental interactions is far from trivial, and it is not so easy to tell where the boundary line between precognition and psychokinesis is. The first realization along these lines was that precognition and long term memory are different aspects of the same phenomenon. Then came the idea that also PK and retro PK could be seen as different aspects of the same phenomenon if PK can be regarded a generalized motor action in which target becomes effectively part of the body of the psychokinesist.

A possible view about remote viewing

The basic question is whether negative energy MEs are always generated actively by the system in the geometric future or whether also active sucking of the negative energy from the geometric

future is possible. The simplest assumption is that the sucking of negative energy is not a sensible concept. The motivation comes from the fact that it seems to be impossible to distinguish between sucking and passive receival of the negative energy since the entangled systems are in a completely symmetric position.

1. Active and passive aspects

Whether one can regard remote viewing as active or passive process depends on whether it is geometric past or future which is viewed.

1. If geometric future is viewed, the task of the remote viewer is to tune to the "correct wave length" in order to be able to receive the negative energy ME from the geometric future. This requires that remove viewer tries to get rid of mental images competing for the metabolic resources and tend to mask the viewed mental image. The initiative is possessed by the system in the geometric future sending the negative energy ME. The reaction of the remote viewer realized as classical communications could give rise to PK effect in the target. If the time-mirror mechanism based on induced phase transition is involved also with remote viewing, the reaction of remote viewer would be automatic so that some kind of PK effect would be unavoidable.

   One cannot completely exclude the possibility of time reversed classical communications. In ordinary classical communications the high frequency positive energy MEs absorbed by the receiver kicks it to a higher energy state wherefrom it returns to the ground state spontaneously. A system receiving high frequency negative energy MEs inside low frequency negative energy ME can drop to a lower energy state only if the magnitude of the energy is below thermal energy or if the system is analogous to population inverted laser. In the latter case the receiver would not however return spontaneously to the original state unless their is a feed of energy to the system.

2. If the geometric past is viewed, the process is active process and completely analogous to long term memory recall except that negative energy MEs generated by the remote viewer are not received by the brain of the viewer but some other system. Note that now also classical communications are possible and would be analogous declarative memories. These communications might be possible if the target is living system and be based on memetic code using the common vocabulary defined by common memes [K52].

2. Sharing of mental images

Since remote viewing by the sharing of mental images does not involve classical communications at all so that one cannot characterize the process in terms of bit currents. There are indeed arguments that if the field patterns of EEG waves were responsible for the remote viewing realized as classical communications, the bit rates required would not be high enough since the frequency defines an upper bound for the bit rate.

Sharing of mental images does not pose any obvious upper bound for the amount of conscious information transferred. Measures for the amount of information contained by mental image could be provided by the number theoretical information measures predicted by TGD approach [K73, K81].

What would be communicated would be more like impressions instead of messages consisting of symbol sequences. The message, say visual perception, would contain huge amounts of irrelevant information. Of course, the mental images could be also cognitive or symbolic representation, say internal speech. The translation of these impressions to language involves cognition and analytic thinking and can lead to misinterpretations. The reports about telepathic communications suggest that mental images transferred in telepathic communications are fragmented more like sensory and emotional impressions and often what might be regarded as separate "features" of the perceptive field rather than complete percepts. If sensory organs are the seats of the sensory representations, telepathy should thus involve entanglement of the viewer with the brain of the sender containing the symbolic representations. Fragmentation would reflect that fact that brain does for sensory input same as catabolism makes for food.

It is known that the entropy gradients associated with the target correlate with the probability that target is remote viewed [J135]. In TGD framework this can explained as a basic

characteristic of conscious experience [K50]. All gradients, also spatial gradients, such as textures of visual field or gradients of illumination at particular wave length, are transformed to subjecto-temporal gradients and only changes are perceived in accordance with quantum jump as moment of consciousness identification. In TGD Universe the intensities of emotions are proportional to the gradients of entropies associated with various quantum number and zero mode increments and only objects generating strong enough emotional response catch the attention. Targets with low entropy gradients do not generate intense mental images in any perceiver (not necessarily human!), and thus do not generate remote perception by a sharing of mental images.

3. Remote viewing is not only viewer-target phenomenon

Remote viewing does not seem to be only a viewer-target phenomenon but involves many-brained magnetospheric selves receiving information from the brains involved with the typical experiment whose protocol is such that viewer does not know the location of the target. In particular, the ability of the remote viewer to view target about which he knows only coordinates having no significance as such to him but for someone involved with the protocol supports this view [J113]. Also the reported healings induced by prayer groups and meditation groups whose members do not know the healees and even where they are, support the same conclusion [J68]. Thus remote viewing as well as healing might involve multiple entanglement. For instance, healer would be entangled with higher level self in turn entangled with the healee. Fractality suggests that one could apply the wisdom about brain functioning to the modelling of the multi-brained selves. The notion of associations might make sense for instance. The analogy with brain encourages to think that also classical communications by positive energy MEs might be involved and make possible feedback and thus PK.

An interesting practical question is how to characterize the strength of the entanglement by negative energy MEs. The lifetime of the resulting bound state is one such measure. One could guess that this time scale is of the order of the relevant p-adic time scale. Somewhat paradoxically but in consistency with Uncertainty Principle, the duration would be the longer, the weaker the binding energy would be. Second measure is the number of MEs involved. If collective multi-brained selves are involved the number of brains involved and having information about target would be a significant factor.

Sharing of mental images as the basic mechanism of remote viewing

Sharing of mental images does not require neither target nor receiver to be able to communicate symbolically. Therefore the target and receiver could be any living system: animal, plant, even bacterium. In TGD Universe one cannot exclude even "non-living" systems as targets and even sharers of mental images. The remote viewing of non-living targets is indeed possible and in this case either mental images of target or some system perceiving target are shared.

Support for the extreme generality of the sharing of the mental images as a basic mechanism of remote viewing comes the fascinating experimental discoveries made by Cleve Backster [J30, J53]. These findings have led Backster to introduce the notion of primary perception, which seems to have a natural identification as sharing of mental images.

1. Plants, eggs, and even bacteria are able to have primary perceptions. Backster tells in the interview that even yoghurt got wild when he took a chicken out of refrigerator and began pulling off strips of meat. Plants respond electrically to strong negative emotions and to the violence or death suffered by other living organisms. That primary perception correlates with the strength of emotions conforms with the view that entropy gradients with respect to subjective time, which are indeed identifiable as emotions, measure the strength of perception.

2. Distance does not seem to matter much. Sperm separated by a large distance from its donor reacted when the donor inhaled amyl nitrate. White cells were found to remotely react to the emotions of their donors. Same was found to apply to plants and their owners.

3. Plants and even bacteria seem to have a defence mechanism resembling shock. If bacteria share the mental images of suffering organisms by receiving negative energy MEs sent by them, the shock could be interpreted as resulting from the depletion of positive energy resources (all excited states of population inverted many-sheeted lasers decay to the ground state) or be a mechanism preventing this depletion.

An interesting question is whether humans have lost this ability or is this reaction usually unconscious at our level of self hierarchy and whether human skin could exhibit GSR to say death of other life-forms.

Precognition and memory as different aspects of the same phenomenon?

It is tempting to see precognition and long term memory as different aspects of the same phenomenon involving sharing of the mental image resulting as fusion of mental images by time-like entanglement induced by negative energy ME.

1. This identification would explain why precognition is a rare instance whereas memories would pop up more or less spontaneously. The reason is that precognition means giving energy to the future self whereas memory means receiving it. During wake-up period brain has to utilize its metabolic energy to build sensory representations, to plan and realize motor actions, and cognize. Therefore not much energy is not available unless these activities are silenced. This kind of silencing is indeed a prerequisite for precognition [J113].

2. Sleep state is for metabolic reasons ideal for precognition. During sleep state it is however the larger self resulting as a fusion of brain with some other self which precognizes, so that these precognitions are usually not remembered. It should be however possible to precognize during dreams, especially so during lucid dreaming. The problem is that dreams are forgotten very rapidly unless they are documented immediately. The classic work "Experiment with time" of Dunne provides strong support for the prediction that dreams can be precognitive [J118]. Also Joe McMoneagle has told in his book about height ened precognitive abilities during lucid dreaming [J113]. Probably almost anyone has had dreams which develop logically to the ringing of the alarm clock.

3. In this picture the one who remembers, that is generates negative energy ME, is a natural candidate for the active participant in the process. Therefore precognizer can only calm his/her mind and try to "tune at the same wave length" in order to entangle with the self of geometric future and try to eliminate the mental images that would mask the precognized one and compete for metabolic resources. The tuning to the same wave length has quite literal meaning since the fundamental frequency of ME determined by its temporal duration characterizes what might be called the extension of the memory field. There is indeed evidence for the notion of memory field [J150]. If memory and precognition are aspects of the same phenomenon then also the notion of precognitive field makes sense.

PK and retro PK as essentially same phenomenon?

The ideas that PK is just motor action with target taking the role of the motor organs and motor action involves negative energy W ME leads to a new view about PK and retro PK.

1. Ordinary motor actions are initiated by higher level selves by sucking negative energy from motor organs and the process proceeds upwards in CNS to the direction of geometric past wherefrom classical response comes from. In the case of PK this would mean that psychokinesis would be initiated by psychokinesists by sucking energy from the target by sending negative energy MEs to the target. If this picture is correct, all motor actions, in particular PK, would be by definition retro PK since the reaction would occur in the geometric past always and only the time scale of the time lapse would distinguish between PK and retro PK.

2. One can of course imagine also a situation in which positive energy W MEs are generated and exotically ionize and entangle part of brain with a system located in the geometric future. Certainly this mechanism is not the one favored by the life in jungle. It is also far from obvious whether magnetic body has the needed metabolic energy resources to generate positive energy W MEs.

   In the case of non-living targets one can imagine that PK able person is able to transfer the metabolic energy of his own biological body to the target, perhaps by sucking it first to his own magnetic body and sending then to the target. Target could also generate negative

energy MEs send most naturally to motor organs or perhaps skin of the psychokinesist. This could induce the flow of various particles to say atomic space-time sheets, where they can induce dissipative effects. This and the universality of metabolism based on zero point kinetic energies forces to consider quite seriously the possibility that the magnetic body of almost any system can be a conscious experiencer or an intentional agent.

3. Not all targets are optimal. Targets should allow the generation of dark plasmoids giving rise to dark plasma oscillations. Capacitor like systems near di-electric breakdown would be optimal in this respect and this kind of systems has been used in PK experiments (this is discussed in [K98]. Targets made of organic material are also favored. If all PK is actually retro PK, PK is possible only if the target is able to provide or receive from some source the metabolic energy needed. Organic or living targets would be optimal but one might expect that living systems have developed immune systems in order to avoid of becoming possessed by alien magnetic bodies. There are indeed reports about PK effects on films which have gelatin as one component [I56]: I have discussed a model for these effects in [K53].

4. MEs can also play a role of mere control function by acting as bridges along which particles can flow between various space-time sheets but not accelerating the charges. The flow of particles between say magnetic flux tubes and atomic space-time-sheets induces a recoil effect and the explanation for the report of Modanese and [H7] [H6] about a new kind of radiation which induces motion of material particles without giving them appreciable energy, supports the view that this recoil effect can induce macroscopic motion. Also the model for the PK effects induced by Russian psychokinesists in charged objects at table near the critical potential inducing discharge leads to the idea that the flow of ions between space-time sheets inducing recoil effects is responsible for PK effect [K98]. Psychokinesist would provide the energy needed for the control of motion but that part of the momentum could come from (say) magnetic flux tubes carrying the ionic supra currents.

5. The idea about long term memory and precognition as different aspects of the same phenomenon does not generalize as such. Psychokinesist would perform (retro) PK to the target while living target could communicate sensory data as a reaction to the motor action coded into Josephson radiation giving rise to generalized EEGs. Hence remote sensing could appear as one aspect of PK and make possible controlled OK in the case that direct sensory input from the target is not available.

In the famous chicken-robot [J155] experiments chicken was imprinted to a robot with the consequence that the robots motion in room coded earlier to a random number sequence changed so that the robot tended to stay near chicken. In this case one could say that chicken performed retro PK in the computer program responsible for generating the random number sequence or sequence itself by generating negative energy MEs. The resulting PK effect on chicken was at the level of chicken brain and provided for chicken metabolic energy. Perhaps the interaction between child and parents involves a similar transfer of energy.

From remote viewing to quantum remote sensing?

Ordinary remote sensing technology is limited by the finite velocity of light making it impossible to remote sense actively objects that are too faraway. Time mirror mechanism (see **Fig. ??**) not only makes it possible to survive utilizing.3-.5 seconds old sensory data but also suggest a technology of active remote sensing based on time reflection at the studied object and thus involving no time lapse, and making possible remote sensing of arbitrarily distant, even astrophysical, objects.

A phase conjugate laser wave would travel to the geometric past and time-reflect back as an ordinary laser wave from an object containing population inverted many-sheeted laser mirrors. If negative energy ME is able to draw some critical number of particles to the ground state, a phase transition to the ground state occurs since the rate for the transition is proportional to the number of particles already existing in the ground state. The only additional condition is the presence of the many-sheeted population reversal. This condition could be satisfied for living matter at least.

Dela-Warr camera [J66] might be based on this mechanism. Even more science-fictively and a little bit of tongue in cheek, one can consider also the possibility of communicating with the

civilizations of the geometric future by using population inverted lasers. Send to the geometric future classical k-bit signals (k harmonics of the fundamental) at p-adic frequencies $f(n,k)$ to tell that we have discovered p-adic cognitive codes, and wait whether the population inverted lasers at these frequencies return to the ground state with an abnormally high rate! One can easily imagine simple codes for communication. For instance, for p-adic length scales corresponding to visible wave lengths the typical number of bits would be 163.

In the technological context remote metabolism would translate to a remote utilization of energy stores making un-necessary the costly transport of the fuel. Only negative energy signal of critical intensity would be required to generate amplified positive energy signal from the geometric past providing the energy instantaneously and over long distances. For instance, the need to carry large amounts of fuel and the limitations posed by the maximal classical signal velocity are the basic problems of the space technology. The technological variant of the remote metabolism might provide at least a partial solution to these problems.

12.4.5 Some Paradoxes Solved By The New View About Time

In the sequel some paradoxes of modern physics and philosophy of mind related closely to the notion of time, are discussed.

Paradoxes related to quantum physics

The basic paradox is the conflict between the non-determinism of the state function reduction and the determinism of the Schrödinger equation. At a more general level this paradox is the conflict between the subjectively experienced actuality of the free will and the determinism of the objective world. The resolution of this paradox in TGD context is already discussed.

In the context of the deterministic physics, theoretician encounters three rather unpleasant paradoxes.

1. The determinism implies that the unique objective reality corresponds to a single solution of the field equations. The first question is "What determines the initial conditions, say at the moment of the big bang?". The attempt to answer this question leads necessarily outside the physical theory: one possibility is to postulate anthropic principle. In TGD objective reality changes at each quantum jump and the localization in zero modes and Negentropy Maximization Principle imply a genuine p-adic evolution: therefore the recent objective reality is indeed an outcome of conscious selections.

2. The second paradox encountered by a theoretician is that in principle it is not possible to test a deterministic theory since only single solution of the field equations is realized and a genuine testing would require the comparison of the time developments for various initial data. In practice this problem can be circumvented by assuming the existence of identical sub-systems having very weak interactions with the external world but in principle the problem remains unsolved. In TGD framework the hopping in the space of quantum histories makes possible the conscious comparison of the "solutions of field equations".

3. A further paradox relates to the dualism between theories and reality. Sooner or later theoretician is forced to ask about in what sense the theories exists. In TGD framework there is no need to postulate any further reality behind the theory. Quantum histories/ WCW spinor fields are what exists, model of reality is the reality. The hopping around in the space of these mathematical structures gives rise to the experiences of the pain and the concepts of toe and stone.

The famous Einstein-Bohr debate was related with the question whether God plays dice or not. In TGD context both were correct in their own ways. Quantum histories are indeed deterministic but God can replace the old quantum history with a new one: perhaps one should not however call this act dice playing but simply an act of free will. Einstein was also an advocate of local realism: this led to Einstein-Podolski-Rosen paradox created by the possibility of quantum entanglement between distant system. In TGD framework local realism holds true at the level of the infinite-dimensional WCW but not at the level of space-time since point like particles are replaced with 3-surfaces.

The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that the fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of the fundamental physics and the irreversible and mathematically rather ugly "real" world, seem to exist simultaneously. The quantum jumps between quantum histories concept solves the paradox and one can understand the dissipative world as an effective description forming an "almost" -envelope for the sequence of reversible worlds (time developments).

Paradoxes related to the theories of consciousness

Chalmers describes in his book "Conscious Mind" [J59] several paradoxes related to the materialistic and dualistic theories of mind. A common denominator for these problems is the assumption that consciousness is a property of a physical state: hence these paradoxes disappear in TGD context. These paradoxes are encountered also in the quantum theories of consciousness identifying consciousness as a property of a macroscopic quantum state, say Bose Einstein condensate.

In the materialistic theories of mind, postulating a unique objective reality, consciousness is an epiphenomenon and free will is necessarily a peculiar illusion and one can always ask why the consciousness is needed at all. Nothing changes in the physical reality if consciousness is dropped away. It is also very difficult to understand how the contents of consciousness are determined by the state of the material world.

In the dualistic theories postulating a unique objective reality (say the theory of Chalmers [J59]), the problems are related to the coupling between matter and mind. The basic problem of the dualistic theories is what Chalmers calls hard problem: how the physical processes in the brain give rise to conscious experience? If the laws of the physics determine the behavior of the system completely then one ends up immediately either with a complete separation of the mind and matter so that our conscious experience tells nothing about the material world or with materialism and epiphenomenalism. One can also consider a non-trivial coupling between matter and "mind like" fields but assuming a deterministic physics one ends up with a situation in in which the mind fields are effectively just additional physical fields and consciousness is again redundant.

In TGD framework, which could be called tripartistic, hard problem and other problems of the dualistic theories disappear since there is no need to assign consciousness to quantum history. Moment of consciousness as quantum jump between quantum histories hypothesis allows even to define measures for the information contents of the conscious experience despite the fact that one cannot write explicit formulas for the contents of conscious experience.

Logical paradoxes and concept of time

Many logical paradoxes could be resolved if one assumes that there are two times: geometric and subjective and that the space-time surface providing linguistic representations changes quantum jump by quantum jump. In particular, during the conscious argument leading to the logical paradox!

The objections of Uri Fidelman [J172] against the Platonic vision about reality involve the paradoxes of the cyclic cosmology (one might think that Turing machine in cyclic cosmology might be able to "know" whether it has halted immediately after starting and thus be much more powerful than ordinary Turing machine). Basic paradox is that in cyclic cosmology allowing time travel one can imagine a psychopathic son who murders his mother.

It is interesting to consider this paradox as resulting from identification of the identification of subjective time with geometric time, which I see only as an approximation. In TGD the counterpart of time travel would be sequence of quantum jumps changing the entire classical history quantum jump by quantum jump and inducing the shift of the space-time region, where the contents of consciousness of time traveller are concentrated, to the geometric past. No paradoxes result since space-time is not a fixed arena of dynamics but changes in each quantum jump.

As a second example one can take the second objection of Uri Fidelman [J172] against Penrose's program known as Berry's paradox.

Non-formalizable theory cannot provide a model of the physical world which includes the brain's cognitive function, since such a model must be lingual, written or spoken. However, such

a model implies the following paradox of Berry: Let n be the smallest number which cannot be defined by an English sentence having less than, say, a hundred letters. This number exists, since the number of all possible combinations of a hundred letters is finite. Nevertheless, it has just now been defined by a sentence comprising less than a hundred letters.

Berry's paradox could be understood when the piece of text is seen as inducing a sequence of quantum jumps in which the space-time region at which the argument is represented symbolically changes. For the initial space-time region representing my cognitive state there is indeed smallest number n which cannot be defined by using less than one hundred words (using the English in that space-time!). After reading the statement quantum history is replaced by a new, more complex one in which this this number can be defined by using less than one hundred words since a new reflective level of cognitive consciousness has emerged and is represented at space-time level.

This example encourages to think the possibility of replacing the idea of a fixed axiomatic system with a living and dynamically evolving system becoming conscious of new axioms from which new theorems can grow. Mathematician would not be anymore an outsider but and active participator affecting the mathematical system he is studying. For instance, when paradoxical statement represented symbolically becomes conscious in quantum jump sequence, also the context in which it was originally stated changes. This dynamical view about mathematical system could allow to solve antinomies.

12.4.6 Comparison With The Approach Of Barbour

The comparison of TGD based view about time with that of Barbour might help to understand what distinguishes TGD view from quantum general relativistic view. Barbour has proposed in his book [J108] that time is illusion. Barbour is a proponent of canonically quantized general relativity, where the canonical quantization rules eliminate time completely from the formulation. This reflects that fact that the dynamical arena is the space of 3-geometries rather than 4-geometries. This is also the situation in the super-space approach of Wheeler, which served as an inspirer of the WCW geometry approach in TGD framework. Barbour's conclusion that time is illusion is certainly counter-intuitive but perfectly logical if one identifies time as geometric time and takes canonically quantized general relativity completely seriously.

There are of course objections against this conclusion. General coordinate invariance is a four-dimensional symmetry and the notion of space-time is crucial in all practical applications of general relativity: therefore the disappearance of time from quantum theory tells that something has gone wrong. Indeed, Schrödinger equation and canonical quantizations were derived originally for non-relativistic systems so that the application of the formalism in general relativity might lead to astray. Secondly, the mathematical formalism resulting exists only formally since the naïve generalization of non-linear field equations to infinite-dimensional context fails.

Accepting for a moment the absence of geometric time, one can ask whether the experienced time could have a place in Barbour's universe. If one accepts the notion of quantum jump sequence also the space of 3-geometries, one would indeed have subjective time. In the transition to TGD Universe space-times become 4-surfaces and the geometric time would emerge automatically. The fundamental deviation from the canonical quantization is that the fundamental variational principle means something more than the extremization of the action defining the theory. This led to the notion of preferred extremal as analog for Bohr orbit.

Zero energy ontology (ZEO) was a great step of progress in the development of TGD. Now pairs of space-like 3-surfaces at the boundaries of causal diamond become the basic objects. It is important to notice that preferred extremal property itself in ZEO is un-necessary unless one requires Bohr orbit property: the reason is that for given pair of 3-surfaces at boundaries CD the space-time surface would be unique for deterministic dynamics. In the case of non-deterministic dynamics situation can change but this seems to relate to hierarchy of Planck constants bringing in new degrees of freedom related to the non-determinism and to super-conformal symmetries acting as gauge symmetries. Bohr orbit property would be space-time correlate for the correlations of the positive and negative energy states at the ends of CD and non-triviality of quantum dynamics so that preferred extremal property would be another name for Bohr orbit property. Therefore it seems reasonable to assume that the notion of preferred extremal indeed makes sense and is needed.

After several guesses what the preferred extremals might be, it became clear that the formulation of the theory in terms of the modified Dirac equation requires the existence of infinite number of deformations of the space-time surface with vanishing second variation of Kähler action. This is nothing but classical correlate for quantum criticality. The interpretation in terms of conformal symmetries is highly attractive and suggests that most of the conserved charges vanish.

Besides allowing to get rid of the infinities of the local quantum field theories, preferred extremal property implies generalized Bohr rules and assigns to given 3-surface (counterpart of 3-geometry) a unique space-time surface. This however requires generalization of the notion of 3-surface since standard form of determinism fails for Kähler action, Even this is not enough for having the psychological time: the localization of conscious experience requires classical non-determinism (which becomes determinism if 3-surfaces are generalized to sequences of 3-surfaces with time like separations). As found, also p-adic physics as physics of intentionality is required to understand the emergence of the psychological time.

12.5 Cosmology Of Consciousness And Four-Dimensional Brain

The paradigm of 4-dimensional brain is the most important consequence of the Grand Scenario. The non-determinism of the Kähler action (non-determinism is understood here in the conventional sense of the word) is the quintessential, purely TGD based element of the Grand Scenario: without there would not be any evolution, the contents of conscious experience would be diffused around entire quantum histories and there would be no systems with strongly time-localized contents of consciousness. A second key element is p-adic nondeterminism making possible intentionality and cognition.

12.5.1 Cosmology Of Consciousness

Cosmology of consciousness scenario is inspired by the notion of infinite self hierarchy and by the quantum-classical correspondence principle stating that the fractal structure of the many-sheeted space-time should directly reflect the general structure for the cosmology of consciousness. For instance, the p-adic evolution of consciousness should have its counterpart at space-time level: indeed, there are good reasons to believe that 4-surfaces have decomposition into regions obeying real or finite-p p-adic topology just like WCW has decomposition into real regions and regions D_P labelled by infinite primes characterizing the appropriate functions space topology. Fractality suggests that there are conscious universes within conscious universes and that the experiences of universes involve kind of abstractions about the experiences of the sub-universes they contain. Summation hypothesis for the experiences of selves indeed states just this.

Each self corresponds geometrically to its own subset of space-time sheets, separate conscious cosmology. Mind like space-time sheets are bounded in time direction since they belong inside CDs. p-Adic length scale L_p gives a first guess for the typical duration $T_p = L_p/c$ of the space-time sheet. Even human body could correspond to mind like space-time sheet: time duration would be of order of lifetime. Note however that the visible body might be only tip of iceberg, and it indeed seems that our magnetic body could have size for which light life is natural unit of size. Since selves contain sub-selves with various values of psychological time, the experiences are actually multi-time experiences with respect to both geometric and subjective time. The most natural identification of the psychological time is kind of center of mass coordinate associated with the sensory selves.

If quantum entanglement in the direction of time is a relatively rare phenomenon (it is completely absent in standard theories), entangled mind like space-time sheets correspond to nearly the same value of time so that our conscious experience gets dominant contribution from time values around the mean value of the time coordinate for our space-time sheet of finite duration. Entanglement in time direction gives rise to multi-snapshot experiences which would resemble vivid long term memories. The interpretation as genuine memories is however not correct. Rather, multi-time experiences with contents coming from geometric past and recent are in question.

The conclusion would be that the entire 4-dimensional space-time is a living system in TGD universe: both the geometric future and past are living and participate in each moment of

consciousness. Each moment of consciousness decomposes into infinite number of sub-moments of consciousness of selves in the self hierarchy with the values of psychological time varying from zero to infinity. The value of our own psychological time of roughly 10^{11} years is just an accident. Entire civilizations can live in different geometric times without knowing anything about each other unless they happen to have entanglement in time direction. If they have, the resulting experiences could be interpreted as memories, dreams, religious or mystic experiences or simply as hallucinations. The inhabitants of sufficiently but not sufficiently advanced sub-cosmologies tend to believe that they are the only conscious beings in the Universe, construct their own cosmology and try desperately to understand why the value of cosmological time happens to be what it is and, to certain degree quite correctly, conclude that Anthropic Principle is the only explanation.

The civilizations of past could still exist and participate to each quantum jump. Also the civilizations of future coexist consciously with us. The hierarchy of selves implies that selves have increasingly longer geometric and subjective memories. The hypothesis about infinite primes implies a hierarchy of literally infinite values of psychological time and God like conscious beings with infinitely long geometric and subjective memories is possible if infinite primes. At the top of the hierarchy is the entire universe having infinitely long geometric and subjective memories and integrating all experiences at the lower levels of the hierarchy in single abstracted experience. Note that this picture gives hopes to understand how universe is able to construct theory about itself. Notice also that any theory of consciousness should be able to predict its own discovery and the infinite hierarchy of selves gives good hopes in this respect.

12.5.2 Communications In Four-Dimensional Society

The idea about four-dimensional society makes sense only if communication between members of this society is possible. It would be even better if communication could occur in "real subjective time". This seems to be possible in principle as the following arguments show.

Communication method

A simple model for real time communication between societies of the geometric future and past is based on the possibility of space-time sheets of negative time orientation having negative energy density. It seems natural to assume that at least classical signals propagate from geometric future to geometric past along these space-time sheets. As suggested in [K23, K85] "massless extremals" could make possible coherent motion of living systems. It seems that they could make possible also "real subjective time" communications in four-dimensional society.

1. Signals to the geometric future propagate along space-time sheets of positive time orientation. These space-time sheets can correspond to ordinary material space-time sheets but also almost vacuum space-time sheets can be considered. In particular, so called "massless extremals" [K85] are possible.

2. Signals to the geometric past propagate along space-time sheets of negative time orientation. Negative energy massless extremals are the optimal choice as far as classical communication is involved. The reason is that signal propagates with maximal signal velocity and consists of Fourier components with same momentum direction so that the shape of pulse is preserved. Polarization direction at a given point of the massless extremal is constant and depends on the transversal coordinates only. Solution involves two arbitrary functions and linear superposition of parallel Fourier components with identical polarization directions is possible. Therefore all possible pulse shapes are possible.

3. What happens in the communication is following. Sender performs quantum jump in which massless extremal of positive/negative energy is generated representing signal propagating to geometric future/past. Some standardized alphabet formed by the pulse forms for massless extremals: two basic pulse shapes identifiable as binary digits is the simplest choice. Receiver interacts with the massless extremal purely classically to receive the message and generates a massless extremal propagating to geometric past/future as a reply. The difference between sender and receiver is that sender performs quantum jump whereas receiver just acts purely classically to receive the message.

4. The communication is on-line "real subjective time" communication. There is no need to wait for next billion years for reply and members of cultures separated by billions of light years can have real time chat about their family problems! Also communication with effective signal velocity larger than light velocity becomes possible by using a "radio mast" in the geometric future able to send past-directed signals: the mast receives a signal from the geometric past and sends it to the second receiver in the geometric past.

Anomalies related to spinning astrophysical objects as empirical support for the idea

The proposed communication method could be regarded as mere wild science fiction unless there were some empirical support for the possibility of communication from geometric future to geometric past. In the articles [H10, H5] various anomalies related to spinning objects are reviewed. These anomalies are discussed in [K128]. There are also anomalies related to spinning astrophysical objects. Kozyrev [H4] has conducted astronomical observations using a receiving system of a new type. These observations have been replicated later by other groups [H2]. These anomalies give also support for the possibility of the signal propagation backwards in time.

1. When a telescope was directed at a certain star, the detector positioned within the telescope registered the incoming signal even if the main mirror of the telescope was shielded by metal screens. This indicated that electromagnetic waves were accompanied by some waves not shielded by the metal screens.

2. When the telescope was directed to the true position, the signal became stronger. As if there had been almost instantaneous propagation of signal with velocity billions times greater than the velocity of light!

3. When the telescope was directed to a position symmetrical with respect to the visible position, again signal was detected: the imaginative interpretation was that the signal came from future position of the star!

Leaving aside the objections of a typical sceptic and the question whether the effect is real or not, one can ask whether the concepts of many-sheeted space-time concept and classical Z^0 field could somehow give rise to this kind of effect in strong conflict with the conventional wisdom.

1. Propagating photons (extremely tiny 3-surface glued to macroscopic space-time sheet) affect the space-time sheet and could generate propagating classical Z^0 field causing the effect in the detector. Of course, one cannot exclude the possibility of negative energy photons although the experimental arrangement eliminating the ordinary photons should eliminate also these.

2. The strong signal from the true position could have explanation in terms of a coherent classical Z^0 field of astronomical size. This kind of coherence is forced by the imbeddability requirement and was coined as topological field quantization in [K61]. One can intuitively understand it as follows. In TGD elementary particle is replaced with 3-surface, which can have arbitrarily large size and absolution minimization of Kähler action forces 3-surface to behave coherently like single particle (in case that it does not so, it decomposes into disjoint components!). The results of Kozyrev are not the only evidence for this kind of behavior. Total eclipses of the Sun by the Moon reach maximum eclipse about 40 seconds before Sun's and Moon's gravitational forces on Earth align [H9]. If gravity is a propagating force, this 3-body test implies that gravity propagates at least 20 times faster than light. The result is consistent with the assumption that the acceleration of Earth is towards the true instantaneous direction of the Sun now, rather than being parallel to the direction of the arriving solar photons now. The TGD based explanation is that the changes of the classical gravitational field are not propagating effects but that the classical gravitational field behaves like single coherent whole (it could of course contain also small propagating part).

3. The signal in the symmetric position could indeed come from geometric future. An attractive possibility is that classical Z^0 field propagated along space-time sheet with negative time orientation: for negative time orientation the propagation is expected to occur backwards in time.

There are also reports about the anomalies related to rotated magnetic systems in laboratory scale and these effects are under intensive study (for instance in Faraday Lab in Russia). The TGD based explanation of the anomalies reported in [H8] is developed in [K128]. The model involves in an essential manner the generation of both negative energy space-time sheets and many particle states with negative single particle energies residing at these sheets and some of the observed strange effects involved support the generation of the negative energy particles. The model allows to seriously consider the possibility that even ordinary ions and atoms could have negative energy counterparts.

12.5.3 The Paradigm Of Four-Dimensional Brain

The cosmology of consciousness implies that each conscious experience decomposes into separate sub-experiences with the values of the psychological time varying from zero to infinity. Furthermore, the experiences are in general multitime experiences both with respect to both geometric and subjective time. This picture forces the paradigm of 4-dimensional brain having profound consequences concerning the understanding of the brain functioning.

The difficult problems related to the understanding of conscious memory recall could trivialize. No separate mechanisms of memory storage or retrieval are needed and the difficult problems related to the interpretation of the stored memories are circumvented. There are two basic types of memories: geometric and subjective memories. Geometric memories provide as simulation for what happened and will happen provided no quantum jumps occur and has occurred and subjective memories tell what actually occurred. Actual memories are indeed known to be creative reconstructions of past and hence it seems that geometric memories are an essential part of construction. The comparison of expectations and actuality made possible by the two memory types gives rise to the emotions involving comparison aspect.

Subjective memory corresponds to immediate short term memory and the only possible identification of the *genuine* long term memories is as subjective memories at the higher level of self hierarchy, where the time span of subjective memory is longer. One possibility is periodic wake-up of sub-selves representing mental images and giving in this manner rise to long term memories: this requires some kind of periodic neural activity giving rise to the same sub-self periodically. Of course, it is not at all obvious whether long term memories are genuine! It is indeed known that long term memories are a result of a creative process and are not reliable. This would suggest that long term memories are actually geometric memories and are reasonably reliable because our geometric past is rather stable under quantum jumping. Of course, we do not usually test the reliability of our long term memories but take them as granted. The notion of mind like space-time sheet allows multitime experiences containing simultaneous contributions from both geometric present and past and the memories of, say, childhood could be genuine multitime experiences.

The "averaging" associated with the subjective memory implies that volition cannot correspond to the quantum jump occurring in the measurement of the density matrix. Rather, volitional activities must correspond to a localization in zero modes, most naturally selections between degenerate maxima of Kähler function. Besides volition associated with the motor activities, also the focusing of attention and even the selection of premises of logical thought very probably involve this kind of selection. The most probable function of the motor nerve pulses is the generation of multi-furcations in an initial value sensitive system between which the choice occurs. Various motor programs correspond to various branches of the multi-furcation. Just as sensory experience, motor activity is predicted to be a top-down self cascade of quantum jumps starting from the level of the entire body. Each selection of the space-time branch creates self inside which subsystems perform quantum jumps as long as self is awake and these quantum jumps in turn lead to even smaller sub-selves: in this manner a precise and flexible coordination and control of the movement involving volition at all length scales becomes possible whereas in the standard neuroscience picture body would act like a robot with fixed motor programs.

12.5.4 Geometric And Subjective Memories

TGD predicts two kinds of memories corresponding to two different time developments. There is deterministic (in generalized sense) geometric time development and the non-deterministic subjective time development by quantum jumps. The memories with respect to subjective time are

about previous conscious experiences and "real" whereas geometric "memories" are prophecies giving simulation of geometric past and future assuming that quantum jumps do not alter the macroscopic properties of the space-time surface.

A good visualization is following: each quantum jump represents particular geometric memory whereas the heap of these memories gives rise to subjective memory. The comparison between expectations and reality is obviously a central part of mentality and the heap structure of conscious experience implies that this comparison is a basic function of conscious mind not reducible to anything simpler. It is well-known that our memories involve a lot of construction and are more like stories consistent with what we actually have experienced than actual documents of what happened. This suggests that geometric memories, possibly constrained by subjective memories, give rise to the "story" about past.

12.5.5 Memories With Respect To Geometric Time As Simulations

Geometric memories are about both future and past and are predictions/simulations for what would happen if no further quantum jumps would occur and what would have happened if no quantum jumps had occurred in past. Geometric memories are also about past: we continually make guesses about the sequences of events which could have led to some event and this is nothing but predicting the geometric past. Of course, geometric memories are simulations rather than real memories. Geometric "memories" are real in the classical limit, when the effect of quantum jumps becomes negligible. In classical physics geometric memory is all that is needed to make predictions of past and future. We can indeed predict rather reliably what will happen in the solar system during the next decade. Also the computational approach to mind assumes only geometric memories. p-Adic geometric memories about future give rise to intentionality often regarded as a basic characteristic of conscious mind: beliefs, expectations, plans, etc. can be understood in terms of the p-adic geometric memory of future.

Intentionality manifests itself in many ways: as expectations of future, planning, goals, desires, fears, imagination, disappointments, etc.. The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. The temporal extension of the mind like space-time sheet makes possible expectations of what happens in the future assuming that no quantum jumps occur or at least that quantum jumps do not change the macroscopic space-time. Single quantum jump contains information about this kind of expectations. Subjective memory in turn tells what happened actually. Therefore it seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to assume that all aspects of intentionality are made possible the predictions of the expected geometric future and past provided by the mind like space-time sheets.

What is nice is that subjective memory makes it possible to compare the expectations with what really occurred since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. The origin of at least some emotions, which often involve a comparison of what happened and what was expected to happen, is perhaps here. It is quite well possible that all comparisons must be realized as comparisons of the subjective and geometric time developments (it could be that self is also able to compare its sub-selves).

The possibility of this comparison perhaps provides a solution to the paradox raised by the innocent question "How do I know that the me of today is the same as the me of the yesterday? How do I even know that I existed yesterday?". The solution might be simple: mind like space-time sheets have extension which can be much longer than the duration of the subjective memory. Therefore subjective memories contain information about the geometric me of the yesterday and geometric me of today and since these me's resemble each other quite a lot, the conclusion is that also the yesterday's me was a conscious self living in this same body. It is however quite possible that temporal entanglement with higher selves still remembering my past wake-up states is also involved and realized as a formation of join along boundaries bonds/magnetic flux tubes between the mind like space-time sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

12.5.6 Are Long Term Memories Geometric Or Subjective Memories?

The answer to the question whether long term memories are geometric memories and thus only simulations or genuine subjective memories of higher level self somehow communicated to us, is not obvious.

Long term memories as geometric memories?

Geometric memories realized as multitime experiences involving mind like space-time sheets located around several moments of the geometric time, provide the simplest realization for the long term memories.

1. The model solves the basic difficulties of the neural net models of long term memory. In the neural net models long term memories are represented by synaptic strengths. The problem is that the learning of new memories destroys old memories. In particular, the stability of the childhood memories is difficult to understand. It is also hard to understand how brain knows that the experience represents memory. One cannot avoid the difficulty by saying that novelty detection tells that experience occurs for the first time since the notion of novelty does not make sense if conscious experience contains only information from single moment of geometric time.

2. TGD model is consistent with neural net models and actually generalizes them. Neural net in the spirit of TGD corresponds to brain as system moving in spin glass energy landscape. Self-organization by quantum jumps leads the system to a bottom of an energy valley representing memory. This model is consistent with the fact that there is no upper bound for autobiographical memory. One can also understand how learning occurs. The repetition of an experience means that energy valley becomes a canyon in time direction so that mind like space-time sheets in the geometric past have a large probability to end up to the region representing memory. In particular, reverberating nerve pulse patterns are ideal for representing cognitive long term memories.

3. Highly emotional experiences generate deep valleys and increase the probability of the system of the geometric past to stay at the bottom of valley. This explains why childhood experiences are so stable. In fact, one could identify primitive emotions of pleasure and pain as related to the motion in the spin glass energy landscape. Pleasure and pain could even directly correlate with the sign of the increment of the Kähler function in the hopping motion in the spin glass energy landscape. Note that primitive pleasure and pain are are very much like sensory experiences and one could regard them as sensory experiences of brain about its own motion in spin glass energy landscape. This leads to the generalization of the notions of sensory experience and motor action to include the motion in spin glass energy landscape and to a considerably new insight about the meaning of the brain architecture.

There are also perinatal experiences, memories about previous lives and transpersonal experiences having natural explanation in terms of geometric memory realized as multitime experiences associated with mind like space-time sheets located at different values of the geometric time.

Transpersonal experiences suggests that self is dynamical: if prenatal experiences, memories about previous lives and transpersonal experiences are really what they seem to be, the geometric time extension of self should dramatically increase during these experiences.

Long term memories as subjective memories of higher level self?

The natural identification of the immediate short term memory as subjective memory predicts that the life time of a human sensory self cannot be much longer than .1 seconds, the duration of psychological moment of time. Our long term memories correspond to much longer time interval and cannot thus correspond to our subjective memories. Entire hierarchy of subjective memories is however predicted and a possible model for *genuine* long term memories (whose existence is questionable) is as resulting from temporary entanglement with selves belonging to the higher level of the hierarchy. Also this identification is consistent with the fact that there seems to be no upper bound on autobiographical memory.

Quantum-classical correspondence principle suggests that entanglement could correspond geometrically to temporary flux tubes between the mind like space-time sheets of self and higher level self. Summation hypothesis implies that our genuine long term memories would be sums over a large number of wake-up periods of self in the subjective past of the self. Therefore one could perhaps understand how aging self gains gradually wisdom from experience: also the identification of the long term memories as geometric memories explains this. It would seem that our self must be able to shift the hierarchy level in order to remember details on one hand and to form abstractions on the other hand and that the detailed memories about the wake-up periods of self are unavoidably lost.

There are however serious counter arguments against this identification.

1. It is not at all clear why the experiences of the higher level selves during entangled state could be ours! For instance, during sleep without dreams entanglement with some higher level self should occur and we do not remember anything about this. Trance is a second example of this: subject person does not remember anything about the trance state.

2. The averaging involved with the temporal binding means that the subjective memories of the higher level selves cannot possess the details of our long term memories.

3. It is not obvious how to understand learning and the role of emotions in learning.

The entanglement with the higher level self is not necessary to have genuine long term memories. One could consider also the possibility that higher level self could somehow communicate the long term memories to the lower level selves. One function of sleep might be the generation of the entanglement with higher selves making in turn possible the communication of genuine memories of subjective past to our mind. This communication could realize these memories as thoughts about the experiences of past realized as nerve pulse patterns regenerating these thoughts. The lack of a precise realization of this mechanism makes the realization of the long term memories as geometric memories much more attractive option.

Long term memories as a communication between now and geometric past

The basic challenge is to identify concrete mechanisms of long term memory recall. According to the idea of magnetic sensory canvas discussed in [K99], the positions of objects of perceptive field are coded by the frequency scale of the magnetic transitions occurring at the magnetic flux tube structures having size of wave lengths associated with EEG frequencies. The slowly varying thickness of the magnetic flux tube codes for the position of the object of the perceptive field.

This encourages to consider the possibility that also the temporal position of the object of perceptive field could be coded in this manner. There are however two difficulties involved:

1. Since the time scales are of order life time T , the needed frequency resolution is $\Delta f/f \sim \Delta T/T$, if the time resolution is ΔT. This requires frequency resolutions of order $\Delta f/f \sim 10^{-8}$ at least and this kind of resolution is certainly not achievable in the neuronal circuits.

2. If ELF MEs (massless extremals) are involved it is difficult to understand how one could circumvent the fact that the ME represents geometrically a light ray escaping from the system. This ray should be reflected somewhere. Kind of mirror would be required. Magnetic flux tubes could serve as this kind of mirror and allow the radiation to travel in zigzag curve in space-time to geometric past.

There is however a much more elegant mechanism of long term memory recall based on MEs. First, of all what makes MEs so interesting from the point of view of long term memories, is that light like selves has a temporal extension, which can be arbitrary long in given rest system. Secondly, the pairs of MEs resulting when ME reflects from some structure such as magnetic flux tube structure serving as a mirror, provide a TGD based model of long term memories relying on the idea that long term memory recall involves a "question" sent to the geometric past as a classical signal reflected back to brain in a magnetic mirror, and a subsequent quantum entanglement in which the selves of the geometric past and now as well as ME selves entangle to single self so that the self of the geometric now can share the experience of the self of the geometric past.

What is so elegant in this mechanism is that there is no necessity of sending the information as a classical signal, only the time like entanglement is needed. In this case the MEs would have a length of order lifetime so that long term memories would be astrophysical phenomena involving magnetic flux tube structures and MEs. The temporal location T of the memory (or rather, shared conscious event) of the geometric past would be coded by the length L of ME: $L = cT/2$. The TGD based notion of time indeed allows geometric time scales of order lifetime to be involved with subjective experiences in psychological time scale of a fraction of second. Certainly this mechanism is completely out of question in standard physics.

12.6 Time Delays Of Consciousness

TGD based concept of time has rather dramatic implications and it would be important to show that the new time concept indeed solves conceptual problems and anomalies. One should also device experiments to test the new time concept. Dissipation is the black sheep in the family of theoretical physics and quantum jump between quantum histories concept explains dissipation in elegant manner. Quantum jumps between quantum histories concept together with the notion of self explains also the peculiar time delays of consciousness revealed in the experiments relating to the active and passive roles of consciousness [J87, J44] and described by Penrose in his book [J154]. It is also possible to explain the causal anomalies revealed by the experiments of Radin and Bierman [J46, J47, J67]. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

12.6.1 Dissipation As Evidence For Consciousness

TGD based picture about time relies crucially on the notion that quantum jumps occur between quantum histories, objective realities. This hypothesis obviously means giving up the materialistic idea about single objective reality behind our experiences. It took quite long time to realize that our everyday experiences reveals directly the occurrence of quantum jumps between quantum histories! The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally believed that fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. This leads to a rather schizophrenic situation. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and the mathematically horribly ugly "real" world, seem to exist simultaneously. Quantum jumps between quantum histories concept solves the paradox and one can understand dissipative world as an effective description forming "almost" envelope for the sequence of reversible worlds (understood as entire time evolutions).

Dissipation can be also regarded as a direct evidence for the presence of the self hierarchy. One can imagine quite spectacular tests for the idea. NMP predicts that self can be in two modes of consciousness: quantum jumps reduce either matter-mind like entanglement or reduced matter+mind-matter+mind type entanglement leading to an unentangled subsystem giving rise to two new self candidates (sub-system and its complement inside self). The first mode corresponds to "whole-body" consciousness and in this mode matter-mind like dissipation in short length scales should be completely absent. The lowered dissipation should reflect itself as lowered metabolism. The measurement of cell level dissipation occurred during meditative states could provide a test for this picture. TGD explanation for the phenomenon of synesthesia [J151] discussed in [K105] relies on the hypothesis that left brain or considerable parts of it get quantum entangled and spends part of time in "whole-body consciousness". Indeed, synesthesia can involve lowering of left brain metabolism by as much 18 per cent [J151]: this should lead to paralysis if standard wisdom about brain functioning would hold true!

12.6.2 Strange Time Delays Of Consciousness: Experiments Related To The Active Role Of Consciousness

Libet has carried out classical experiments about active and passive aspects of consciousness [J87, J44]. It has gradually become clear that these experiments can be interpreted as a support for the identification of "me" as the personal magnetic body.The first class of experiments [J164, J44]

is related to the active role of consciousness. For example, the human subject moves his hand at free will. What happens is that neurophysiological processes (changes in EEG, readiness potential) start $T_1 = .35 - .45$ seconds before the conscious decision to move the hand whereas the awareness about the decision to move the hand comes $T_2 = .2 - .1$ seconds before the hand movement. Decision seems to be followed by the action rather than action by decision! This is in apparent accordance with the point of view that consciousness is indeed a passive spectator and the act of free will is pure illusion. What is interesting from the p-adic point of view, is that the most plausible estimates for the time delays involved are $T_1 \simeq .45$ seconds and $T_2 = .1$ seconds [J164]. T_1 is very near to the p-adic time scale $T(6,43) = .4$ seconds and T_2 to the fundamental p-adic time scale $T(2,127)$ defining the duration of the memetic codon.

One can imagine two explanations for the paradoxical findings. The explanations turn out to be mutually consistent.

The geometric past changes in quantum jump

Quantum jump between histories picture explains the time delays associated with the active aspect of consciousness nicely and also gives an example of two kinds of causalities.

1. The simplest assumption is that the subjective experience of the hand movement corresponds to the moment, when subject person experiences that hand movement occurs.

2. The space-time surfaces (resulting as the final state of quantum jump) associated with the new quantum history differ in a detectable manner from the old quantum history already before the moment of hand movement since otherwise the new space-time surface would contain an instantaneous and discontinuous jump from the initial to final body configuration, which is not allowed by field equations. Same argument applies to the state of brain. $\Delta T \sim .5$ seconds seems to be the relevant time scale.

3. The attempt of the experimenter to be objective means that in an ideal experiment the observations correspond to the new deterministic history in the associated quantum jump and hence experimenter sees neurophysiological processes as the (apparent) cause of the hand movement with respect to geometric time. With respect to the subjective time the cause of the hand movement is the decision of the subject person.

Motor action is initiated from the magnetic body and proceeds to shorter length scales in reversed direction of geometric time

The vision that motor actions are initiated by magnetic body by feeding negative energy to motor organs and proceed upwards in CNS in a reversed time direction is in accordance with the idea of quantum credit card implying maximal flexibility and would mean that motor actions are only apparently initiated from brain. Motor organs send negative energy MEs to get metabolic energy, say to cortex. If there is lapse $\sim .5$ seconds involved then the observed lapse would find explanation. This view concretizes the idea about the editing of the geometric past and is consistent with the more general explanation discussed above.

This view about motor action means that it proceeds from long length scales to short ones whereas in the standard neuroscience view motor motor action would be planned and initiated in the brain and proceed to the level of motor organs, from short to long length scales. This certainly seems to be the case if one looks only the classical communications (say nerve pulse patterns). The extreme coherence of and synchrony of motor activities is however in conflict with this picture: neuronal communications are simply too slow to achieve the synchrony. This has been emphasized by Mae-Wan Ho [I45]. Since quantum communications proceed backwards in geometric time, classical signalling such as nerve pulses from brain to motor organs are actually reactions to the initiation of the motor action from the magnetic body.

12.6.3 Strange Time Delays Of Consciousness: Experiments Related To The Passive Role Of Consciousness

Libet's experiments [J87] about the strange time delays related to the passive aspects of consciousness have served as a continual source of inspiration and headache. Every time I read again about

these experiments, I feel equally confused and must start explanations from scratch.

What is so important and puzzling is that the backwards time referral of sensory experience is so immensely long: about.5 seconds. The time taken for nerve pulses to travel through brain is not more than .01 seconds and the time to arrive from sensory organs is at most.1 seconds (for axon with length of 1 meter and very slow conduction velocity 10 m/s). For the purposes of survival it would be advantageous to have a sensory input with a minimal time delay.

Why then this long delay? TGD inspired answer is simple: the "me" does not correspond to the material body but to the magnetic body associated with the physical body, and is analogous to the manual of electronic instrument, kind of a monitor screen to which sensory, symbolic and cognitive representations are projected by quantum and classical communications. Since the size of the magnetic body is measured using Earth's circumference as a natural unit, the long time lapse results from the finite velocity of light.

The following explanation is a variant of the model of the sensory representations on the magnetic canvas outside the body and having size measured by typical EEG wave lengths. The basic sensory representations are realized at the level of the sensory organs and entangled with magnetic body whereas symbolic representations are either shared as mental images by or communicated classically to the magnetic body. This differs from the original scenario in which sensory representations were assumed to result by classical communications from brain to the magnetic body.

Communications from brain to magnetic body

One must consider two kinds of communications from body to magnetic body corresponding to positive energy MEs generated by at least brain and negative energy ME sent by magnetic body to at least sensory organs. The assumptions are following.

1. Negative energy MEs bound state entangle the magnetic body with the sensory representations realized at the level of sensory organs, and constructed using back projection from brain and possibly also from higher levels. Fusion and sharing sensory mental images is involved. Also the classical communication of memories to magnetic body could be involved with the build up of sensory and symbolic representations at the magnetic body. In both cases sensory representations are memories with the same time lapse determined by the length of the MEs involved, a fraction of second typically if the magnetic body is of an astrophysical size. During sensory and motor imagination magnetic body entangles by negative energy MEs with some higher level of CNS.

2. Symbolic representations in brain can entangle with the sensory representations entangling in turn with the magnetic body so that CNS defines tree like structure with roots corresponding to sensory organs and branches and leaves corresponding to the higher levels of CNS. Direction of attention selects some path along this tree somewhat analogous to the path defining computer file in some subdirectory.

3. Symbolic representations of the perceptive field can be projected to the magnetic body using also classical signalling by positive energy MEs with phase velocity in a good approximation equal to the light velocity. For instance, if perceptive field contains something important, classical signal to the magnetic body could induce the generation of negative energy MEs turning attention to a particular part of perceptive field. Projection to the magnetic flux tubes of the Earth's magnetic field is possible. The spatial direction of the object could be coded by the direction of ME located in brain whereas its distance could be coded by the dominating frequency of ME which corresponds to a magnetic transition frequency which varies along the radial magnetic flux tubes slowly so that place coding by magnetic frequency results. Field pattern could be realized the coding of information to bits in some time scale, perhaps even in the time scale of millisecond associated with the memetic code. Positive energy MEs generated by brain realize the representation and this implies time delay. In the original model it was assumed that the direction and distance of the object of perceptive field are coded as direction and distance at the magnetic body. The representations are expected to be rather abstract, and it might be enough to perform this coding at the level of magnetic bodies associated with the sensory organs.

Libet's findings

Libet's experiments [J87] about the strange time delays related to the passive aspects of consciousness serve as a continual source of inspiration and headache. Every time one reads again about these experiments, one feels equally confused and must start explanations from scratch. The following explanation is based on the model of the sensory representations on the magnetic canvas outside the body and having size measured by typical EEG wave lengths [K99].

The basic argument leading to this model is the observation that although our brain changes its position and orientation, the mental image of the external world is not experienced to move: as if we were looking some kind of sensory canvas inside cortex from outside so that the motion of canvas does not matter. Or equivalently: the ultimate sensory representation is outside brain at a fixed sensory canvas. In this model the objects of the perceptive field are represented on the magnetic canvas. The direction of the object is coded by the direction of ME located on brain whereas its distance is coded by the dominating frequency of ME which corresponds to a magnetic transition frequency which varies along the radial magnetic flux tubes slowly so that place coding by magnetic frequency results.

According to the summary of Penrose in his book "Emperor's New Mind" these experiments tell the following.

1. With respect to the psychological time of the external observer subject person becomes conscious about the electric stimulation of skin in about .5 seconds. This leaves a considerable amount of time for the construction of the sensory representations.

2. What is important is that subject person feels no time delay. For instance she can tell the time clock shows when the stimulus starts. This can be understood if the sensory representation which is basically a geometric memory takes care that the clock of the memory shows correct time: this requires backwards referral of about .5 seconds. Visual and tactile sensory inputs enter into cortex essentially simultaneously so that this is possible. The projection to the magnetic canvas and the generation of the magnetic quantum phase transition might quite well explain the time lapse of .5 seconds.

3. One can combine an electric stimulation of skin with the stimulation of the cortex. The electric stimulation of the cortex requires a duration longer than .5 seconds to become conscious. This suggests that the cortical mental image (sub-self) is created only after this critical period of stimulation. A possible explanation is that the stimulation generates quantum phase transition "waking up" the mental image so that threshold is involved.

4. If the stimulation of the cortex begins (with respect to the psychological time of the observer) for not more than .5 seconds *before* the stimulation of the skin starts, both the stimulation of the skin and cortex are experienced separately but their time ordering is experienced as being reversed!

   A crucial question is whether the ordering is changed with respect to the subjective or geometric time of the subject person. If the ordering is with respect to the subjective time of the subject person, as it seems, the situation becomes puzzling. The only possibility seems to be that the cortical stimulus generates a sensory mental image about touch only after it has lasted for .5 seconds.

   In TGD framework sensory qualia are at the level of of sensory organs so that the sensation of touch assignable to cortical stimulation requires back-projection from cortex to the skin. The mental images generated by direct stimulation of cortex could be called cognitive this is created first and takes some time. If the construction of cognitive mental images about cortical stimulation and the formation of back projection takes at least about.5 seconds the observations can be understood. Genuine sensory stimulus starts to build cortical mental image almost immediately: this mental image is then communicated to magnetic body.

   For instance, assume that the preparation of cognitive mental image at cortex takes something like.4 seconds and its communication to magnetic body about.1 seconds and that back projection is possible only after that and takes roughly the same time to the sensory organs at skin and back. This would explain the change of time order of mental images.

5. If the stimulation of the cortex begins in the interval $T \in [.25 - .5]$ seconds *after* the stimulation of the skin, the latter is not consciously perceived. This effect - known as backward masking - looks really mysterious. It would be interesting to know whether also in this case there is a lapse of.5 seconds before the cortical stimulation is felt.

   If the construction of cognitive mental image about direct stimulation of cortex takes about.4 second, it does not allow the buildup of cognitive mental image associated with the stimulation of skin. Hence the stimulation of skin does not create conscious cognitive or sensory mental image communicated to magnetic body.

12.6.4 The Experiment Of Radin And Bierman As Evidence For Quantum Jump Between Quantum Histories Concept

The experiments of Radin [J67] and the later experiments by Radin and Bierman [J46, J47] gave evidence for anomalous unconscious emotional responses preceding their cause. Radin monitored the sympathetic and parasympathetic behavior of the autonomic nervous system with skin conductance, heart rate and fingertip blood volume measurements. Subjects were asked to look at a computer monitor and press a button to start a trial. Button press caused the display of a blank screen for five seconds, then a randomly selected calm or emotional picture was shown for three seconds, and this was followed by ten seconds of a blank screen. In three studies, Radin found significant differences in autonomic physiology, most notably skin conductance, *preceding* the exposure of emotional vs. calm pictures. Radin examined a number of possible normal explanations for the result and concluded that they did not apply.

Radin and Bierman interpreted the result of the experiment as evidence for a reversal of the arrow of time. The constancy of the arrow of psychological time is by no means obvious in TGD Universe and one of the basic challenges of TGD inspired theory of consciousness is to understand how the (probably statistical) arrow of psychological time emerges. Moment of consciousness as quantum jump between quantum histories concept provides however an elegant explanation of the effect without any need to assume the reversal of the arrow of psychological time. What is important that one can also avoid the poorly defined concept of effects propagating backwards in time, which is needed in explanations based on quantum state as time=constant snapshot concept.

Consider now the TGD based explanation. In quantum jump deterministic quantum history is replaced with a new one: this means that, not only the future, but also the *past* changes. Therefore, if the mean galvanic skin response of the subject person provides a faithful representation for some aspects of subject person's deterministic quantum history, the entire time record about skin response must change to a new one in any quantum jump. If subject person experiences a highly emotional stimulus, the moment of consciousness is expected to be more intensive than for calm stimulus in the sense that the non-determinism associated with the quantum jump is expected to cause observable effects in a larger space-time volume of the quantum history (represented to a good approximation as quantum average space-time surface geometrically). Therefore also the change of the quantum past is expected to be more dramatic as it indeed seems to be according to the results of the experiment.

At first it might seem that there are no means to test whether the past has changed at the moment of consciousness. The experimental arrangement of Bierman and Radin, although certainly not originally planned to test quantum jumps between histories concept, circumvents in an ingenious manner this difficulty by comparing the skin responses associated with calm and emotional trials. Standard physics, which is based on assumption that there is no signal propagation backwards in time, predicts that the average skin responses before the stimulus should be identical for calm and emotional trials. This is not the case so that the results of the experiments indeed support TGD based world view.

One can in fact imagine even more dramatic test based on a modification of Radin-Bierman experiment. In quantum-mind discussion group Stan Klein [J164] suggested a modification of Radin-Bierman experiment [J46, J47, J67] providing a test for Stapp's and Sarfatti's theories of consciousness [J103, J1]. One could perhaps consider the following further modification of Radin-Bierman experiment so that it would simultaneously discriminate between Stapp's and Sarfatti's theories and TGD.

1. It might be possible for computer to perform a comparison of the response with average

calm and emotional responses *before* the subject person A sees the picture and, depending on whether the response is nearer to calm or emotional average response, to print C or E to a computer screen such that the printing result is seen by person B *before* A sees the picture.

2. The theories explaining phenomenon in terms of effects propagating backwards in time (say Sarfatti's theory [J1]) would predict that computer record and the sequence of letters remembered by B are identical and contain both C: s and E: s. According to [J164] Stapp's theory would predict that both computer record and B's memories contain only C: s.

3. TGD predicts that B would *see* only C: s. The concept of subjective memory implies that B also *remembers* of seing only C: s whereas computer records would contain both C: s and E: s. This would provide dramatic support for quantum jump between quantum histories concept and for the notion of subjective memory.

In TGD framework one can also consider an alternative explanation for the result of Radin-Bierman experiment. If this explanation is correct, the report of B is consistent with the computer record just as in Sarfatti's theory. The argument goes as follows.

1. Given moment of consciousness contains several irreducible sub-experiences besides the experience corresponding to the "real I", which presumably corresponds to "I" able to communicate using language and possessing long term memories. These "I": s are usually collectively identified as subconscious mind. The phenomenon of blind sight and related phenomena [J32] give support for the idea that there is second "I", most naturally at the same level of self hierarchy. One can even imagine entire population of selves at some lower level of self hierarchy giving rise to "Zombi within us" or shortly Z. In the latter case the response of Z is dictated by statistical determinism at the level of ensemble. Deterministic response has definite value in fight for survival.

2. The values of the psychological times associated with these various "I": s need not be same in given quantum jump. Suppose that Z has psychological time slightly larger than the psychological time of the ordinary "I" so that Z sees the state of the world at time $t + \Delta t$ whereas "the real I" sees it at time t in given quantum jump. The order of magnitude for Δt is roughly one second. Assume further that Z is able to assign emotional content to the picture. If the decision about what picture is shown is purely mechanical involving no quantum jump (and hence only effectively random) then Z can perceive the picture before the ordinary "I" perceives it with the result that galvanic response is created. Galvanic response is deterministic in case that Z is an entire population of "I": s.

Some remarks about the model are in order.

1. The criticism against this kind of model is that Z is perhaps not able to assign any emotional content to the pictures. The experiments supporting the existence of Z mildly suggest that Z sees the things "as they are" (for instance Z cannot be fooled by visual illusions) which in turn suggests that emotional response is perhaps not involved.

2. Z could also receive the information about the picture by precognition in principle made possible by the diffuse contribution to the contents of conscious experience coming from entire initial and final quantum histories. If this is the mechanism, one can however wonder why the "real" I is not capable to same so that also "real" "I" would have *conscious experience* about the nature of the picture before seing it.

3. In case of Kornhuber experiments similar explanation would lead to the veto model: the conscious decision to raise index finger is preceded by the conscious decision of Z to raise it and the "real I" can decide whether to allow various neural processes to continue or not.

4. In principle (probably only in principle) one could test the model by allowing the selection of the figure to be shown to A be determined by a quantum jump rather than by deterministic process. If this quantum jump occurs only very short time before A sees the picture, response should disappear.

An effect resembling Radin-Bierman effect might occur in much more concrete situation. There is a legend about the ability of the short distance runners to anticipate the shot of the starting pistol and start already before the gun shot. Perhaps this really occurs but in the following sense. When short distance runners hear the shot they perform a quantum jump to a new history. For obvious reasons they might have developed a skill to jump to a quantum history at which they started before the gun shot. Whether this effect occurs could be tested by using video camera or some more sophisticated arrangement (gun shot can be accompanied or even replaced by light signal to make the timing precise). What could happen is that the man with the gun honestly claims that the runner started after the shot whereas videocamera tells that runner started before the shot. This effect deserves the nickname "tribar effect" (tribar is the famous non-existing triangle like structure formed from three bars): in its various forms the effect could provide very general hard evidence for TGD based view about space-time.

Notice that the paradox of ping pong game described in the book of Penrose [J154] can be resolved in quantum jumps between quantum histories picture. The problem is that the time delays of consciousness are so long that no conscious action seems to be possible in ping pong game. The resolution is simple. The players can quite well miss the ball time on the old history but perform a jump to a new history: on this history they do not miss the ball thanks to the rapid deterministic reflex action.

12.7 Good And Evil, Life And Death

In principle the proposed conceptual framework allows already now a consideration of the basic questions relating to concepts like Good and Evil and Life and Death. Of course, too many uncertainties are involved to allow any definite conclusions, and one could also regard the speculations as outputs of the babbling period necessarily accompanying the development of the linguistic and conceptual apparatus making ultimately possible to discuss these questions more seriously.

Even the most hard boiled materialistic sceptic mentions ethics and moral when suffering personal injustice. Is there actual justification for moral laws? Are they only social conventions or is there some hard core involved? Is there some basic ethical principle telling what deeds are good and what deeds are bad?

Second group of questions relates to life and biological death. How should on define life? What happens in the biological death? Is self preserved in the biological death in some form? Is there something deserving to be called soul? Are reincarnations possible? Are we perhaps responsible for our deeds even after our biological death? Could the law of Karma be consistent with physics? Is liberation from the cycle of Karma possible?

In the sequel these questions are discussed from the point of view of TGD inspired theory of consciousness. It must be emphasized that the discussion represents various points of view rather than being a final summary. Also mutually conflicting points of view are considered. The cosmology of consciousness, the concept of self having space-time sheet and causal diamond as its correlates, the vision about the fundamental role of negentropic entanglement, and the hierarchy of Planck constants identified as hierarchy of dark matters and of quantum critical systems, provide the building blocks needed to make guesses about what biological death could mean from subjective point of view.

12.7.1 Life And Death

There are rather important steps of progress occurred during that last years (I am doing this updating 2015), which allow a more serious consideration of the notions of life and death in TGD framework.

1. NMP and the notion negentropic entanglement imply that state function reductions do not only destroy entanglement but can also create negentropic entanglement for which the density matrix is projector to a higher-dimensional sub-space of state space. This changes completely the standard rather gloomy view about evolution as approach to maximal entropy. Also now second law holds but for the ensemble entropy which is single particle quantity whereas entanglement entropy characterizes a system with at least two particles. The stable correlation between system and complement becomes information carrier.

A possible interpretation is as an abstraction: the pairs of stase in the superposition are instances of the abstraction, concept, or rule. I have christened the negentropic resources as Akashic records. In this view Universe is a gigantic library, which grows all the time. It is not a priori clear whether the information coded to negentropic entanglement is conscious.

The original idea that interaction free measurement generalizes so that it applies to deduce information about negentropic entanglement turned out to be wrong. Negentropic entanglement must be experienced directly. Interaction free measurement can be however used to read memories represented in terms of bits. For interaction free measurement Elizur-Weizman bomb tester is an excellent representation (see `http://tinyurl.com/y9zenssv`) involves state function reduction. The outcome of interaction free measurement now tells whether the bomb can act as quantum measurement apparatus or not (is it active or not) and at idealized limit the state of bomb is not changed (it does not explode).

The only option consistent with the recent formulation of quantum measurement theory in ZEO and based on NMP is that negentropic entanglement is directly experienced as a rule or concept during state function reduction sequences at the same boundary of CD so that no measurement is needed. This option is the only possible one in the recent formulation.

2. TGD Universe is quantum critical. This statement has now an elegant formulation as a hierarchy of quantum criticalities assignable to a fractal hierarchy of sub-algebras of various conformal algebras associated with TGD acting as gauge symmetries, and labeled by effective Planck constants $h_{eff} = n \times h$. The levels of the hierarchy have interpretation in terms of dark matter. The most important algebra of this kind is super-symplectic algebra. The phase transitions increasing $n = h_{eff}/h$ correspond to scalings $n \to m \times n$ for some integer m and criticality is reduced so that these phase transitions should occur spontaneously. Living systems can be seen as systems trying to stay at the existing criticality. This requires metabolic energy and homeostasis serves this purposed. Eastern philosophies talk about Karma's cycle and the need to preserve ego preventing the spontaneously occurring extension of consciousness.

   One can argue that this view about life as a battle against enlightenment is rather cynical. The attempt to stay at quantum criticality should have some deep positive meaning. Maybe the jumping forth and back between criticalities is what gives life its positive meaning and helps to build Akashic records by generating negentropic entanglement. Maybe living systems could be seen as kind of publishing producing systematically replicas of Akashic records could be the deep rationale behind life.

3. ZEO allows a precise identification of self as a sequence of state function reductions at the same boundary of CD. This allows also to understand how the experience about flow of time and arrow of time emerge. One can also formulate precisely the life-time of the system in geometric sense as the increase of the average distances between the tips in the superposition of CDs associated with self. The life-time in subjective sense can be identified as the number of quantum jumps at passive boundary of CD.

   The first state function at the opposite boundary of CD means the death of self and rebirth of self at the opposite boundary. NMP forces this first state function reduction and when it occurs for sub-self higher level self interprets it as an act of volition.

4. NMP has become central principle of TGD inspired theory of consciousness. Quite generally, NMP replaces quantum randomness with intentional evolution: Universe has a goal and this is to increase negentropic resources. The analogs of slee-wake-up cycles in which self and its shadow wake up would be realized in all scales. Can one interpret also human life cycle as on example about this kind of cycles.

   The basic questions seem to be following ones.

1. Is me the self defined by my biological body? In this case biological death would mean reincarnation of me at opposite boundary of CD and life lived in opposite direction of time. Or does my biological body corresponds to my subs-elf/mental image. Me could in this case correspond to my magnetic body or field body having possibly astrophysical size. The death

of my biological body would replaced the mental image about biological body with time reversed mental image.

2. A further interesting question is whether there is a continuity of conscious experience in the re-incarnation of self at opposite boundary of CD. We remember something about our dreams. Does this new self have memories about the earlier life?

3. Also NMP raises questions. Can self perform bad deeds or does NMP automatically imply possible deeds increase the negentropic resources. In thermodynamics thermodynamical fluctuations can break second law in some short enough time scales. NMP has structure very similar to second law. Could it be that bad deeds are analogous to thermodynamical fluctuations: possible but present only in short time scales?

   Or is the only remaining non-predictability related to the ordinary state function reductions in which outcome is non-deterministic and random. But how can one see the deeds of Hitler as creation of negentropy? His deeds produced a lot of suffering but did they teach for humanity something very importan: Do not do like Hitler?

   Perhaps the only reasonable option is that NMP allows but does not force state function reduction to a density matrix which is a higher-dimensional projector. Self can select whether it performs a reduction to this or a lower-dimensional space or even to a ray of Hilbert space. This allows also bad deeds and the optimistic view would be that these bad deeds are analogous to thermodynamical fluctuations.

What is Death

One can interpret aging in two senses. The aging with respect to geometric time and the ageing with respect to the subjective time. Before discussing aging in the sense of geometric time one must specify what one means with geometric time and what one believes its relationship to subjective time to be.

1. There are two geometric times corresponding to the times assignable to space-time surface and embedding space and by general coordinate each of these times can be identified in various number of ways.

2. Geometric time increases in discrete steps and corresponds to sub-sequent scalings of CD size defined by the distance between its tips by integer. One could call this geometric time associated with particle CD/self personal geometric time. Each self/CD defines its own embedding space time and the increase of the proper time distance between the tips of CD is the natural choice for the definition of the age of self. There is also time associated with space-time surfaces. Both time coordinates can be chosen in many ways but symmetry conditions favor certain choices.

3. Subjective time corresponds to the number of the state function reductions already occurred at the passive boundary since the first one. The ratio of subjective age to geometric age measures the number of conscious experiences per geometric time and the larger this number is the longer of the subjectively experience time is.

4. aging itself with the biological and spiritual aspects that we know could be seen in two ways. Biological aging which corresponds to $h_{eff}/h = 1$ sector consisting of ordinary visible matter and second law which follows also from TGD. Variants of second law are expected also for other values of h_{eff}/h corresponding to dark matter and be a manifestation of the non-determinism of state function reduction at ensemble level. Spiritual aging would correspond to the gradual increase h_{eff}/h and quite literally leading to the increase of the scope of consciousness. The increase would be due to giving up in the fight against spontaneous increase of criticality to keep h_{eff}/h unchanged and allowing the transition to criticality at longer length scales. Eastern thinking would translate this to ego attachment.

   There must of course be some point in fighting against the spontaneous increase of h_{eff} and there is. The longer the lifetime of self is, the wiser the sub-selves representing mental images can become by repeated re-incarnations. aging means getting wiser! By favoring the generation of negentropic mental images, self can live longer.

5. The challenge is to understand in more detail how biological death as the first state function reduction at the opposite boundary of CD is forced by NMP. This relates to the growth of entropy at the lowest and also other levels by the challenge is to understand the details. The increase of the total negentropy of CD by generation of negentropic mental images can postpone the biological death.

   Could it be that a cascade of state function reductions proceeding down to shorter scales from the level of CD cannot anymore produce negentropic entanglement and after that NMP forces the biological death. Since h_{eff} can increase in the first reduction to the opposite boundary of CD, NMP forces this reduction to eventually occur. An interesting question already posed is whether the integer multiples of the original size of CD correspond to especially critical moments for the biological death.

   There is present an entropy growth due to the randomness of state function reduction leading to a thermalization or the ensemble of mental images. This would correspond to second law, which still hold true for ensemble entropy. NMP predicts that the negentropy of conscious experience tends to increase and the biological death is only a transformation to some new form of existence. The dark matter hierarchy with levels labeled by the values of Planck constants has become a key element of TGD inspired theory of consciousness and one can imagine that during aging these levels of existence begin gradually dominate consciousness.

What interests us mostly is obviously the subjective aging and biological death. What dying person might experience? Is there a continuity of subjective experience or does suffering end with a loss of consciousness. What follows after biological death? How our deeds affect what happens in biological death and to the experiences after the biological death? Here are some possible answers.

1. If biological body corresponds only a mental images of the magnetic body, the only thing that happens in biological death could be that the contribution of biological body to the contents of consciousness disappears so that other contributions usually masked to a high degree by sensory input and motor activities become into full light of consciousness. In fact biological body and magnetic body are 4-dimensional and there are good reasons to expect that it continues to contribute to the consciousness of some self- not necessarily the self which possessed the body. The question is however about what this particular self that I have experiences in biological death and after it.

2. The notion of negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig.** 21 in the appendix of this book) allows to consider an answer to what might happen in biological death from the point of subjective time. Depending on the choices of self which has the dying person as sub-self, dying person generates bound state entropic entanglement with a loss of consciousness or negentropic entanglement accompanied by an expansion of consciousness. What option the higher level self chooses depends on the probability of the size of the contribution of the state with negentropic entanglement.

3. If the dying person has a strong negentropic entanglement with external world, it tends to be preserved in quantum jumps and only a small entropic contribution is present and there is only a small probability to lose consciousness. Another manner to see this is that a sub-self having very entropic sub-selves (mental images) is experienced by self as something unpleasant and by generalized NMP self might want to get rid of this kind of mental image. This would reduce the chances of experiencing an expansion of consciousness. Perhaps death could be seen as the price for sins.

4. One could also argue that although consciousness might be lost it might be not be in any manner different from sleep. It could be gained back in wake-up but as something different from ordinary wake-up consciousness and determined by the 4-D biological and magnetic bodies and the deceased could remember his former life by still existing 4-D body. The notion of electromagnetic body, when combined with the view about psychological time, allows to consider a general answer to these questions. Magnetic body probably survives the biological death, and since it serves as the sensory canvas, there are all reasons to expect that subjective consciousness continues after the biological death. The contents of consciousness would be determined by the 4-dimensional physical and electromagnetic bodies and the

dominating contribution creating the illusion about reality as a time=constant snapshot would be absent. Kind of timeless consciousness would be in question in accordance with the life review experiences associated with NDEs.

5. One can also ask what might be the physical correlate of self after the biological death. The self associated with the biological body should re-incarnated at the opposite boundary of CD associated with it and defined kind of "shadow me". The 4-D space-time sheet representing self very probably does not disappear in biological death and the 4-D character of the perceptive field suggests that this 4-D body continues to exist as a conscious entity and the sub-CDs of the geometric past representing mental images still exist. Only at the future boundary of CD the flow of 4-D biological body ceases but the sub-CDs representing existing mental images float to the direction of geometric past in the river of time and remain consciousness.

Ageing from the point of view of second law

In standard quantum theory framework not allowing negentropic entanglement self could be regarded as a statistical ensemble of mental images defined by the unentangled final states of the quantum jumps. Since the size of this ensemble increases quantum jump by quantum jump, the approach of this ensemble to thermal equilibrium is unavoidable although living matter has probably invented ways to fight against the second law of thermodynamics. Thus aging of self means dissipation.

The hierarchy of Planck constants and negentropic entanglement mean deviations from this picture.

1. For higher levels of dark matter hierarchy the dissipation rate is expected to be slower: the naïve expectation is that the rate is inversely proportional to Planck constant.

2. Negentropic entanglement means second exception to the rule and for given CD second law can be broken in time scales shorter than the time scale characterizing CD [K73].

Each p-adic length scale defines its characteristic dissipation rates. In case of a self decomposing into sub-selves the rate of dissipation is sum over the real dissipation rates associated with the nested system formed by the self, its sub-selves, their sub-selves, etc.... The dissipation associated with states of whole-body consciousness can be anomalously small since only negentropic mental images are absent and if there is only one such mental image (or no mental images at all) there is no generation of ensemble entropy. A possible test for this is the study of total rate of metabolism during meditation.

Dissipation causes the aging of self: getting old at least at the level of biological body would be the price for having self. More concretely, the entropies associated with various distributions of quantum number and zero mode increments increase during aging so that mental images are gradually blurred. Note that also our self which defines a mental image of a higher level self is blurred. Also biological death, or at least death experience, seems to be unavoidable fate of self.

Ageing and death from the point of NMP

The possility of negentropic entanglement allows to see aging from different point of view if NMP is taken as the analog of second law holding in the realm of subjective existence.

1. aging as an entropic process could be seen also as a process analogous to the process of getting drowsy and falling asleep but in much longer time scales. Bodily sub-self would not remember anything about these periods in the case that the entanglement was entropic. Also sleep could represent a similar conscious state without bodily mental image and the impossibility to remember anything about this period of consciousness might be simply due to the fact that one can remember something about sleep state only in sleep state. The periods during which negentropic entanglement prevails would be experienced as enlightenment like experiences. During aging bodily sub-self would spend more and more time near the critical line at which this kind of phase transition occurs.

2. aging could be seen as a process of personal growth generating negentropic entanglement. The negentropic entanglements generated with larger selves would give rise to larger selves and the metaphor "awakening" would thus be much more than a metaphor. Time-like negentropic entanglement would mean longer time span of attention. Person would spend more and more time in extended state of consciousness and in death finally leave the confines of the biological body. Note that person need not, and probably doesn't, remember anything about the periods of entanglement in which the local topology of self changes. This would make possible the evolution of selves continuing after death to higher levels of conscious existence.

This picture is rather optimistic: one must also consider the possibility that the evolution of self is not always a continuous personal growth! The fact that the individual development of most people seems to be a process of continual abstraction suggests that biological death is only one step in the process of abstractions and that our self consciously experiences the final transition to higher level of existence in biological death.

Why childhood memories are recalled so intensely?

The first manner to see aging is as a subjective experience: as aging with respect to subjective time. Our self contains sub-selves representing our memories, sensory input from the geometric now and future plans. At the old age it often happens that childhood memories begin to dominate whereas the recall of more recent memories is gradually lost. Of course, the contribution of future plans becomes also gradually negligible. This suggests that the contents of consciousness for our self can suffer a gradual transformation such that the childhood begins to dominate: of course, this need not happen always. That the childhood dominates is not easy to understand if the memories of the past are stored in the geometric now as assumed in the standard brain science. In TGD framework the very fact that the childhood consciousness is very intense and un-conceptual, explains the dominance of the episodal memories of childhood.

Who is the subjective experiencer in this kind of situation? Is it the old person with vivid memories or a child with some very diffuse ideas about future? The view about psychological time would suggest that the general experience gradually becomes some kind of a 4-dimensional life review such that the very intense childhood memories dominate but that the person in the psychological now is still the only one who can transform intentions to actions effectively whereas the 4-D body of the past is more or less frozen.

Death as disappearance of the mental image representing the biological body?

If one takes seriously the following two assumptions behind the TGD based model of quantum control and coordinate based on the symbiosis of MEs, magnetic flux tube structures, and matter at the atomic space-time sheets, one ends up with rather concrete view about what happens after the biological death. The ultimate sensory representations are realized on the sensory canvas provided by magnetic flux tube structures of similar size, so that we have magnetic body providing sensory representation of the biological body and external world [K99]. Our magnetic self very probably survives in the biological death by the conservation of the magnetic flux.

In this picture the body of after-life body would consists of the magnetic body plus MEs possibly surviving the death of the biological body. The only difference as compared to the life before death would be that the sensory and cognitive mental images representing the biological body (sub-selves) would disappear and the attention of our self would be directed to something else. Possibly to the entire time span of 4-D biological body since sensory input and motor actions at the upper boundary of peresonal CD are absent. Near death experiences indeed support this view [K23]. In this picture re-incarnation is possible and even plausible and means only that the magnetic flux tube structure representing our bodily self turns its attention to some other biological body and uses it as a sensory and motor organ. This new biological body could be plant, animal, human, or perhaps something else. In this picture the metaphor about biological body as a cloth becomes very concrete.

Since self has an extension with respect to geometric time, it has memories about its earlier history and one could perhaps identify the continuation of self after the death as that self which has the memories of self with respect to geometric time before death. In this extended state of

consciousness self could experience the subjective past of the space-time sheet of self and associate it with self's recent mind-like space-time sheet.

Near death experiences

Near death experiences provide a testing ground for the general ideas about what might happen in the physical death. Experiences resembling near death experiences can be produced now in controlled manner in laboratory circumstances for people well and alive and irrespective of their belief structure subject persons tell about light tunnels and meeting of deceased relatives [J38] . These experiences have been found to be therapeutic and are indeed used as therapy to cure severe psychic traumas. Therefore the materialistic explanation as a hallucination associated with dying brain seems to be excluded. Near death experiences involve experiences like being in light tunnel, seeing beautiful and rich landscapes and meeting dead relatives. Also out-of-body experiences are involved. The model of NDEs are discussed in detail in [K98] and here only some brief comments are represented.

The proposed picture about physical death allows a lot of room to interpret these experiences. For instance, OBEs allow two explanations.

1. The first explanation is based on the fact that in TGD based model of sensory representations the magnetic sensory canvas far outside body basically sees the brain in ELF light. This light usually comes from brain and provides a sensory representation for the external world. TGD predicts also a mechanism producing background ELF radiation from the entire body at magnetic transition frequencies and this background would make possible to see the body 3-dimensionally from outside when the sensory input is absent and does not mask this weak contribution. NDE OBEs might correspond to this kind of vision reported also by yogis.

2. The experience looking one's body from outside could mean that some higher level self corresponding to slow EEG waves and higher em selves formed physically by the personnel of hospital in the hospital room begins to dominate. This self could perhaps see patient's body with the combined eyes of the hospital personnel. Indeed, since the sensory input from the biological body ceases, the illusory identification of "me" with the biological body ceases and attention can be directed to this higher level sensory input.

Geometrically the em bodies of our dead relatives would exist in the geometric past and now, perhaps already in a re-incarnated form. This allows several explanation for the experience of meeting dead or living relatives. A very concrete model would be based on electromagnetic bridges formed by magnetic mirrors and connecting us with our relatives and friends. This would make possible for us to see them in ELF light just like we would see ourselves.

The experience about meeting deceased relatives could be also understood as a special kind of geometric memory. Generation of the long term memory means classically looking to a magnetic mirror at classical level and seing the me of the past in the mirror. It is however possible to see someone else in the mirror since the magnetic flux tube from the mirror could continue to the body of the deceased relative of friend instead of my body. In the usual states of consciousness the sensory input from the psychological now dominates and this contribution is masked. In near death experiences sensory input from the geometric now is diminished and the transpersonal background contribution becomes unmasked.

What after biological death?

Biological death could mean the loss of sub-self representing body image and involve extension of the physical self: this would explain out of body experiences and near death experiences (person near death looking his body from outside). In fact, an attractive hypothesis, motivated by the quantum model of brain, is that the topological field quanta associated with photons generated by EEG currents having size of order Earth by Uncertainty Principle, could correspond to selves in our personal self hierarchy. Also magnetic flux tube structures associated with body and brain could have similar sizes and serve as a magnetic body [K99]. In biological death these ELF selves could continue to oscillate as Schumann resonances in the wave cavity between Earth's surface and ionosphere interacting with magnetic flux tube structures!

If one believes that even cell sized structures have their own CDs then the primary p-adic length scale defined by the size scale of a large neuron (10^{-4} meters) would correspond to a time scale of the order of the age of the Universe! It seems implausible that these CDs could disappear totally although zero energy ontology in principle allows it.

Biological body is accompanied by magnetic body and radiation body which provide representation for the physical (or better to say, material) body. The latter consists of radiation selves (massless extremals representing topologically rays of light) representing classically the ELF radiation fields generated by EEG currents, one is led to ask what happens for these em selves in biological death. Some of them correspond to resonant frequencies of the em fields in the 80 km thick wave cavity between Earth surface and ionosphere known as Schumann frequencies and one can consider the possibility that that something which might be called soul remains after the biological death and is represented as Schumann resonances.

The most plausible hypothesis is that both ULF MEs and magnetic flux tube structures remaining after physical death together with the 4-dimensional body of geometric past define our self after the biological death. This leads to the following speculative vision about consciousness after the biological death.

1. The transformation of intentions to actions ceases in the biological death so that the dominating contribution of the psychological now to the experience disappears and conscious experience becomes kind of four-dimensional life review in which also the contributions from other bodies (say deceased relatives) appear as unmasked.

2. The geometric past, or rather experiences about it, can be gradually refined but no big changes are possible, so that a totally new life based on different decisions does not seem to be possible. The assumption about totally new life would also lead to paradoxes. On the other hand, the instability of the long term memories suggests that the memories about the past life could be edited. The conscious experience contains also the contribution of the magnetic body continuing to exist.

3. The surviving magnetic body could attach to some new organism which it begins to use as a sensory and motor organ. The re-incarnation would have the memories of the past life as an unconscious background masked strongly by the sensory input and coming clearly conscious only in some altered states of consciousness. The reports about children remembering they previous life could be understood in this conceptual framework. This of course makes one wonder whether young children could remember their past lives. Perhaps someone should ask!

4. ZEO inspired view about state function reduction suggests more concrete view. The new self is generated at the previously active boundary of CD assignable to the biological body and the new life is lived in reversed direction.

Does soul exist in some sense?

An open question is what happens for the space-time sheet (or CD) assignable to self after biological death.

1. Could this space-time sheet or CD be called soul? Does this soul continue drift in light-cone and get attached to some new material system. Or can it disappear in quantum jump? This would not be a reincarnation in the usual sense of the word. The re-incarnation in the usual sense if the word would mean that one has memories about the life of someone whose has lived in past. In TGD Universe this is quite possible since the mechanisms of remote mental interactions are basically the same as the interaction mechanisms making possible for the magnetic body to control the biological body receive information from it.

   "Ontogeny recapitulates phylogeny" principle suggests that the evolution of an individual is image for the evolution of the entire universe. Biological death would be only a metamorphosis to some new form of existence, perhaps as topologically quantized classical fields associated with the biological body. Magnetic flux tube structures having sizes measured in scale of light lifetime are especially promising candidates for the components of electromagnetic body

surviving in the death of what is usually identified as the biological body. Some experimental facts lead to rather precise ideas about the geometric representation of our selves and also suggest that our existence continues in electromagnetic form after death [K23].

3. An attractive identification of "soul" would be as negentropic entanglement resources - Akashic records - serving also as a quantum correlate of love and other positive atributes of consciousness. Could this negentropic entanglement become conscious (be read) in repeated state function reductions or is the counterpart of interaction free quantum measurement require for this to happen?

Indirect support for the survival of space-time sheets carrying associated with negentropic entanglement/large h_{eff} after death comes from rather unexpected direction.

1. The phenomenon of phantom DNA suggesting that dark space-time sheets associated with DNA remain in the chamber which contained DNA: in the experiments of Poponin [I69] the signature of phantom DNA is its interaction with laser light at visible frequencies. Phantom DNA would be represented by mind-like space-time sheets with size of at least the wavelength of visible light (10^{-7} meters). The em selves remaining after our death would have consirably larger size! One can however consider the possibility that some detectable interaction between ELF frequency em fields and "phantom brain" ("em soul") could be possible and make it possible to prove experimentally the presence of em soul!

2. The claimed successes of homeopathy (for phantom DNA and homeopathy see [K142] and [K53]). could also have explanation in terms of the mind-like space-time sheets. Homeopathic drugs are fabricated by a repeated dilution of the active drug so that the concentration of the drug in solution becomes extremely low. The method of fabrication could however imply that final product contains quite many mind-like space-time sheets of the drug molecules. These mind-like space-time sheets might be able to affect the sickness since the mind-like space-time sheets provide a cognitive representation for drug and this mimicry could "cheat" the patient to cure. The law of similarities could have something to do with the mechanism involved.

   More concretely, a given quantum transition frequency characterizing the medicine would be represented as ME with length equal to the wavelength associated with the transition frequency. The electromagnetic body of the molecule could be mimicked by liquid crystal water blobs producing similar transition frequencies and thus containing similar MEs in their electromagnetic bodies. The effect of the medicine would be mediated by the electromagnetic body so that the "fake" medicine could indeed cure.

Some support for the extension of self in death is provided by near death experiences (NDEs). For instance, looking one's body from outside could mean that self is entangled with a larger self formed by the personnel of hospital in the hospital room and sees patient's body with the eyes of the personnel. This experience could be understood as experience of, say self representing hospital room: in this experience the visual experiences of persons in the hospital room would fuse to the experience experienced by patient entangled with the hospital room. Meeting one's relatives and elders could mean entanglement with a larger self formed by the selves of dead and living relatives. This larger self could experience the abstracted experiences of dead and living relatives. Also the ability of subjects of surgical operations to occasionally remember about events occurred during unconscious state, supports this view. Magnetic flux tube structures are the most plausible candidates for the "body" remaining in physical death: this point is discussed in more detail in [K23].

Is it possible to get into contact with deceased?

There is a lot of anecdotal evidence consistent with life after death. Near-death experiences are not the only manner to get convinced for life after death. So called eye-movement de-sensitization and reprocessing (EMDR) discovered by Francine Shapiro [J38, J97] induces what could be interpreted as after-death communications.

1. The experiences of subject persons can be induced by this therapy in highly reliable manner: according to [J38] 98 per cent of patients willing to participate the therapy had after death communication experience It does not matter what the religious convictions of the subject person are and the experiences are actually rather easy to induce. It does not matter if the loss is traumatic or not or whether it is recent or occurred for decades in past.

2. The experiences resemble near death experiences (light tunnels, beautiful landscapes) and involve spiritual contact with the deceased. The EMDR technique involves getting the patient to move his or her eyes in a particular rhythmic fashion while at the same time attending to a particular aspect of the traumatic memory.

3. How EMRD works is poorly understood as yet: possibly the fact that the shifting of eyes leads to increased brain processing is of importance. Notice that rapid eye movements REM are also involved with dreams. A possible explanation is that EMDR experiences could involve communication with the recent selves of the deceased ones located possibly in the geometric recent or past and represented by magnetic flux tube structure and MEs interacting with them.

12.7.2 Good And Evil

The vision about life as something in the intersection of real and p-adic worlds together with the notion of negentropic entanglement gives hopes for understanding the quantum correlates of evolution and even ethics. The basic principle would be that good deeds generate negentropic entanglement and Negentropy Maximization Principle - perhaps suitably generalized from its original form- would define the basic principle of ethics.

Quantum ethics very briefly

The proposal is that the basic ethical principle is that good deeds help evolution to occur. This proposal can be criticized. Evolution should correspond to the increase of negentropic entanglement. NMP in trong forces it and in weak form allows it.

1. If strong form of NMP prevails, one can worry that TGD Universe does not allow Evil at all, perhaps not even genuine free will! No-one wants Evil but Evil seems to be present in this world.

2. Could one weaken NMP so that it does not force but only allows to make a reduction to a final state characterized by density matrix which is projection operator? Self would choose whether to perform a projection to some sub-space of this subspace, say 1-D ray as in ordinary state function reduction. NMP would be like Christian God allowing the sinner to choose between Good and Evil. The final entanglement negentropy would be measure for the goodness of the deed. This is so if entanglement negentropy is a correlate for love. Deeds which are done with love would be good. Reduction of entanglement would in turn mean loneliness and separation.

3. Or could could think that the definition of good deed is as a selection between deeds, which correspond to the same maximal increase of negentropy so that NMP cannot tell what happens. For instance the density matrix operator is direct sum of projection operators of same dimension but varying coefficients and there is a selection between these. It is difficult to imagine what the criterion for a good deed could be in this case. And how self can know what is the good deed and what is the bad deed.

Good deeds would support evolution. There are many ways to interpret evolution in TGD Universe.

1. p-Adic evolution would mean a gradual increase of the p-adic primes characterizing individual partonic 2-surfaces and therefore their size. The identification of p-adic space-time sheets as representations for cognitions gives additional concreteness to this vision. The earlier proposal that p-adic–real-phase transitions correspond to realization of intentions and

formations of cognitions seems however to be wrong. Instead, adelic view that both real and p-adic sectors are present simultaneously and that fermions at string world sheets correspond to the intersection of realities and p-adicities seems more realistic.

The inclusion of phases $q = exp(i2\pi/n)$ in the algebraic extension of p-adics allows to define the notion of angle in p-adic context but only with a finite resolution since only finite number of angles are represented as phases for a given value of n. The increase of the integers n could be interpreted as the emergence of higher algebraic extensions of p-adic numbers in the intersection of the real and p-adic worlds. These observations suggest that all three views about evolution are closely related.

2. The hierarchy of Planck constants suggests evolution as the gradual increase of the Planck constant characterizing p-adic space-time sheet (or partonic 2-surface for the minimal option). The original vision about this evolution was as a migration to the pages of the book like structure defined by the generalized embedding space and has therefore quite concrete geometric meaning. It implies longer time scales of long term memory and planned action and macroscopic quantum coherence in longer scales.

   The new view is in terms of first quantum jumps to the opposite boundary of CD leading to the death of self and its re-incarnation at the opposite boundary.

3. The vision about life as something in the intersection of real and p-adic words allows to see evolution information theoretically as the increase of number entanglement negentropy implying entanglement in increasing length scales. This option is equivalent with the second view and consistent with the first one if the effective p-adic topology characterizes the real partonic 2-surfaces in the intersection of p-adic and real worlds.

The third kind of evolution would mean also the evolution of spiritual consciousness if the proposed interpretation is correct. In each quantum jump U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction process involves also the choice of the type of entanglement it could be interpreted as a choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the negentropic entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The selfish option means separation and loneliness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices.

In this framework one could understand the physics correlates of ethics and moral. The ethics is simple: evolution of consciousness to higher levels is a good thing. Anything which tends to reduce consciousness represents violence and is a bad thing. Moral rules are related to the relationship between individual and society and presumably develop via self-organization process and are by no means unique. Moral rules however tend to optimize evolution. As blind normative rules they can however become a source of violence identified as any action which reduces the level of consciousness. There is an entire hierarchy of selves and every self has the selfish desire to survive and moral rules develop as a kind of compromise and evolve all the time. ZEO leads to the notion that I have christened cosmology of consciousness. It forces to extend the concept of society to four-dimensional society.

There is an entire hierarchy of selves and every self has the selfish desire to survive and moral rules develop as a kind of compromise and evolve all the time. The newest progress in this evolution is brought by the cosmology of consciousness, which forces to extend the concept of society to four-dimensional society! The decisions of "me now" affect both my past and future and time like quantum entanglement makes possible conscious communication in time direction by sharing conscious experiences. One can therefore speak of genuinely four-dimensional society. Besides my next-door neighbors I had better to take into account also my nearest neighbors in past and future (the nearest ones being perhaps copies of me!). If I make wrong decisions those copies of me in future and past will suffer the most. Perhaps my personal hell and paradise are here and are created mostly by me.

What could the quantum correlates of moral be?

We make moral choices all the time. Some deeds are good, some deeds are bad. In the world of materialist there are no moral choices, the deeds are not good or bad, there are just physical events. I am not a materialist so that I cannot avoid questions such as how do the moral rules emerge and how some deeds become good and some deeds bad. Negentropic entanglement is the obvious first guess if one wants to understand emergence of moral.

1. One can start from ordinary quantum entanglement. It corresponds to a superposition of pairs of states. Second state corresponds to the internal state of the self and second state to a state of external world or biological body of self. In negentropic quantum entanglement each is replaced with a pair of sub-spaces of state spaces of self and external world. The dimension of the sub-space depends on the which pair is in question. In state function reduction one of these pairs is selected and deed is done. How to make some of these deeds good and some bad?

2. Obviously the value of $h_{eff}/h = n$ gives the criterion in the case that weak form of NMP holds true. Recall that weak form of NMP allows only the possibility to generate negentropic entanglement but does not force it. NMP is like God allowing the possibility to do good but not forcing good deeds.

   Self can choose any sub-space of the subspace defined by n-dimensional projector and 1-D subspace corresponds to the standard quantum measurement. For $n = 1$ the state function reduction leads to vanishing negentropy, and separation of self and the target of the action. Negentropy does not increase in this action and self is isolated from the target: kind of price for sin.

   For the maximal dimension of this sub-space the negentropy gain is maximal. This deed would be good and by the proposed criterion the negentropic entanglement corresponds to love or more neutrally, positively colored conscious experience. Interestingly, there are $2^n - 1$ possible choices which is almost the dimension of Boolean algebra consisting of n independent bits. The excluded option corresponds to 0-dimensional sub-space - empty set in set theoretic realization of Boolean algebra. This could relate directly to fermionic oscillator operators defining basis of Boolean algebra- here Fock vacuum would be the excluded state. The deed in this sense would be a choice of how loving the attention towards system of external world is.

3. A map between between the different choices of k-dimensional sub-space to k-fermion states is suggestive. The realization of logic in terms of emotions of different degrees of positivity would be mapped to many-fermion states - perhaps zero energy states with vanishing total fermion number. State function reductions to k-dimensional spaces would be mapped to k-fermion states: quantum jumps to quantum states!

   The problem brings in mind quantum classical correspondence in quantum measurement theory. The direction of the pointer of the measurement apparatus (in very metaphoral sense) corresponds to the outcome of state function reduction, which is now 1-d subspace. For ordinary measurement the pointer has n positions. Now it must have $2^n - 1$ positions. To the discrete space of n pointer positions one must assign fermionic Clifford algebra of second quantized fermionic oscillator operators. The hierarchy of Planck constants and dark matter suggests the realization. Replace the pointer with its space-time n-sheeted covering and consider zero energy energy states made of pairs of k-fermion states at the sheets of the n-sheeted covering? Dark matter would be therefore necessary for cognition. The role of fermions would be to "mark" the k space-time sheets in the covering.

   One can make further questions.

1. Could the moral rules of society be represented as this kind of entanglement patterns between its members? Here one of course has entire fractal hierarchy of societies corresponding different length scales. Attention and magnetic flux tubes serving as its correlates is the basic element also in TGD inspired quantum biology already at the level of bio-molecules and even elementary particles. The value of $h_{eff}/h = n$ associated with the magnetic flux

tube connecting members of the pair, would serve as a measure for the ethical value of maximally good deed. Dark phases of matter would correspond to good: usually darkness is associated with bad!

2. These moral rules seem to be universal. There are however also moral rules or should one talk about rules of survival, which are based on negative emotions such as fear. Moral rules as rules of desired behavior are often tailored for the purposes of power holder. How this kind of moral rules could develop? Maybe they cannot be realized in terms of negentropic entanglement. Maybe the superposition of the allowed alternatives for the deed contains only the alternatives allowed by the power holder and the superposition in question corresponds to ordinary entanglement for which the signature is simple: the probabilities of various options are different. This forces the self to choose just one option from the options that power holder accepts. These rules do not allow the generation of loving relationship.

Moral rules seem to be generated by society, up-bringing, culture, civilization. How the moral rules develop? One can try to formulate and answer in terms of quantum physical correlates.

1. Basically the rules should be generated in the state function reductions which correspond to volitional action which corresponds to the first state function reduction to the earlier active boundary of CD. Old self dies and new self is born at the opposite boundary of CD and the arrow of time associated with CD changes.

2. The repeated sequences of state function reductions can generate negentropic entanglement during the quantum evolutions between them. This time evolution would be the analog for the time evolution defined by Hamiltonian - that is energy - associated with ordinary time translation whereas the first state function reduction at the opposite boundary inducing scaling of h_{eff} and CD would be accompanied by time evolution defined by conformal scaling generator L_0.

   Note that the state at passive boundary does not change during the sequence of repeated state function reductions. These repeated reductions however change the parts of zero energy states associated with the new active boundary and generate also negentropic entanglement. As the self dies the moral choices can made if the weak form of NMP is true.

3. Who makes the moral choices? It looks of course very weird that self would apply free will only at the moment of its death or birth! The situation is saved by the fact that self has also sub-selves, which correspond to sub-CDs and represent mental images of self. We know that mental images die as also we do some day and are born again (as also we do some day) and these mental images can generate negentropic resources within CD of self.

   One can argue that these mental images do not decide about whether to do maximally ethical choice at the moment of death. The decision must be made by a self at higher level. It is me who decides about the fate of my mental images - to some degree also after their death! I can choose the how negentropic the quantum entanglement characterizing the relationship of my mental image and the world outside it. I realize, that the misused idea of positive thinking seems to unavoidably creep in! I have however no intention to make money with it!

4. It is difficult to avoid an association with the basic myth of Christianity about the death of God's Son which is said to mean that sins of sinners are forgiven. How could one make sense of this? Or is the Freudian interpretation the only possible explanation? If negentropy increases as self dies, the paradox begins to disappear. God was self and his Son was his mental image, whose death increased the negentropic resources of the Universe and made it better. We are Gods of our mental images and we are mental images of higher level Gods.

Do positively colored emotions allow a representation of Boolean logic?

Weak form of NMP allows the state function reduction to occur in $2^n - 1$ ways corresponding to subspaces of the sub-space defined by n-dimensional projector if the density matrix is n-dimensional projector (the outcome corresponding to 0-dimensional subspace and is excluded). If the probability for the outcome of state function reduction is same for all values of the dimension $1 \leq m \leq n$,

the probability distribution for outcome is given by binomial distribution $B(n,p)$ for $p = 1/2$ (head and tail are equally probable) and given by $p(m) = b(n,m) \times 2^{-n} = (n!/m!(n-m)!) \times 2^{-n}$. This gives for the average dimesion $E(m) = n/2$ so that the negentropy would increase on the average. The world would become gradually better. Note that one assumes that there is some preferred basis for the states and these numbers apply when this basis is given.

One cannot avoid the idea that these different degrees of negentropic entanglement could actually give a realization of Boolean algebra in terms of conscious experiences.

1. There should be a mapping of k-dimensional subspaces of n-dimensional space to the fermionic representation of Boolean algebra

2. Could one speak about a hierarchies of codes of cognition based on the assignment of different degrees of "feeling good" to the Boolean statements? If one assumes that the n:th bit is always 1, all independent statements except one correspond at least two non-vanishing bits and corresponds to negentropic entanglement. Only of statement (only last bit equal to 1) would correspond 1 bit and to state function reduction reducing the entanglement completely (brings in mind the fruit in the tree of Good and Bad Knowlege!).

3. A given hierarchy of breakings of super-symplectic symmetry corresponds to a hierarchy of integers $n_{i+1} = \prod_{k \leq i} m_k$. The codons of the first code would consist of sequences of m_1 bits. The codons of the second code consists of m_2 codons of the first code and so on. One would have a hierarchy in which codons of previous level become the letters of the code words at the next level of the hierarchy.

In fact, I ended up with almost Boolean algebra for decades ago when considering the hierarchy of genetic codes suggested by the hierarchy of Mersenne primes $M(n+1) = M_{M(n)}$, $M_n = 2^n - 1$.

1. The hierarchy starting from $M_2 = 3$ contains the Mersenne primes $3, 7, 127, 2^{127} - 1$ and Hilbert conjectured that all these integers are primes. These numbers are almost dimensions of Boolean algebras with $n = 2, 3, 7, 127$ bits. The maximal Boolean sub-algebras have $m = n - 1 = 1, 2, 6, 126$ bits.

2. The observation that $m = 6$ gives 64 elements led to the proposal that it corresponds to a Boolean algebraic assignable to genetic code and that the sub-algebra represents maximal number of independent statements defining analogs of axioms. The remaining elements would correspond to negations of these statements. I also proposed that the Boolean algebra with $m = 126 = 6 \times 21$ bits (21 pieces consisting of 6 bits) corresponds to what I called memetic code obviously realizable as sequences of 21 DNA codons with stop codons included. Emotions and information are closely related and peptides are regarded as both information molecules and molecules of emotion.

3. This hierarchy of codes would have the additional property that the Boolean algebra at $n+1$:th level can be regarded as the set of statements about statements of the previous level. One would have a hierarchy representing thoughts about thoughts about.... It should be emphasized that there is no need to assume that the Hilbert's conjecture is true.

   One can obtain this kind of hierarchies as hierarchies with dimensions $m, 2^m, 2^{2^m}, ...$ that is $n(i+1) = 2^{n(i)}$. The conditions that $n(i)$ divides $n(i+1)$ is non-trivial only for at the lowest step and implies that m is power of 2 so that the hierarchies starting from $m = 2^k$. This is natural since Boolean algebras are involved. If n corresponds to the size scale of CD, it would come as a power of 2.

   p-Adic length scale hypothesis has also led to this conjecture. A related conjecture is that the sizes of CDs correspond to secondary p-adic length scales which indeed come as powers of two. In case of electron this predicts that the minimal size of CD associated with electron corresponds to time scale $T = .1$ seconds, the fundamental time scale in living matter (10 Hz is the fundamental biorhythm). It seems that the basic hypothesis of TGD inspired partly by the study of elementary particle mass spectrum and basic bio-scales (there are 4 p-adic length scales defined by Gaussian Mersenne primes in the range between cell membrane thickness

10 nmandsize 2.5 μm of cell nucleus!) follow from the proposed connection between emotions and Boolean cognition.

Hilbert's conjecture relates in interesting manner to space-time dimension. Suppose that Hilbert's conjecture fails and only the four lowest Mersenne integers in the hierarchy are Mersenne primes that is $3, 7, 127, 2^{127} - 1$. In TGD one has hierarchy of dimensions associated with space-time surface coming as 0, 1, 2, 4 plus embedding space dimension 8. The abstraction hierarchy associated with space-time dimensions would correspond discretization of partonic 2-surfaces as point set, discretization of 3-surfaces as a set of strings connecting partonic 2-surfaces characterized by discrete parameters, discretization of space-time surfaces as a collection of string world sheet with discretized parameters, and maybe - discretization of embedding space by a collection of space-time surfaces. Discretization means that the parameters in question are algebraic numbers in an extension of rationals associated with p-adic numbers.

In TGD framework it is clear why embedding space cannot be higher-dimensional and why the hierarchy does not continue. Could there be a deeper connection between these two hierarchies. For instance, could it be that higher dimensional manifolds of dimension $2 \times n$ can be represented physically only as unions of say n 2-D partonic 2-surfaces (just like $3 \times N$ dimensional space can be represented as configuration space of N point-like particles)? Also infinite primes define a hierarchy of abstractions. Could it be that one has also now similar restriction so that the hierarchy would have only finite number of levels, say four. Note that the notion of n-group and n-algebra involves an analogous abstraction hierarchy.

Some questions

There are still many questions that are waiting for more detailed answer. These questions are also a good manner to detect logical inconsistencies.

1. What is the size of CD characterizing self? For electron it would be at least of the order of Earth size. During the lifetime of CD the size of CD increases and the order of magnitude is measured in light-life time for us. This would allow to understand our usual deeds affecting the environment in terms of our subselves and their entanglement with the external world which is actually our internal world, at least if magnetic bodies are considered.

2. Can one assume that the dynamics inside CD is independent from what happens outside CD. Can one say that the boundaries of CD define the ends of space-time or does space-time continue outside them. Do the boundaries of CD define boundaries for 4-D spotlight of attention or for one particular reality? Does the answer to this question have any relevance if everything physically testable is formulated in term physics of string world sheets associated with space-time surfaces inside CD?

   Note that the (average) size of CDs (, which could be in superposition but need not if every repeated state function reduction is followed by a localization in the moduli space of CDs) increases during the life cycle of self. This makes possible generation of negentropic entanglement between more and more distant systems. I have written about the possibility that ZEO could make possible interaction with distant civilizations [K69]. The possibility of having communications in both time directions would allow to circumvent the barrier due to the finite light-velocity, and gravitational quantum coherence in cosmic scales would make possible negentropic entanglement.

3. How selves interact? CDs as spot-lights of attention should overlap in order that the interaction is possible. Formation of flux tubes makes possible quantum entanglement. The string world sheets carrying fermions also essential correlates of entanglement and the possibly entanglement is between fermions associated with partonic 2-surfaces. The string world sheets define the intersection of real and p-adic worlds, where cognition and life resides.

How the law of Karma could be realized?

The existence of self hierarchy means that our deeds are remembered also after our death at higher level of self hierarchy although only as an abstracted summary. Also the shadow me which is born

at the opposite boundary of my personal CD remembers my deeds like a person remembers his dreams just after wake-up.

One can therefore ask whether the law of Karma or something akin to it might be implied by basic principles of consciousness theory.

First of all, self has two life strategies: be a sinner or saint. Sinner is selfish and minimizes the dependence on the environment be avoiding negentropic entanglement. Saint does the opposite and develops love towards surrounding world.

1. Self can fight for the metabolic energy feed giving rise to the self-organization of self. This strategy works as long as self is a young, brisk and arrogant sinner. Sinners are not desirable mental images from the point of view of higher level self since they induce a lot of entropic mental images (pain). This strategy is also in conflict with the possible goal of the higher level self to achieve fusion of its own mental images.

2. Self can attempt to share mental images by quantum entangling its sub-selves with the sub-selves of other, possibly, higher level selves. This mechanism gives rise to quantum metabolism and expanded states of consciousness, favors the generation of social structures, and means fusion of mental images from the point of view of higher level self. The cognitive mental images of the saintlike self are highly negentropic and favored by p-adic NMP.

On basis of these findings the policy for higher level selves looks obvious: try to get rid of the unpleasant mental images represented by sinners. Higher level self could apply this policy for purely selfish reasons: too bad sinners might affect like a poison to the moral level of the higher level self and, since the law of Karma is universal, could eventually lead to the decline of the higher level self to a lower level of the hierarchy: the world would seem to be a tough place also after death!

What "liberation" might mean?

The strong analogies with eastern spirituality encourage to ask whether the TGD inspired quantum counterpart for the concept of liberation might make sense.

1. Quantum-classical correspondence suggests that the endless evolution at the level of the entire universe corresponds to endless evolution at the level of individual so that the notion of liberation would make sense only as kind of transformation to a higher level of consciousness.

2. In the real context selves having only single mental image or no mental images at all are in state of "oneness" and experience no divisions and separations since the analysis process represented by state function reductions and self measurements is absent. This kind of state realized at the level of field body is a possible candidate for enlightened state. Certainly it cannot last forever.

3. Liberation experience might also relate to the experience of "cosmic consciousness". Most naturally a generation of negentropic entanglement fusing self to a self at higher level of self hierarchy. The fear about the loss of consciousness is what gives self an ego, since ego is something which can be lost. This can happen via the generation of entropic bound state entanglement with some other system. This can happen for any subsystem of Universe but not for the entire Universe enjoying an eternal state of consciousness. The state of cosmic consciousness thus means being a self without ego. The counterpart for this would be negentropic entanglement. Leaving aside the question whether we are able to experience ideal cosmic consciousness, one can consider the possibility that even human beings could achieve a state of consciousness in which the loss of consciousness is highly un-probable and that this loss of ego is synonymous with the experience of liberation.

The term "cosmic consciousness" looks somewhat pompous notion to anyone identifying himself with his suffering biological body and it would be certainly very difficult to sell this concept to a neuroscientist. The notion of magnetic body, the hierarchy of Planck constants, and the identification of quantum gravitational bound states in terms of astroscopic quantum coherence assignable to gravitational Planck constant, allow to take this notion seriously. In ZEO the arrow

of geometric time can change so that finite light velocity does not prevent instantaneous communications over cosmic distances so that communications with life forms in distant galaxies become possible. I have considered a concrete model for what might be involved in [K69].

12.7.3 About God Theory Of Bernard Haisch

I have found that the best manner to learn about TGD is to read books about other theories, and after many years at the border of basic survival I now have opportunity to do this thanks to some generous people making this possible.

Just now I have been reading Bernard Haisch's book "The God theory" (see `http://tinyurl.com/yaa94c64`) [J43]. Haisch himself is an astrophysicist who might have become priest. The book discusses the possibility of spirituality consistent with physics. It also discusses Zero Point Energy (ZPE) hypothesis and the idea that inertia might emerge from vacuum fluctuations of various fields.

I agree in many respects with Haisch's vision about possibility to build bridge between fundamental physics and spirituality. The new view about spirituality requires that a lot of horrendous stuff of religions (such as eternal purgatory, the sadistic God of Old Testament killing his own son, blind belief in dogmas, etc...) is thrown away. Where I disagree with Haisch is the notion of ZPE but think that I understand why he wants ZPE. In TGD all that can be done using ZPE can be replaced with zero energy ontology (ZEO) to achieve the possibility of re-creation without breaking of conservation laws: without ability go generate new sub-Universes God would be rather powerless creature. I also disagree with the idea that inertia follows from zero point fields although again I understand the underlying motivations of the proposal as relating to a genuine problem of General Relativity. This problem also inspired TGD.

Haisch lists three questions usually regarded as highly non-scientific. Is there really a God? What am I? What is my destiny? As I started to build theory of consciousness, these questions began to make more and more sense also to me. One must be however ready to give up some dogmas such as God as a sage with white hair and long beard, the idea that we are nothing but our neurophysiology generating a brief flash of light in infinite darkness, and the belief that heat death dictated by second law is the eventual fate of the universe as whole.

Putting Haisch in box

When thinkers happen to encounter genuine thinking they want to classify it in order to feel safe. For safety reason some of us also debunk the new idea. The first classification is philosophical. I use three boxes for this purpose (safety reasons). The first box has label "monism". It contains two smaller boxes. "Materialist" contains thinkers accepting only third person view as an acceptable - objective - view about the world. I close to "Idealist" those thinkers who accept only the first person view as fundamental. Most of my colleagues are happy to live in the box "Materialist". The second box has label "Dualist" and contains thinkers accepting both first and third person views - also this box decomposes to smaller boxes depending on how closely the first and third person views are assumed to be related: if the correspondence is exactly 1-1 then the view reduces to materialism. To the third box - "Miscellaneous" - I put the others and live also myself in this box.

Haisch perfoms the classification himself and completely voluntarily chooses the box "Idealist". Hence consciousness is fundamental form of existence for him. In TGD framework both first and third person perspectives are tolerated: consciousness is however in quantum jump between quantum superpositions of objective realities identified as zero energy states and does not define another world as it does in dualistic theories. As a matter fact, in TGD several ontological levels are accepted: geometric existence at space-time and embedding space levels in real and various p-adic versions, existence as zero energy states identified as spinor fields of world of classical worlds (WCW)) and subjective existence as quantum jumps.

Universe as God

Haisch postulates God as an infinite intelligence. We are God's eyes and ears through which God experiences her (no reference to gender here) own creation. Haisch's God is not the Newtonian

clock-smith who creates deterministic universe and then forgets it completely. This God is free to create universes with he chooses freely using her infinite intelligence. This God is also somehow outside the realm of space-time.

The possibility of universes with different laws of physics inside each of them brings in mind inflationary cosmology, multiverse, and the landscape of M-theory. Haisch indeed takes inflationary scenario and multiverse idea rather seriously and also talks about superstrings. The landscape of string theory is catastrophe from the point of view of physics but would fit with the idea about God who can freely decide about the laws of physics in the limits of mathematical consistency. But what mathematical consistency means? Have M-theorists really thought about this?

What about TGD? In TGD framework nothing prevents from calling conscious selves gods since free will is genuine and the essence of creation. Thus God is replaced with an infinite hierarchy of god like entities. Nothing prevents from calling the entire Universe as God, which is re-creating itself in every quantum jump. This God has us as mental images or to be more precise: as mental images of mental images of..... of its mental images. The sequence could be rather long)!

Concerning the laws of physics the situation in TGD framework. The surprising outcome already from the geometrization of loop spaces is that geometry of the infinite-dimensional world of classical worlds (WCW) is expected to be unique if it consists of 4-D surfaces of some higher-dimensional space. This comes from mere mathematical existence requiring the WCW metric to have infinite-dimensional group of isometries (generalization of various conformal symmetries of super string models). This means that also physics is unique just from its existence. As a matter fact, in TGD there is no need to assume any physical existence behind mathematical existence since consciousness is in quantum jumps. Space-time dimension and the choice embedding space are forced by very general mathematical conditions closely related to the structure of classical number fields. Four-dimensional Minkowski space and space-time dimension four are forced by the condition of maximal symmetries needed for the existences of WCW geometry.

Inflation in TGD framework is replaced with quantum criticality making the Universe maximally sensitive perceiver and motor instrument. Quantum criticality means absence of scales (or actually discrete hierarchy of them) and the flatness of 3-space (dimensional curvature scalar vanishes) is the correlate of quantum criticality in cosmology. The inflaton field producing via its decay matter is in TGD framework replaced with monopole magnetic fluxes assignable to magnetic flux quanta which near Big Bang correspond to what I call cosmic strings. The decay of magnetic energy of flux quanta to particles produces matter and radiation. The basic difference to string landscape is that standard model symmetries apply in all these sub-cosmologies although there are dynamical parameters distinguishing between them. Hence TGD is highly predictive theory. Even God must bow to the laws of mathematics. TGD space-time is many-sheeted and one has Russian doll cosmology natural also in inflationary scenarios.

In superstring theory the landscape problem forces to assume anthropic principle: the fact that we exist becomes the basic guide line when we try to identify the particular universe in which we happen to live. In TGD framework the evolution implied by Negentropy Maximization Principle (NMP, [K73]) stating that the conscious information gained in quantum jump is maximal, implies evolution. Evolution gradually fine tunes the values of various parameters so that they generate maximal intelligence. This implies that our existence indeed fixes the values of various parameter very precisely. Of course there are some parameters such as Kähler coupling strength (analogous to critical temperature), whose possible values are dictated by quantum criticality. Note that NMP challenges second law as a universal law - at least a generalization is required in ZEO - and it is now clear that the recent view about universe neglects completely the huge negentropy sources associated with the negentropic entanglement assignable to magnetic flux tubes carrying dark matter. In human scale these resources - "Akashic records" - give rise to memories and plans of future, ideas, ...

The purpose of lifes

Haisch adopts the vision about endless sequence of reincarnations as a kind of "life-school" in which one transcends life by life to higher levels of consciousness - to upper class in school (and sometime to same or even to lower one).

This vision could have rather concrete realization in TGD framework. In the average sense the average size scale for personal causal diamonds (CDs) in their quantum superposition grows in a

given quantum jump, and a biological death now and then does not stop this process. New sub-CDs also pop up and mean creation of new small sub-Universes which began to evolve. Asymptotically the size of the personal CD approaches infinity - asymptotic Universe, asymptotic Godness!

Biological death would not mean the end of consciousness, only a transformation to a new level: perhaps higher, perhaps same, or maybe even lower. This depending on the Karma - the law of action and reaction at spiritual level as Haisch puts it - that we have gathered by our deeds. By doing bad deeds reduce our level of consciousness guaranteeing the return to a lower level in hierarchy. This has quite concrete quantum physical correlate: reduction of the effective Planck constants reducing the quantal size scales of the magnetic flux tubes connecting as as bridges of attention to the rest of the world and reducing thus quantum coherence lengths and times characterizing us. It also reduces our long range goals from those dictated by a mission to short range goals dictated by opportunism.

What could happen in biological death?

"What is my fate?" is one of the questions of Haisch. A more concrete formulation for this question is "What happens to the magnetic body in biological death?". TGD framework provides the tools for a glass pearl game around this question.

It would not be too surprising if at least some upper layers of this onion-like structure were preserved. NMP might guarantee the approximate conservation of the entire magnetic body since its braiding serves as a correlate for negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) defining "Akashic records", a kind of cumulative collective wisdom having as a counterpart Sheldrake's morphic fields defining among other things also species memory.

What it means that in 4-D sense (contents of consciousness are from 4-D embedding space region: either boundary of CD in given scale) also our biological body still exists as sub-CD of the larger CD we continue to exist subjectively? Only the sensory input and motor output conscious-to-us has ceased in biological death.

Does my biological body continue its life in reversed direction of embedding space geometric time? The answer is negative if one relies on the assumption that the arrow of embedding space time changes and the folded bath towel argument for the arrow of 4-D time defined by thermodynamical entropy holds true: my body would continue becoming older than it was at the moment of death. Not very plausible or desirable scenario!

NMP requires that negentropic entanglement is generated at the moment of biological death and adds to existing negentropic entanglement defining "Akashic records" about previous life conserved in good approximation. What I painfully learned during my lifetime is not waste! Attention is directed to some target generates negentropic entanglement. It has braiding of magnetic flux tubes connecting the attending system to the attenfed one. Reconnection is the mechanism for building flux tube bridges between the systems.

Tibetan book of dead supports what NMP suggests: I direct my attention somewhere else from my biological body which has become rather uninteresting. The new target of attention could be some new brisk young life form not yet caught the attention (almost anywhere in planet or even elsewhere but inside my personal CD: my magnetic body is big with size scale of - as I hope - about one hundred light years at least!). My new life would proceed in opposite direction of embedding space time (recall that two subsequent quantum jumps create zero energy states with opposite arrows of embedding space geometric time). Maybe I remember the teachings of Tibetan book of dead and manage to direct my attention to a higher level in self hierarchy, larger CD, representing perhaps a collective level of consciousness.

If one takes fractality seriously, the death of civilizations and cultures could be a process analogous to biological death. It is difficult to avoid the feeling that this is something which could happen in not so distant future. If this process corresponds to quantum jump, NMP tells that negentropy is generated but does not exclude the possibility of a catastrophe in which even entire species suffers extinction and some of our relatives, maybe bonobos, take the lead. The transition could also lead to a new higher level of consciousness with the prevailing materialistic world view being replaced with a new one? The individuals who have become aware about the need for a new world view and about what it might be could serve as seeds of the quantum phase transition.

ZPE or ZEO?

Laws of physics and conservation laws are the basic problem of Haisch and all those who want free will in the existing ontology of physics. Haisch is also a physicist so that the problem becomes even more difficult to circumvent! How God can re-create the reality without breaking the well-established conservation laws? Or are these laws just rules of game that God has chosen to obey in this particular part of multiverse? But would this lead to mere quantum randomness and does statistical determinism mean a loss of genuine free will?

If I have guessed correctly, Haisch hopes that ZPE could help God over this problem but to my opinion ZPE is mathematically hopelessly ill-defined and reflects the mathematical problems of quantum field theory rather than reality.

In TGD framework ZPE is effectively replaced with ZEO - zero energy ontology instead of zero point energy. Zero energy states have vanishing total quantum numbers so that re-creation can be carried out without breaking conservation laws and standard laws of physics remain true. One can assign to the positive (say) energy part of zero energy state conserved energy and other quantum numbers and positive and negative energy parts correspond to initial and final state of physical event in the usual positive energy ontology: no states - just events! Therefore there is room also for God in TGD Universe. Together with re-creation as quantum jump one obtains maximal free will: any zero energy state can be created or vacuum in principle.

A possible test for ZEO would be creation of zero energy states apparently breaking conservation laws in the framework of positive energy ontology. In cosmology the non-conservation of gravitational energy indeed takes place and can be understood in terms of ZEO: the energy and other quantum numbers are conserved only in scale which correspond to spotlight of consciousness defined by one particular causal diamond (CD). Therefore also the consistency of Poincare invariance of TGD with cosmology requires ZEO.

Does the replacement of personal CD with a larger one in quantum jump (perhaps increasing the effective value of Planck constant) involve also generation of smaller sub-CDs representing mental images. Are our mental images these tiny Universes that we create?

How to a new sub-Universe this in laboratory? Quantum physicists would perhaps speak about generating long lived enough quantum fluctuations creating matter from vacuum. I remember having seen a popular article about a planned experiment in which very intense laser beams would generate particle pairs from vacuum. Of course, the probability for generating CD containing matter might be very small but maybe for some selected CDs this might not be the case!

The origin of inertia

Haisch and Rueda claim of having derived inertia appearing as a mass parameter in Newton's equations from vacuum energy (see `http://tinyurl.com/yafx6aew`). The basic idea behind the derivation does not however make much sense to me. Here is the condensed form of argument.

If one assumes that the quarks and electrons in such an object scatter this radiation, the semi-classical techniques of stochastic electrodynamics show that there will result a reaction force on that accelerating object having the form $f_r = \mu a$, where the μ parameter quantifies the strength of the scattering process. In order to maintain the state of acceleration, a motive force f must continuously be applied to balance this reaction force f_r. Applying Newton's third law to the region of contact between the agent and the object, $f = f_r$, we thus immediately arrive at $f = \mu a$, which is identical to Newton's equation of motion.

I confess that I have do not have a slightest idea what this statement might mean. The standard wisdom is that particle to which no forces are applied does not suffer acceleration. Now it would suffer acceleration although net force vanishes: $f + f_r = 0$.

The standard view is that in special relativity Poincare invariance combined with Noether's theorem allows to assign to any system conserved four-momentum and angular momentum. Given a variational principle coupling particles to fields one obtains automatically the analog of Newton's equations stating that the momentum lost/gained by fields is gained/lost by particles. Therefore in special relativity based theories there are no problems.

In general relativity situation however changes.

1. First of all, space-time becomes curved and the symmetries behind Poincare invariance are lost. One cannot use Noether's theorem to deduce expressions for conserved quantities:

this is especially catastrophic outcome in quantum theory where the conserved quantities interpreted as operators play fundamental role. This was indeed the basic motivation of TGD: by replacing abstract space-time with a 4-D surface in higher-D space possessing the symmetries of empty Minkowski space, one does not loose the classical conservation laws.

2. There is also another, closely related problem. In Newtonian approach to gravity gravitation accelerating test particle experiences a genuine force. In general relativity test particle however suffers no acceleration nor force. There seems to be now manner for how these pictures could be consistent. Maybe Haisch and Rueda were thinking about this aspect when they made their attempt to derive inertia from vacuum energy in general relativistic context.

   TGD provides a neat solution also to this problem. At 4-D space-time level the orbit of neutral test particle is indeed a geodesic line and 4-D acceleration vanishes. At 8-D embedding space level the orbit of test particle is not a geodesic line anymore and it experiences genuine 8-D acceleration, whose M^4 part defines the Newtonian force. The CP_2 part of the force is also present can be neglected since the scale of CP_2 is so small (about 10^4 Planck lengths).

Chapter 13

About the Nature of Time

13.1 Introduction

The notion of time remains one of the most problematic concepts of physics. In classical physics the different properties of the time of Newton's equations and thermodynamical time are puzzling. In special relativity and general relativity the notion of simultaneity becomes a problematic concept and challenges the naive Newtonian view about time flow as a motion of 3-D time=constant snapshot of 4-D space-time. The replacement of time=constant 3-surface with past directed light-cone assignable to the world-line of observer resolves this problem. In general relativity the problem is that past light-cones need make sense only locally. In quantum measurement theory the localization of the state function reduction process into a finite space-time volume is in conflict with the determinism of Schrödinger equation. In biology the presence of self-organization processes like self assembly challenge second law of thermodynamics in short time scales. In neuroscience the finding of Libet suggesting that neural activity seems to precede conscious decision forces to give up the notion of free will or the naive identification of experienced and geometrical time.

In this chapter I will consider a new view about time based on Topological Geometrodynamics [K136], which can be regarded as an attempt to unify fundamental interactions assuming that space-times are representable as 4-dimensional surfaces of certain higher-dimensional space-time $H = M^4 \times CP_2$ (M^4 denotes 4-D Minkowski space and CP_2 complex projective space of 2 complex dimensions) fixed by the requirement that the theory explains standard model symmetries and provides a geometrization of classical gauge fields and gravitational fields.

The construction of quantum TGD leads to a radical revision of space-time concept (many-sheeted space-time and topological field quantization), and forces also to generalize the original view about embedding space. p-Adic physics as physics of cognition is part of TGD inspired theory of consciousness and the need to fuse real and p-adic physics to single coherent whole forces to revise the notions of number and space-time: the outcome seems to be what one could call adelic space-time [K133]. Reals and p-adic number fields together with their extensions are glued together to form a larger structure and same applies to space-time and embedding space. It has been also necessary to replace the standard positive energy ontology with what I call zero energy ontology. These generalizations are of special importance in TGD inspired theory of consciousness and of quantum biology.

There are several first principle approaches to quantum TGD and following gives only a very concise summary of them.

1. Generalization of Einstein's program of geometrizing classical physics so that quantum theory can be seen as a theory of *classical* spinor fields in the world of classical worlds (WCW) consisting of light-like 3-surfaces and possessing Kähler geometry [K30, K139]. By general coordinate invariance (GCI) classical physics becomes an exact part of quantum theory in a well-defined sense. A geometrization of Fermi statistics is obtained, and the Clifford algebra associated with the spinors of WCW can be regarded as a direct sum of von Neumann algebras known as hyper-finite factors of type II_1 (HFFs) closely related to quantum groups and non-commutative geometry.

2. Quantum TGD as almost topological field theory (TQFT) with fundamental objects identified as light-like 3-surfaces and having generalized super-conformal symmetries as symmetries [K29, K28] : the notion of braid is the basic building block of this approach.

3. There are two kinds of conformal symmetries corresponding to the boundary of light-cone of Minkowski space and light-like 3-surfaces, and these symmetries alone dictate to high degree the physics. Quite recently it turned that also a symplectic analog of conformal field theory emerges naturally in TGD framework (super-symplectic symmetries) and this led to a concrete proposal for how to construct n-point functions needed to calculate M-matrix [K126].

   There are two new elements [K126]. The first one is the generalization of twistors from 4-dimensional to 8-dimensional context made possible by the octonion structure of embedding space. $H = M^4 \times CP_2$ has completely unique twistorial properties. Second new element is actually a revival of the old idea that scattering amplitudes are representations for sequences of algebraic operations - product and co-product defining fundamental 3-vertices - connecting two sets of algebraic objects. The algebraic objects are elements of the Yangian associated with super-symplectic algebra realizes as Noether charges assignable to strings connecting partonic 2-surfaces. Universe would be performing quantum algebraic manipulations.

4. Physics as a generalized number theory involves three different threads corresponding to need fuse real and various p-adic physics to single coherent whole by using a generalization of number concept obtained by gluing reals and various p-adic number fields and their extensions together along rationals and common algebraics [K119] ; the observation that standard model symmetries and dynamics of quantum and classical TGD are to high degree dictated by classical number fields [K120] ; and the ideas inspired by the notion of infinite prime [K118].

5. The identification of WCW Clifford algebra elements as hyper-octonion (subspace of complexified octonions spanned by real unit and octonionic imaginary units multiplied by the commuting additional imaginary unit) valued conformal fields having values in HFF provides a justification for the concept of number theoretic braid needed both in the fusion of real and p-adic physics and in TGD as almost TQFT approach.

   What number theoretic braid is has remained unclear. Now it is however clear that string world sheets belong in a well-defined sense to the intersection of reality and various p-adicities defining adelic embedding space and space-time as its surface. Number theoretic braids identified as boundaries of string world sheets would be very simple: they would consist of segments which are light-like geodesics of embedding space. Whether they can be braided without consisting of this kind of pieces remains unclear.

   Discretization is not so simple as one might think: the problem is that standard discretization defines only 0-dimensional objects consisting of points. What I call co-dimension two rule tells how the discretization is achieved for higher-dimensional objects. Partonic 2-surfaces are mapped to a discrete set of points- the ends of string boundaries carrying fermion number, their 3-D light-like orbits are replaced with the boundaries of string world sheets whose defining parameters are algebraic numbers, space-time surfaces in turn are replaced by string world sheets whose parameters are again algebraic numbers. Thus discretizations defined abstraction hierarchy. This brings in mind category theoretical construct of n-objects with $n = 1, 2, 3$ giving three hierarchy levels. Remarkably the hierarchy ends at the third step and string world sheets are the highest dimensional objects that can reside in the intersection of realities and p-adicities.

6. The hierarchy of Planck constants $h_{eff}/h = n$ realizing quantum criticality [K44] in terms of infinite number dark matter phases suggests a generalization of the notion of embedding space by replacing it with a book like structure having as its pages singular coverings and factor spaces of H and allowing to realize geometric correlates for the choice of quantization axis in quantum measurement: the particles at different pages of this book are "relatively dark" since they do not possess local interaction vertices which means a radically new way to interpret dark matter. It has turned out that this generalization is only an auxialiary tool. The proper notion is space-time surface with a structure of n-dimensional covering and the sheets of covering are due to the non-determinism of Kähler action. There are n

conformal equivalence classes of space-time surfaces connecting the space-like surfaces at opposite boundaries of causal diamond (CD). One allows not only space-time surface with one such sheet but also those consisting of several sheets and this should lead to charge fractionization.

There is infinite fractal hierarchy of breakings of super-symplectic symmetry having structure of conformal symmetry: the elements of the sub-algebra have conformal weights are n-ples of those for the full algebra act as gauge symmetries so that it is isomorphic to the entire algebra. There is infinite number of inclusion series for these algebras such that n_i divides n_{i+1} and they correspond to reduction of criticality. Therefore TGD Universe is like a hill at the top of hill at the top of hill....The phase transitions increasing h_{eff} and generating dark matter occur spontaneously. Living systems however tend to stay at criticality defined by particular h_{eff} and the phase transition changing it can be said to mean death of self and its re-incarnation at opposite boundary of CD. In the phase transition some gauge degrees of freedom transform to physical ones. The interpretation is as improvement of measurement resolution. Basically this measurement resolution is cognitive and derives from number theoretic constraints and reflects the character of algebraic extension of p-adic numbers.

7. Zero energy ontology and the notion of finite measurement resolution formulated in terms of inclusions of HFFs fix quantum dynamics highly in terms of Connes tensor product allowing to interpret quantum theory as a square root of thermodynamics [K136, K28]: finite measurement resolution has number theoretic braid as its space-time correlate so that various approaches to TGD are closely related. The hierarchies of super-symplectic symmetry breakings define hierarchies of inclusions for HFFs.

8. Quantum theory of consciousness as a generalization of quantum measurement theory to include observer to the theory [L11].

The article series about TGD and its applications to biology and consciousness [**?**, K129] , [L11, L9, L5, L7, L6, L4] gives an overall view about quantum TGD. In the following I will concentrate only on the aspects of quantum TGD relevant for the notion of time. I will first describe zero energy ontology and p-adicization program and after that consider the problem of time.

The TGD based vision about how the arrow of geometric time is by no means fully developed and final. I will describe also the approaches which look now partially wrong.

1. What seems clear now is the decisive role of ZEO and hierarchy of CDs, and the fact that the quantum arrow of geometric time is coded into the structure of zero energy states to a high extent. The still questionable but attractively simple hypothesis is that U matrix connects two basis with opposite quantum arrows of geometric time: is this assumption really consistent with what we know about the arrow of time? If this is the case, the question is how the relatively well-defined quantum arrow of geometric time implies the experienced arrow of geometric time. Should one assume the arrow of geometric time separately as a basic property of the state function reduction cascade or more economically- does it follow from the arrow of time for zero energy states?

2. The first idea was that state function reductions occur alternately at the two boundaries of CD. If the reduction occurs at given boundary is immediately followed by a reduction at the opposite boundary, the arrow of time alternates: this does not conform with intuitive expectations: for instance, this would imply that there are two selves assignable to the opposite boundaries!

3. Zero energy states are however de-localized in the moduli space CDs (size of CD plus discrete subgroup of Lorentz group defining boosts of CD leaving second tip invariant). One has quantum superposition of CDs with difference scales but with fixed upper or lower boundary belonging to the same light-cone boundary after state function reduction.

   In standard quantum measurement theory the repetition of state function reduction does not change the state but now it would give rise to the experienced flow of time. Zeno effect indeed requires that state function reductions can occur repeatedly at the same boundary.

In these reductions the wave function in moduli degrees of freedom of CD changes. This implies "dispersion" in the moduli space of CDs experienced as flow of time with definite arrow. This view lead to a precise definition of self as sequence of quantum jumps to the reducing to the same boundary of CD.

Each reduction leaves the passive boundary of CD invariance and also the part of zero energy state associated with it but can induce localization to single CD. The reduction must have some effect on state and it might be that the localization is this effect.

4. This approach codes also the arrow of time at the space-time level: the average space-time sheet in quantum superposition increases in size as the average position of the "upper boundaries" of CDs drift towards future state function reduction by state function reduction.

5. In principle the arrow of time can temporarily change and probably takes place in elementary particle scales and living matter routinely. Phase conjugate laser beam is a non-biological example about reversal of the arrow of time. The act of volition would correspond to the first state function reduction to the opposite boundary so that the reversal of time arrow at some level of the hierarchy of selves would take place in the act of volition.

This vision involves minimal number of assumption and is the most convincing one found hitherto and the challenge is to invent objections in order to develop it in more detail.

In the following different views about how the arrow of time is generated, how self experiences the quantum jumps at lower levels of self hierarchy as a continuous flow of time, and how the contents of sensory experience seem to be localized around a rather narrow interval of geometric time.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

13.2 The Most Recent Vision About Zero Energy Ontology And P-adicization

The generalization of the number concept obtained by fusing real and p-adics along rationals and common algebraics is the basic philosophy behind p-adicization. One must be able to speak about rational points common to real and various p-adic variants of H. The basic objection is the necessity to fix some special coordinates in turn implying the loss of a manifest general coordinate invariance. The isometries of the embedding space could save the situation provided one can identify some special coordinate system in which isometry group reduces to its discrete subgroup. The loss of the full isometry group could be compensated by assuming that WCW is union over sub- WCW s obtained by applying isometries on basic sub- WCW with discrete subgroup of isometries.

The combination of zero energy ontology realized in terms of a hierarchy of causal diamonds (CDs) and hierarchy of Planck constants providing a description of dark matter and leading to a generalization of the notion of embedding space suggests that it is possible to realize this dream. The article [K136] provides a brief summary about recent state of quantum TGD helping to understand the big picture behind the following considerations.

13.2.1 Zero Energy Ontology Briefly

1. The basic construct in the zero energy ontology is the space $CD \times CP_2$, where the causal diamond CD is defined as an intersection of future and past directed light-cones with time-like separation between their tips regarded as points of the underlying universal Minkowski space M^4. In zero energy ontology physical states correspond to pairs of positive and negative energy states located at the boundaries of the future and past directed light-cones of a particular CD.

2. CDs form a fractal hierarchy and one can glue smaller CDs within larger CDs. This construction recipe when combined with TGD inspired theory of consciousness allows to understand the asymmetry between positive and negative energies and why the arrow of experienced

time corresponds to the arrow of geometric time and why the contents of sensory experience is located to so narrow interval of geometric time. One can imagine evolution to occur as quantum leaps in which the size of the largest CD in the hierarchy of personal CDs increases in such a manner that it becomes sub-CD of a larger CD. p-Adic length scale hypothesis [K136] follows if the values of temporal distance T between tips of CD come in powers of 2^n: $T = 2^n T_0$. This is probably too strong an assumption: a more realistic hypothesis is that the distances are integer multiples of T_0.

All conserved quantum numbers for zero energy states have vanishing net values. The interpretation of zero energy states in the framework of positive energy ontology is as physical events, say scattering events with positive and negative energy parts of the state interpreted as initial and final states of the event.

3. In the realization of the hierarchy of Planck constants $CD \times CP_2$ is replaced with a Cartesian product of book like structures formed by almost copies of CDs and CP_2s defined by singular coverings and factors spaces of CD and CP_2 with singularities corresponding to intersection $M^2 \cap CD$ and homologically trivial geodesic sphere S^2 of CP_2 for which the induced Kähler form vanishes. The coverings and factor spaces of CDs are glued together along common $M^2 \cap CD$. The coverings and factors spaces of CP_2 are glued together along common homologically non-trivial geodesic sphere S^2. The choice of preferred M^2 as subspace of tangent space of X^4 at all its points and interpreted as space of non-physical polarizations, brings M^2 into the theory also in different manner. S^2 in turn defines a subspace of the much larger space of vacuum extremals as surfaces inside $M^4 \times S^2$.

4. WCW (the world of classical worlds, WCW) decomposes into a union of sub- WCW s corresponding to different choices of M^2 and S^2 and also to different choices of the quantization axes of spin and energy, color isospin and hyper-charge for each choice of this kind. This means breaking down of the isometries to a subgroup. This can be compensated by the fact that the union can be taken over the different choices of this subgroup.

5. p-Adicization requires a further breakdown to discrete subgroups of the resulting sub-groups of the isometry groups but again a union over sub- WCW s corresponding to different choices of the discrete subgroup can be assumed. Discretization relates also naturally to the notion of number theoretic braid.

13.2.2 WCW Spinor Fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW . The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub- WCW s association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future light-cone M^4_+ is quantized for positive energy states. For negative energy states this happens to the lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that first tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of second tip - or rather the space M^4_+ representing the relative position of the tips- to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [K113]. Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub- WCW s with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M^4_\pm$. These degrees of freedom

generalize those of a quantum field in Minkowski space. If the upper tip is assigned with observer, the sub-CDs in the interior of CD correspond to astrophysical objects and M^4_+ as empty Robertson-Walker cosmology predicts automatically cosmic redshift.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [A10]. Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ("orbital") degrees of freedom, which can be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

Is it really possible to speak about zero energy states for a given sector defined by generalized embedding space with fixed M^2 and S^2? Classically this is possible and conserved quantities are well defined. In quantal situation the presence of the light-cone boundaries breaks full Poincare invariance although the infinitesimal version of this invariance is preserved. Note that the basic dynamical objects are 3-D light-like "legs" of the generalized Feynman diagrams glued together along their ends at generalized vertices.

13.2.3 Definition Of Energy In Zero Energy Ontology

The approach relying on the two super conformal structures of quantum TGD gives hopes of defining the notion of energy for positive and negative energy parts of the state.

1. CD allows translational invariance only in its interior and since partonic two surfaces are located to the boundary of CD, one can argue that translations assigned to them lead out from CD. One can however argue that if it is enough to assign eigenstates of four-momentum to partons and require that only the total four-momentum generators acts on the physical state by shifting CD. Since total four-momentum vanishes for CD this would mean that wave function in cm degrees of CD is just constant plane wave. Super-conformal invariance would indeed allow to assign momentum eigenstates to the super-conformal representations.

2. A more stringent condition would be that four-momentum generators act as translation like operators on partons themselves. Since light-like 3-surfaces assignable to incoming and outgoing legs of the generalized Feynman diagrams are the basic objects, one can hope of having enough translational invariance to define the notion of energy. If translations are restricted to time-like translations acting in the direction of the future (past) then one has local translation invariance of dynamics for classical field equations inside $\delta M^4_\pm$ as a kind of semigroup. Also the M^4 translations leading to interior of X^4 from the light-like 2-surfaces surfaces act as translations. Classically these restrictions correspond to non-tachyonic momenta defining the allowed directions of translations realizable as particle motions. These two kinds of translations can be assigned to super-symplectic conformal symmetries at $\delta M^4_\pm \times CP_2$ and and super Super-Kac-Moody type conformal symmetries acting as super-symplectic isometries. Super-symplectic algebra is realized in terms of second quantized spinor fields and

covariantly constant modes of right-handed neutrino. Symplectic group has as sub-group symplectic isometries and the Super-Kac-Moody algebra associated with this group and represented in terms of spinor modes localized to string world sheets plays also a key role in TGD.

Finite M^4 translations to the interior of CD do not respect the shape of the partonic 2-surface. Local M^4 translations vanishing at the boundary of CD however act as Kac-Moody symmetries of the light-like 3-surfaces and reduce physically to gauge transformations: hence one could allow also the deformations of the partonic 2-surface in the interior of the light-like 3-surface. This corresponds to the effective metric 2-dimensionality stating that all information both about the geometry of WCW and quantum physics is carried by the partonic 2-surfaces X^2 resulting as intersections of the light-like 3-surfaces X^3_l and space-like 3-D surfaces X^3 at the boundaries of CD and the distribution of 4-D tangent planes of X^2.

3. The condition selecting preferred extremals of Kähler action is induced by a global selection of $M^2 \subset M^4$ as a plane belonging to the tangent space of X^4 at all its points [K29] and interpreted as a plane of nonphysical polarizations so that direct connection with number theory and gauge symmetries emerges. The M^4 translations of X^4 as a whole in general respect the form of this condition in the interior. Furthermore, if M^4 translations are restricted to M^2, also the condition itself - rather than only its general form - is respected. This observation, the earlier experience with p-adic mass calculations, and also the treatment of quarks and gluons in QCD encourage to consider the possibility that translational invariance should be restricted to M^2 translations so that mass squared, longitudinal momentum and transversal mass squared would be well defined quantum numbers. This would be enough to realize zero energy ontology. Encouragingly, M^2 appears also in the generalization of the causal diamond to a book-like structure forced by the realization of the hierarchy of Planck constant at the level of the embedding space.

4. That the cm degrees of freedom for CD would be gauge like degrees of freedom sounds strange. The paradoxical feeling disappears as one realizes that this is not the case for sub-CDs, which indeed can have non-trivial correlation functions with either upper or lower tip of the CD playing a role analogous to that of an argument of n-point function in QFT description. One can also say that largest CD in the hierarchy defines infrared cutoff.

13.2.4 P-Adic Variants Of The Embedding Space And Adelic Structure Of Space-Time And Embedding Space

The need to fuse p-adic physics with TGD emerged originally from the discovery that p-adic mass calculations based on p-adic thermodynamics give excellent predictions for elementary particle masses if one assumes p-adic length scale hypothesis stating that primes near integer powers of 2 are physically favored [K136]. Later came the interpretation of p-adic physics as cognition cognition. The following somewhat technical construction of p-adic variants of the embedding space provides new insights concerning the understanding of the arrow of geometric time.

1. Rational values of p-adic coordinates are non-negative so that light-cone proper time $a_{4,+} = \sqrt{t^2 - z^2 - x^2 - y^2}$ is the unique Lorentz invariant choice for the p-adic time coordinate near the lower tip of CD. For the upper tip the identification of a_4 would be $a_{4,-} = \sqrt{(t-T)^2 - z^2 - x^2 - y^2}$. In the p-adic context the simultaneous existence of both square roots poses additional conditions on T. For 2-adic numbers $T = 2^n T_0$, $n \geq 0$ (or more generally $T = \sum_{k \geq n_0} b_k 2^k$), would allow to satisfy these conditions, which would be one additional reason for $T = 2^n T_0$ implying p-adic length scale hypothesis. The remaining coordinates of CD are naturally (hyperbolic) cosines and sines of the spherical coordinates θ and ϕ (hyperbolic angle $\eta_{\pm,4}$).

2. The existence of the preferred plane M^2 of un-physical polarizations would suggest that 2-D light-cone proper times $a_{2,+} = \sqrt{t^2 - z^2}$ $a_{2,-} = \sqrt{(t-T)^2 - z^2}$ can be also considered. The remaining coordinates would be naturally $\eta_{\pm,2}$ and cylindrical coordinates (ρ, ϕ).

3. The p-adically transcendental values of a_4 and a_2 are literally infinite as real numbers and could be visualized as points in infinitely distant geometric future so that the arrow of time might be said to emerge number theoretically.

4. The selection of the preferred quantization axes of energy and angular momentum unique apart from a Lorentz transformation of M^2 would have purely number theoretic meaning in both cases. One must allow a union over sub-WCWs labeled by points of $SO(1,1)$. This suggests a deep connection between number theory, quantum theory, quantum measurement theory, and even quantum theory of mathematical consciousness.

5. In the case of CP_2 there are three real coordinate patches involved [A23]. The compactness of CP_2 allows to use cosines and sines of the preferred angle variable for a given coordinate patch.

$$\begin{aligned} \xi^1 &= tan(u)exp(i\frac{(\Psi+\Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= tan(u)exp(i\frac{(\Psi-\Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{13.2.1}$$

   The ranges of the variables u, Θ, Φ, Ψ are $[0, \pi/2], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively. Note that u has naturally only positive values in the allowed range. S^2 corresponds to the values $\Phi = \Psi = 0$ of the angle coordinates.

6. The rational values of the (hyperbolic) cosine and sine correspond to Pythagorean triangles having sides of integer length and thus satisfying $m^2 = n^2 + r^2$ ($m^2 = n^2 - r^2$). These conditions are equivalent and allow the well-known explicit solution [A3]. One can construct a p-adic completion for the set of Pythagorean triangles by allowing p-adic integers which are infinite as real integers as solutions of the conditions $m^2 = r^2 \pm s^2$. These angles correspond to genuinely p-adic directions having no real counterpart. Hence one obtains p-adic continuum also in the angle degrees of freedom. Algebraic extensions of the p-adic numbers bringing in cosines and sines of the angles π/n lead to a hierarchy increasingly refined algebraic extensions of generalized embedding space. Since the different sectors of WCW directly serve as correlates of selves, this means a direct correlation with the evolution of the mathematical consciousness. Trigonometric identities allow to construct points which in the real context correspond to sums and differences of angles.

7. Negative rational values of the cosines and sines correspond as p-adic integers to infinite real numbers and it seems that one use several coordinate patches obtained as copies of the octant $(x \geq 0, y \geq 0, z \geq 0,)$. An analogous picture applies in CP_2 degrees of freedom.

How the different variants of p-adic embedding space and real embedding space relate to each other? The original guess was that one can speak about real and p-adic space-time sheets and that in intentional action the p-adic space-time sheet transforms to a real one and in the formation of cognitive representation the opposite transformation occurs. The formulation of quantum transition amplitudes to describe this process might be however impossible. Rather, cognition and sensory aspects of the geometric existence are simultaneously present: space-time and embedding space are adelic. This indeed conforms with the success of p-adic mass calculations.

1. What seems clear that there must exist kind of chart mappings between them. The notion of p-adic space-time surface is formulated in [K140]. The idea is that p-adic space-time surfaces are cognitive charts of real space-time surface. Both real and p-adic space-time surfaces satisfy the field equations and are thus preferred extremals of Kähler action. There is discretization due to both number theoretic reasons and the points in discretization correspond to points which are common to reals and p-adic number fields. This includes rationals and algebraic numbers in the extension of p-adic number field.

2. At the level of world of classical worlds (WCW) the discretization would be more abstract since the naïve discretization of higher-dimensional objects can be argued to be zero-dimensional as a point set. The parameters defining the geometric object are rational or in the algebraic extensions of rationals.

3. It is now clear the discretization introduced in [K140] might be too naïve. The above described abstraction applies also to the discretization various objects such as partonic 2-surfaces and their 3-D light-like orbits, string world sheets, space-like 3-surfaces, and space-time surfaces. Co-dimension two rule would apply. Partonic 2-surfaces are replaced with discrete point sets at which the fermion lines identified as boundaries of string world sheets meet. The orbits of partonic 2-surface correspond to fermion lines. Space-time surfaces is discretized to a collection of string world sheets which are in the intersection of reality and p-aicities in the sense that the defining parameters belong are in the algebraic extensions associated with p-adic numbers.

   Concerning the construction of preferred extremals this means strong form of holography. One starts from string world sheets (carrying vanishing induced W boson fields so that em charge for the spinor modes is well-defined) and partonic 2-surfaces and continues them to space-time surfaces satisfying field equations for preferred extremals. These include infinite number of conditions stating that the Noether charges of super-symplectic algebra vanish and that the classical conserved charges correspond to the eigenvalues of quantal charges associated with string world sheets. This guarantees the generalization of AdS/CFT correspondence. The preferred extremal is defined only modulo conformal gauge transformations defining $n = h_{eff}/h$ conformal equivalence classes.

4. All p-adic variants of the space-time surface are present and meet each other along string world sheets, which is like a back of a book. Fermions representing Boolean cognition reside in this intersection and are thus number theoretically universal, which conforms with the fact that the anti-commutation relations for the oscillator operators can be written in a form which does not involve any numbers except unity. One can say that string world sheets and fermions define the fundamental cognitive representations in the intersection of realities and p-adicities. In this intersection also the notion of negentropic entanglement makes sense.

5. One can assign to elementary particles definite value of p-adic prime. For this p-adic prime the p-adic preferred extremal should provide a better representation of real space-time surface than others. The reason could that the classical nondeterminism of Kähler action for them is very similar to the p-adic non-determinism for the p-adic prime involved. 4-D spin glass character of the landscape of maxima of Kähler function together with the fact that ordinary spin glass landscape consisting of minima of free energy allows ultra-metric topology about which p-adic topologies are examples. This suggests that real preferred extremal obeys some p-adic topology in discretization in some length scale range.

13.3 Zero Energy Ontology, Self Hierarchy, And The Notion Of Time

Consider now the formulation of TGD inspired quantum theory of consciousness [L11] and quantum biology [L9] in terms of zero energy ontology.

One should understand the asymmetry between positive and negative energies and between two directions of geometric time at the level of conscious experience, the correspondence between experienced and geometric time, and the emergence of the arrow of time. One should explain why human sensory experience is about a rather narrow time interval of about.1 seconds and why memories are about the interior of much larger CD with time scale of order life time. One should have a vision about the evolution of consciousness: how quantum leaps leading to an expansion of consciousness occur.

Negative energy signals to geometric past - about which phase conjugate laser light represents an example - provide an attractive tool to realize volitional action as a signal inducing neural activities in the geometric past (this would explain Libet's classical findings), a mechanism of

remote metabolism, and the mechanism of declarative memory as communications with geometric past. One should understand how these signals are realized in zero energy ontology and why their occurrence is so rare.

In the following I try to demonstrate that TGD inspired theory of consciousness and quantum TGD proper indeed are in tune.

13.3.1 Space-Time And Embedding Space Correlates For Selves

Quantum jump as a moment of consciousness, self as a sequence of quantum jumps integrating to self, and self hierarchy with sub-selves experienced as mental images, are the basic notions of TGD inspired theory of consciousness. In the most ambitious vision self hierarchy reduces to a fractal hierarchy of quantum jumps within quantum jumps. Quantum classical correspondence demands selves to have space-time correlates both at the level of space-time and embedding space.

At the level of space-time the first guess for the correlates is as light-like or space-like 3-surfaces. If one believes on effective 2-dimensionality and quantum holography, partonic 2-surfaces plus their 4-D tangent space distribution would code the information about the space-time correlates. By quantum classical correspondence one can also identify space-time sheets as the correlates modulo the gauge degeneracy implied by super-conformal symmetries.

It is natural to interpret CDs as correlates of selves at the level of the embedding space. CDs can be interpreted either as subsets of the generalized embedding space or as sectors of WCW . Accordingly, selves correspond to CDs of the generalized embedding space or sectors of WCW , literally separate interacting quantum Universes. The spiritually oriented reader might speak of Gods. Sub-selves correspond to sub-CDs geometrically. The contents of consciousness of self is about the interior of the corresponding CD at the level of embedding space. For sub-selves the wave function for the position of tip of CD brings in the de-localization of sub- WCW .

The fractal hierarchy of CDs within CDs is the geometric counterpart for the hierarchy of selves: the quantization of the time scale of planned action and memory as $T(k) = 2^k T_0$ suggest an interpretation for the fact that we experience octaves as equivalent in music experience. This assumption is however un-necessarily restrictive. In order to understand interactions between selves one must also allow intersections of CDs. The interactions would correspond to the formation of magnetic flux tubes contacts between the 3-surfaces involving also strings connecting the partonic 2-surfaces and defining string world sheets.

It seems that string world sheets can be identified as the intersection of space-time surfaces in various number fields identified as preferred extremals of Kähler action. They would define the fundamental cognitive representations. Therefore partonic 2-surfaces and string world sheets would serve also as cognitive representation of selves and the negentropic entanglement would be associated the fermions at them serving as correlates of Boolean cognition. To be in the intersection of various number fields would mean in the case of string world sheets and partonic two-surfaces that the parameters characterizing them are algebraic numbers in the extension of p-adic numbers. This suggests that the algebraic continuation to all possible p-adic number fields is not possible. Maybe those p-adic primes for which this is possible characterize the particle. By generalized conformal invariance the algebraic values of conformal moduli of partonic 2-surfaces and string world sheets could define the parameters in question so that the situation would reduce to finite-dimensional one.

13.3.2 Weak Form Of NMP

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities p_n by the logarithms of their p-adic norms $|p_n|_p$. This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding or some positive emotion like love.

Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining

wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness.

NMP combined with number theoretic entropies leads to an important exception to the rule that the generation of bound state entanglement between system and its environment during U process leads to a loss of consciousness. When entanglement probabilities are rational (or even algebraic) numbers, the entanglement entropy defined as a number theoretic variant of Shannon entropy can be non-positive (actually is) so that entanglement carries information. NMP favors the generation of algebraic entanglement. The attractive interpretation is that the generation of algebraic entanglement leads to an expansion of consciousness ("fusion into the ocean of consciousness") instead of its loss.

State function reduction period of the quantum jumps involves much more than in wave mechanics. For instance, the choice of quantization axes realized at the level of geometric delicacies related to CDs is involved. U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction involves also a choice between generic and negentropic entanglement (between real world, a particular p-adic world, or their intersection) it might be possible to identify a candidate for the physical correlate for the choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The hedonistic option is risky since it can lead to non-algebraic bound state entanglement implying a loss of consciousness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices. Note that if the total entanglement negentropy defined as sum of contributions from various levels of CD hierarchy up to the highest matters in NMP then also sub-selves should develop negentropic entanglement. For instance, the generation of entropic entanglement at cell level can lead to a loss of consciousness also at higher levels. Life would evolve from short to long scales.

The consistency with quantum measurement theory leads to an important constraint on the density matrix giving rise to negentropic entanglement. The density matrix of the final state must be a projector as in the ordinary quantum measurement theory. It's dimension can be however higher than one now. Therefore negentropic entanglement cannot be confused with real entanglement and there is no problem due to the fact that for real number based entanglement it is impossible to know in practice whether the entanglement coefficients are rational numbers. The entanglement giving rise to a density matrix, which is projector corresponds in the 2-particle case entanglement matrix proportional to unitary matrix typical for quantum computer type systems.

TGD inspired theory of consciousness forces to challenge the hypothesis that NMP always forces the state function reduction to the sub-space defined by the projector with maximal dimension appearing in the decomposition of the density matrix. NMP would not allow the self to make choices, which are bad deeds in the sense that they do not increase maximally the negentropic resources of the Universe. We would live in the best possible Universe becoming better all the time. This is obviously too good to be true.

A weaker form of NMP allows the choice leading to maximal negentropy gain but allows also those choices for which the reduction occurs to a sub-space of the space defined by projector. When this sub-space is 1-dimensional standard quantum measurement results and the self is isolated from the target of observations. Negentropic entanglement has interpretation as attention with positively colored contents of consciousness. Experience of love would be one attribute of this kind of state. Weak form of NMP would be like God allowing the sinner to chose between Good and Evil.

13.3.3 Conscious Entities And Arrow Of Time In TGD Universe

"Fractality from your blog" posed an interesting question about possible asymmetry between boundaries of causal diamond CD. The answer to the question led to recall once again the incomplete understanding of details about how the arrow of time emerges in zero energy ontology (ZEO).

The basic vision is following.

1. CDs form a fractal scale hierarchy. Zero energy states possess a wave function in moduli degrees of freedom characterizing sizes of CDs as well telling what Lorentz boost leaving

boundary invariant are allowed for them. Boosts form by number theoretic constraints a discrete subgroup of Lorentz group defining analogs of lattices generated by boosts instead of translations.

2. The arrow of subjective time maps to that of geometric time somehow. The origin of arrow comes from the fact that state function reductions can occur to either boundary of given CD and reduction creates time-asymmetric state since second boundary of CD is in a quantum superposition of different sizes and there is a superposition of many-particle states with different particles numbers and quantum number distributions. It is possible that each state function reduction leaving the passive boundary intact, involves localization in the moduli space of CDs with second boundary fixed.

3. Subjective existence corresponds to a sequence *of moments of consciousness*: state function reductions at opposite boundaries of CDs. State function reduction localizes either boundary but the second boundary is in a quantum superposition of several locations and size scales for CD. This predicts that the arrow of time is not constant. In fact, there is considerable evidence for the variation of the arrow of time in living systems and Fantappie [J121] introduced long time ago the notion of syntropy to describe his view about the situation.

4. The first very naïve proposal was that state function reductions occur *alternately* to the two boundaries of CD. This assumption would be indeed natural if one considered single fixed CD rather than superposition CDs with different size and state function reduction localizing their either boundary: restriction to single CD was what I indeed did first.

5. This assumption leads to the question about why do we do not observe this alternation of the arrow of time all the time in our personal experience. Some people actually claim to have actually experienced a temporary change of the arrow of time: I belong to them and I can tell that the experience is frightening. But why do we experience the arrow of time as stable in the standard state of consciousness?

One possible way to solve the problem - perhaps the simplest one - is that state function reduction to the same boundary of CD can occur many times repeatedly. This solution is so absolutely trivial that I could perhaps use this triviality to defend myself for not realizing it immediately!

I made this totally trivial observation only after I had realized that also in this process the wave function in the moduli space of CDs change in these reductions. Zeno effect in ordinary measurement theory relies on the possibility of repeated state function reductions. In the ordinary quantum measurement theory repeated state function reductions do not affect the state in this kind of sequence but in ZEO the wave function in the moduli space labelling different CDs with the same boundary could change in each quantum jump. It would be natural that this sequence of quantum jumps give rise to the experience about flow of time? This option would allow the size scale of CD associated with human consciousness be rather short, say.1 seconds. It would allow to understand why we do not observe continual change of arrow of time.

Maybe living systems are working hardly to keep the personal arrow of time un-changed - living creatures try to prevent kettle from boiling by staring at it intensely. Maybe it would be extremely difficult to live against the collective arrow of time.

An objection against this picture as compared to the original one assuming alternate reductions to the opposite boundaries of CD is that is that one can understand state preparation as state function reduction to the opposite boundary. This interpetation makes sense almost as such also in the new picture if the average time period for which the reductions occur to a given boundary is shorter in elementary particles scales than in macroscopic scales characteristic for human consciousness. The approximate reversibility in elementary particle scales can be understood as summing up of the two arrows of time to no arrow at all.

This picture allows also to identify self as a continuous entity as the sequence of state function reductions occurring at the same boundary of CD. The average increase of the temporal distance between the tips of cD defines the life-time of self. The number of reductions would give a measure for the subjectively experienced of life-time of self.

In elementary particle time scales reversibility is a good approximation and this suggests that in elementary particle scales the number of state function reductions at the same boundary of CD is small so that the effects due to the change of the arrow of time cancel on the average.

NMP would eventually force "death" of self since the state function reduction at opposite boundary would generate more negentropy. "Death" of self would mean birth of self asssociated with the opposite boundary of CD. The age of self identified as the proper time distance between the tips would increase in statistical sense even when its arrow can change. The act of volition would have a natural identification as the first state function reduction at the opposite boundary of CD.

This picture raises a series of questions. Do our wake-up periods correspond to sequences of state function reductions for self and are sleeping periods wake-up periods of the self at the opposite boundary of CD? The arrow of geometric time should change at some space-time sheet associated with the self hierarchy. How could one demonstrate this? Are the memories of the "other" self predictions of future from our point of view? Do we sleep in order to get information from future, to remember what the future will be?

How the hierarchy of Planck constants defining a hierarchy of quantum criticalities does relate to this picture? The aging of self having has as a correlate the increase of the size scale of CD. Could this increase be due to the increase of h_{eff} expected to occur spontaneously since it corresponds to a reduction of criticality and therefore to the appearance of new physical degrees of freedom as symplectic gauge degrees of freedom transform to physical ones in gauge symmetry breaking. This is not the case. The time evolution must be analogous to shift in time rather than scaling. This of course corresponds to the QFT view about time evolution.

In the first state function reduction to the opposite boundary of CD however scaling of CD is possible and would correspond to the scaling of CD represented by exponent of infinitesimal scaling operator as in conformal field theories. The emergence of bew physical degrees of freedom suggest increasing perceptive and cognitive capabilities. The increase of h_{eff} could be seen as evolution as also the associated increase of resources of negentropic entanglement suggests. The total increase of h_{eff} measured by the ratio $h_{eff}(final)/h_{eff}(initial)$ could be seen as a measure for the progress per single life period of self.

13.3.4 Why Sensory Experience Is About So Short Time Interval?

CD picture implies automatically the 4-D character of conscious experience and memories form part of conscious experience even at elementary particle level. Amazingly, the secondary p-adic time scale of electron is $T = 0.1$ seconds defining a fundamental time scale in living matter. The problem is to understand why the sensory experience is about a short time interval of geometric time rather than about the entire personal CD with temporal size of order life-time. The explanation would be that sensory input corresponds to sub-selves (mental images) with $T \simeq .1$ s at the upper light-like boundary of CD in question. This requires a strong asymmetry between upper and lower light-like boundaries of CDs. Certainly this time scale is only minimal CD time scale assignable to electron and the time evolution of electron self should increase this time scale, which would however increase also in the first state function reduction to the opposite boundary of electronic CD.

The localization of the contents of the sensory experience to the upper light-cone boundary and local arrow of time could emerge as a consequence of self-organization process involving conscious intentional action. Sub-CDs would be in the interior of CD and self-organization process would lead to a distribution of CDs concentrated near the upper or lower boundary of CD. The local arrow of geometric time would depend on CD and even differ for CD and sub-CDs.

1. The localization of contents of sensory experience to a narrow time interval would be due to the concentration of sub-CDs representing mental images near the either boundary of CD representing self.

2. Phase conjugate signals identifiable as negative energy signals to geometric past are important when the arrow of time differs from the standard one in some time scale. If the arrow of time establishes itself as a phase transition, this kind of situations are rare. Negative energy signals as a basic mechanism of volitional action and transfer of metabolic energy would explain why living matter is so special.

3. Geometric memories would correspond to sub-selves in the interior of CD, the oldest of them to the regions near "lower" boundaries of CD. Since the density of sub-CDs is small there geometric memories would be rare and not sharp. A temporal sequence of mental images, say the sequence of digits of a phone number, would correspond to a temporal sequence of sub-CDs.

4. Sharing of mental images corresponds to a fusion of sub-selves/mental images to single sub-self by quantum entanglement: the space-time correlate could be flux tubes connecting space-time sheets associated with sub-selves represented also by space-time sheets inside their CDs.

13.3.5 The Mechanism Of Self Reference

Self reference is perhaps the most mysterious aspect of conscious experience. When formulated in somewhat loose manner self reference states that self can be conscious about being conscious of something. When trying to model this ability in say computer paradigm one is easily led to infinite regress. In TGD framework a weaker form of self referentiality holds true: self can become conscious that it *was* conscious of something in previous quantum jump(s). Self reference therefore reduces to memory. Infinite regress is replaced with evolution recreating Universe again and again and adding new reflective levels of consciousness. It is however essential to have also the experience that memory is in question in order to have self reference. This knowledge implies that a reflective level is in question.

The mechanism of self reference would reduce to the ability to code information about quantum jump into the geometry and topology of the space-time surface and to the quantum entanglement assignable the fermions. This representation defines an analog of written text which can be read if needed: memory recall is this reading process. The existence of this kind of representations means quantum classical correspondence in a generalized sense: not only quantum states but also quantum jump sequences responsible for conscious experience can be coded to the space-time geometry. The reading of this text induces self-organization process re-generating the original conscious experience or at least some aspects of it (say verbal representation of it). The failure of strict classical determinism for Kähler action is absolutely essential for the possibility to realize quantum classical correspondence in this sense.

Consider now the problem of coding conscious experience to space-time geometry and topology so that it can be read again in memory recall. Let us first list what I believe to know about memories.

1. In TGD framework memories corresponds to sub-CDs inside CDs and are located in geometric past. This means fundamental difference from neuroscience view according to which memories are in the geometric now. Note that standard physicist would argue that this does not make sense: by the determinism of field equations one cannot think 4-dimensionally. In TGD however field equations fail to be deterministic in the standard sense: this actually led to the introduction of zero energy ontology.

2. The reading wakes up mental images which are essentially 4-D self-organization patterns inside sub-CDs in the geometric past. Metabolic energy is needed to achieve this wake up. What is needed is generation of space-time sheets representing the potential images making possible memories.

This picture combined with the mechanism for generating the arrow of psychological time and explaining why sensory experience is located to so short time interval as it is (.1 second, the time scale of CD associated with electron by p-adic length scale hypothesis) allows to understand the mechanism of self reference. It deserves to be mentioned that the discussion with Stephen Paul King in Time discussion group served as the midwife for this step of progress.

1. When the film makes a shift to the direction of geometric past in quantum jump sub-selves representing mental images representing the reaction to the "news" are generated. These correspond to sub-CDs contains space-time surfaces as correlates of sub-selves created and the information contents of immediate conscious experiences is about this region of space-time and embedding space. They are like additional comment marks on the film giving information about what feelings the news from the geometric future stimulated.

2. In subsequent quantum jumps film moves downwards towards geometric past and markings defined in terms of space-time correlates for mental images are shifted backwards with the film and define the coding of information about previous conscious experience. In memory recall metabolic energy is fed to these subsystems and they wake up and regenerate the mental images about the remembered aspect sof the previous conscious experience. This would not be possible in positive energy ontology and if determinism in strict sense of the world would hold true.

3. Something must bring in the essential information that these experiences are memories rather than genuine sensory experiences (say). Something must distinguish between genuine experiences and memories about them. The space-time sheets representing self reference define cognitive representations. If the space-time sheets representing the correlates for self-referential mental images are p-adic, this distinction emerges naturally. That these space-time sheets are in the intersection of real and p-adic worlds is actually enough and also makes possible negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) carrying the conscious information. In TGD inspired quantum biology this property is indeed the defining characteristic of life.

4. There is quite concrete mechanism for the realization of memories in terms of braidings of magnetic flux tubes discussed in [K3].

Interesting questions relate to the role of p-adicity and the realization of the active aspects of consciousness. One can consider also quantum jumps in which the space-time surface inside CD does not suffer mere passive shift downwards but is affected also in the geometric past. The mechanism of intentional action, which could have been inspired by Libet's finding that neuronal activity seems to precede conscious decision, can be understood in terms of negative energy signals sent to the geometric past, where they generate neuronal activity replacing the space-time surface with a new one.

If p-adicity is involved, the possibility seems that comes to mind is that the space-time sheets representing the signal to the geometric past are first generated as p-adic space-time sheets representing intention and transformed in quantum jump to their real counterparts representing the "desire" for action in turn generating the action.

13.3.6 Can Selves Interact And Evolve?

Interesting questions relate to how dynamical selves are.

1. Is self doomed to live inside the same sub- WCW eternally as a lonely god? This question has been already answered: there are interactions between sub-CDs of given CD, and one can think of selves as quantum superposition of states in CDs with wave function having as its argument the tips of CD, or rather only the second one since T is assumed to be quantized.

2. Is there largest CD in the personal CD hierarchy of self in an absolute sense? Or is the largest CD present only in the sense that the contribution to the contents of consciousness coming from very large CDs is negligible? Long time scales T correspond to low frequencies and thermal noise might mask these contributions. Here however the hierarchy of Planck constants and generalization of the embedding space could come in rescue by allowing dark EEG photons to have energies above thermal energy.

3. Can selves evolve in the sense that the size of CD increases in quantum leaps so that the corresponding time scale $T = 2^k T_0$ of memory and planned action increases? Geometrically this kind of leap would mean that CD becomes a sub-CD of a larger CD - either at the level of conscious experience or in absolute sense. The leap can occur in two senses: as an increase of the largest p-adic time scale in the personal hierarchy of space-time sheets or as increase of the largest value of Planck constants in the personal dark matter hierarchy. At the level of individual organism this would mean emergence of new lower frequencies of generalized EEG and levels of personal dark matter hierarchy with larger value of Planck constant.

13.3.7 Questions And Answers

Answering to question is the best possible manner to develop ideas in more comprehensible form. In this respect the questions of Hamed at my blog have been especially useful. Many questions below are originally made by him and inspired the objections, many of them discussed also in previous discussions. The answers to these questions have changed during latest years as the views about self and the relation between experienced time and geometric time have developed. The following answers are the most recent ones.

Question: The minimalistic option suggests very strongly that our sensory perception can be identified as quantum measurement assignable to state function reductions for upper or lower boundaries of our personal CD. Our sensory perception does not however jump between future and past boundaries of our personal CD (containing sub-CDS in turn containing...)! Why?

Possible answer: The answer to this question comes from the realization that in ordinary quantum theory state function reductions leaving the reduced state invariant are possible. This must have counterpart in ZEO. In ZEO reduces zero energy states are superpositions of zero energy states associated with CDs with second boundary fixes inside light-cone boundary and the position of the second boundary of CD varying: one can speak about wave function in the moduli space of CDs. The temporal distance between the tips of CD and discrete lattice of the 3-D hyperbolic space defined by the Lorentz boosts leaving second tip invariant corresponds to the basic moduli.

The repeated state function reductions leave both the fixed boundary and parts of zero energy states associated with this boundary invariant. They however induce dispersion in the moduli space and the average temporal distance between the tips of CDs increases. This gives rise to the flow of psychological time and to the arrow of time. Self as counterpart of observer can be identified as a sequence of quantum jumps leaving the fixed boundary of CD invariant. Sensory perception gives information about varying boundary and the fixed boundary creates the experience about self as invariant not changed during quantum jumps.

The repeated reductions must do something for the state and the simplest assumption is that they induce localization in the moduli space of CDs. The time evolution operator inducing the superposition could be analogous to exponent of translation generator appearing in quantum field theories.

Self hierarchy corresponds to the hierarchy of CDs. For instance, we perceive from day to day the - say- positive energy part of a state assignable to this very big CD. Hence the world looks rather stable.

Question: This suggests that our sensory perception actually corresponds to sequences of state function reductions to the two fixed boundaries of CDs of superposition of CDs so that our sensory inputs would alternately be about upper and lower boundaries of personal CDs. Sleep-awake cycle could correspond to a flip flop in which self falls asleep at boundary and wakes up at opposite boundary. Doesn't this lead to problems with the arrow of time?

Possible answer: If we measure time relative to the fixed boundary then the geometric time defined as the average distance between tips in superposition of CDs would increase steadily and we get older also during sleep. Hence we would experience subjective time to increase. Larger CDs than our personal CD for which the arrow of time remains fixed in the time scale of life cycle would provide the objective measure of geometric time.

Question: What is the time scale assignable to my personal CD: the typical wake-up cycle: 24 hours? Or of the order of life span. Or perhaps shorter?

Possible answer: The durations of wake-up periods for self is determined by NMP: death means that NMP favors the next state function to take place at the opposite boundary. The first naïve guess is that the duration of the wake up period is of the same order of magnitude as the geometric time scale of our personal CD. In wake-up state we we would be performing state function reduction repeatedly to say "lower" boundary of our personal CD and sensory mental images as sub-CDs would be concentrated near opposite boundary. During sleep same would happen at lower boundary of CD and sensory mental images would be at opposite boundary (dreams, ...).

Question: Are dreams sensory perceptions with opposite arrow of time or is some sub-self in wake-up state and experiences same arrow of time as we during wake-up state? If the arrow is

different in dreams, is the "now" of dreams in past and "past" in the recent of wake-upe state

Possible answer: Here I can suggest an answer based on my own subjective experiences and it would be cautious "yes".

Question: Why we do remember practically nothing about sensory perceptions during sleep period? (Note that we forget actively dream experiences).

Possible answer: That we do not have many memories about sleep and dream time existence and that these memories are unstable should relate to the change of the arrow of personal time as we wake up. Wake-up state should somehow rapidly destroy the ability to recall memories about dreams and sleep state. Wake-up memory recall means communications to geometric past, that is to the boundary of CD which remains fixed during wake-up state. In memory recall for dreams in wake-up state these communications should take place to geometric future. Memory recall of dreams would be seeing to future and much more difficult since the future is changing in each state function reduction so that dream memories are erased automatically during wake-up.

Question: Does the return to childhood at old age relate with this time flip-flop of arrow of time in the scale of life span: do we re-incarnate in biologically death at opposite end of CD with scale of life span?

Possible answer: Maybe this is the case. If this boundary corresponds to time scale of life cycle, the memories would be about childhood. Dreams are often located to the past and childhood.

13.4 What Does Arrow Of Time Mean At The Level Of Quantum States?

The previous discussion does not touch the question what arrow of time means at the level of quantum states. Therefore the notion of negative energy signal propagating backwards in geometric time crucial for TGD inspired quantum biology remains somewhat fuzzy. The recent progress in the understanding of the basic properties of zero energy states makes it possible to understand what arrow of geometric time and the notion of negative energy state and signals propagating to the direction of geometric past mean at the level of zero energy states. This understanding has surprisingly non-trivial philosophical implications.

13.4.1 Arrow Of Time As An Inherent Property Of Zero Energy States

The basic idea can be expressed in very conscise form. In positive energy ontology arrow of time characterizes dynamics. In zero energy ontology arrow of time characterizes quantum states.

1. The breaking of time reversal invariance means that zero energy states can be localized with respect to particle number and other quantum numbers only for future or past light-like boundary of CD but not both. M-matrix generalizing $S-$matrix provides the time-like entanglement coefficients expressing the state at the second boundary as quantum superposition of states with well-defined particle numbers and other quantum numbers. But only at the second end of CD since one cannot choose freely the states at both boundaries: if this were the case the counterpart of Schrödinger equation would be completely non-deterministic. This is what the breaking of time reversal symmetry means. It occurs spontaneously and assigns to the arrow of subjective time geometric arrow of time.

   This picture gives a precise meaning to the arrow of geometric time and therefore also for the otherwise fuzzy notion of negative energy signals propagating backwards in space-time playing key role in TGD based models of memory, metabolism, and intentional action [**?**]

2. Quantum jump begins with the unitary U-process between zero energy states generating a superposition of zero energy states. After that follows state function reduction cascade proceeding from the level of CD to the level of sub-CDs forming a fractal hierarchy. The reductions cannot take independently at both light-like boundaries of CD as is also clear from the fact that scattering state leads from a prepared state to a quantum superposition of prepared states.

The first guess is that the cascade takes place for the second boundary of CD only so that the arrow of geometric time would be same in all scales. This need not be the case always: the geometric arrow of time seems to change in some situations: phase conjugate laser light and spontaneous self-assembly of bio-molecules are good examples about this [K133, **?**]. In fact, one of the defining properties of living matter could be just the possibility that the arrow of geometric time is not same in all scales (size scales of CDs) so that memory, metabolism, and intentional action become possible. In any case, the second end remains a superposition of quantum states.

The lack of quantum measurements at the second end of space-times could explain why the conscious percepts are sharply localized in time at the second end of CD. This could also allow to understand memories as reductions occurring at the second, non-standard, end of sub-CDs in the geometric past.

3. The correspondence between the reduced state and the quantum superposition of states at the opposite boundary of CD allows an interpretation in terms of logical implication arrow with all statements present in the superposition implying the statement represented by the reduced state. Only implication arrow rather than equivalence is possible unless the M-matrix is diagonal meaning that there are no interactions. If it is possible to diagonalize M-matrix then in diagonal basis one has equivalences. It must be however emphasized that the physically preferred state basis fixed as in terms of eigenstates of density matrix does not allow diagonal M-matrix. Number theoretic conditions required that the density matrix corresponds to fixed algebraic extension of rationals can also make possible the diagonalization without leaving the extension and this condition might be highly relevant in the TGD inspired view about cognition relying on p-adic number fields and their algebraic extensions [K119].

4. In classical logic implication corresponds to the inclusion of subset by subset. In quantum case it corresponds to the inclusion for sub-space of state space. The inclusions of hyperfinite factors (WCW spinors define HFF of type II_1) realize the notion of finite measurement resolution, which would suggest that inclusion arrow has also interpretation in terms of finite measurement resolution.

   All quantum states equivalent with a given state in the resolution used imply it. Finite measurement resolution would mean that there would infinite number of instances always in the quantum superposition representing the rule A $\rightarrow$ B. Ironically, both finite measurement resolution and dissipation implying the arrow of geometric time and usually regarded as something negative from the point of view of information processing would be absolutely essential element of logical thinking in this framework.

5. Conscious theorem proving would has as correlate to building of sequences zero energy states representing A $\rightarrow$ B, B $\rightarrow$ C, C $\rightarrow$ D with basic building bricks representing simple basic rules. These sequences would represent more complex truths.

13.4.2 Does State Function-State Preparation Sequence Correspond To Alternating Arrow Of Geometric Time?

The state function reduction at light-like boundary of CD implies de-localization at the opposite boundary. This inspires so fascinating questions.

1. Could the state function reduction process take place alternately at the two boundaries of CD so that a kind of flip-flop in which the arrow of geometric time changes back and forth would result, and have interpretation as an alternating sequence of state function reductions and state preparations in the framework of positive energy ontology?

2. State function reductions are needed for sensory percepts. Could the sleep-wake-up period correspond to this kind of process so that during what we call sleep the past boundary of our personal CD would be in wake-up state? Could dreams and memories represent sharing of mental images of this kind of consciousness? Could it be that in the time scale of entire life cycle death is accompanied by birth at the second boundary of personal CD? Could this quantum physics representation for endless sequence of deaths and rebirths? Could

the fact that old people often spend they last years in childhood have interpretation in this framework?

3. State preparation-reduction cycle might characterize only living matter whereas for inanimate matter second choice for the arrow of time would be dominant between two U-processes. TGD based reformulation [K132] of entropic gravity idea of Verlinde [B5] in terms of ZEO does not assume the absence of gravitons and the emergence of space-time. The formulation leads to the proposal that thermodynamical stability selects the arrow of the geometric time and that it could be different for matter and antimatter implying that matter and antimatter reside at different space-time sheets. This would explain the apparent absence of antimatter and also support the view that the arrow alternates only in living matter. Note that state preparation also corresponds to intentional action not possible in the world of standard thermodynamics with fixed arrow of thermodynamical time.

13.4.3 Or Does "Dispersion" At Second Boundary Of CD Cause Generate The Arrow Of Time?

"Fractality from your blog" posed an interesting question about possible asymmetry between boundaries of causal diamond CD. The answer to the question led to recall once again the incomplete understanding of details about how the arrow of time emerges in zero energy ontology (ZEO).

The basic vision is following.

1. CDs form a fractal scale hierarchy. Zero energy states possess a wave function in moduli degrees of freedom characterizing sizes of CDs as well telling what Lorentz boost leaving boundary invariant are allowed for them. Boosts form by number theoretic constraints a discrete subgroup of Lorentz group defining analogs of lattices generated by boosts instead of translations.

2. The arrow of subjective time maps to that of geometric time somehow. The origin of arrow comes from the fact that state function reductions can occur to either boundary of given CD and reduction creates time-asymmetric state since second boundary of CD is in a quantum superposition of different sizes and there is a superposition of many-particle states with different particles numbers and quantum number distributions.

3. Subjective existence corresponds to a sequence *of moments of consciousness*: state function reductions at opposite boundaries of CDs. State function reduction reduction localizes either boundary but the second boundary is in a quantum superposition of several locations and size scales for CD. This predicts that the arrow of time is not constant. In fact, there is considerable evidence for the variation of the arrow of time in living systems and Fantappie introduced long time ago the notion of syntropy to describe his view about the situation.

4. The first very naïve proposal was that state function reductions occur *alternately* to the two boundaries of CD. This assumption would be indeed natural if one considered single fixed CD rather than superposition CDs with different size and state function reduction localizing their either boundary: restriction to single CD was what I indeed did first.

5. This assumption leads to the question about why do we do not observe this alternation of the arrow of time all the time in our personal experience. Some people actually claim to have actually experienced a temporary change of the arrow of time: I belong to them and I can tell that the experience is frightening. But why do we experience the arrow of time as stable in the standard state of consciousness?

One possible way to solve the problem - perhaps the simplest one - is that state function reduction to the same boundary of CD can occur many times repeatedly. This solution is so absolutely trivial that I could perhaps use this triviality to defend myself for not realizing it immediately!

I made this totally trivial observation only after I had realized that also in this process the wave function in the moduli space of CDs change in these reductions. Zeno effect in ordinary

measurement theory relies on the possibility of repeated state function reductions. In the ordinary quantum measurement theory repeated state function reductions do not affect the state in this kind of sequence but in ZEO the wave function in the moduli space labelling different CDs with the same boundary could change in each quantum jump. It would be natural that this sequence of quantum jumps give rise to the experience about flow of time? This option would allow the size scale of CD associated with human consciousness be rather short, say.1 seconds. It would allow to understand why we do not observe continual change of arrow of time.

Maybe living systems are working hardly to keep the personal arrow of time changed - living creatures try to prevent kettle from boiling by staring at it intensely. Maybe it would be extremely difficult to live against the collective arrow of time.

An objection against this picture as compared to the original one assuming alternate reductions to the opposite boundaries of CD is that is that one can understand state preparation as state function reduction to the opposite boundary. This interpetation makes sense almost as such also in the new picture if the average time period for which the reductions occur to a given boundary is shorter in elementary particles scales than in macroscopic scales characteristic for human consciousness. The approximate reversibility in elementary particle scales can be understood as summing up of the two arrows of time to no arrow at all.

13.4.4 Quantum Dynamics For The Moduli Of CDs And The Arrow Of Geometric Time

How the arrow of geometric time at the level of space-time and embedding space is induced from the arrow of subjective time identified in terms of sequence of quantum jumps forming a fractal hierarchy of quantum jumps within quantum jumps? This is one of the long lasting puzzles of TGD and TGD inspired theory of consciousness.

In zero energy ontology (ZEO) the geometry of CD (I often use the sloppy notation $CD \equiv CD \times CP_2$, where the latter CD is defined as the intersection of future and past directed light-cones) is that of double light-cone (double pyramid) and this must relate closely to the problem at hand. An easy manner to obtain absolute arrow of geometric time at least statistically is to assume that embedding space is $M^4 + \times CP_2$- that is product of future like cone with CP_2. The problem is however that of finding a convincing quantal mechanism generating the arrow of time, and also explaining why the geometric arrow of time sometimes changes from the standard one (say for phase conjugate laser beams).

The latest vision about the generation of the arrow of geometric time the level of embedding space and space-time discussed in previous section involves rather radical features but is consistent with the second law if generalized so that the geometric arrow of time at the level of embedding level alternates as state function reduction takes place alternately at opposite light-like boundaries of a fixed CD. If the partially non-deterministic dynamics at space-time level defines a correlate for the dissipative dynamics of quantum jumps, the arrow of geometric time level at space-time level is constant (space-time surface can assignable to the state function reductions can be seen as folded surface spanned between boundaries of CD) and entropy defines monotonically increasing time coordinate. This is rather radical revision of the standard view but makes definite predictions: in particular syntropic aspects of the physics of living matter [J121] could be assigned with the non-standard direction of geometric time at the space-time level.

This approach however still suffers from a defect. CDs are regarded as completely non-dynamical: once CD is created it remains the same from quantum jump to quantum jump and thus serves as a fixed arena of dynamics. This cannot be the case.

Some questions about CDs and their quantum dynamics

One can raise several questions relating to CDs.

1. CDs are assumed to form a fractal hierarchy of CDs within CDs. The size scale of CD has been argued to come as an integer multiple of CP_2 size scale on basis of number theoretic arguments. One can ask whether CDs can overlap and interact and what interaction means.

2. What is the proper interpretation of CD? Could CD correspond to a spotlight of consciousness directed to a particular region of space-time surface, so that space-time surface need not end

at the boundaries of CD as also generalized Feynman diagrammatics mildly suggests? Or do the space-time surfaces end at the boundaries of CD so that CD defines a sub-Universe?

3. Should one assign CD to every subsystem - even elementary particles and fermion serving as their building bricks? Can one identify CD as a carrier of topologically quantized classical fields associated with a particle?

As already noticed the picture based on static CDs is too simplistic. This inspires several questions relating to the possible dynamics of CDs.

1. In ZEO one can in principle imagine a creation of CD from and its disappearance to vacuum. It is still unclear whether the space-time sheets associated with CD restricted to the interior of CD or whether they can continue outside CD.

   For the first option appearance of CD would be a creation of sub-Universe contained by CD. CD could be assigned with any sub-system. For the latter option the appearance of CD would be a generation of spotlight of consciousness directing attention to a particular region of embedding space and thus to the portions of space-time surfaces inside it. Quantum superposition of space-time surfaces is actually in question and should be determined before the presence of CD by vacuum functional. How to describe possible creation and disappearance of CDs quantally, is not clear. For instance, what is the amplitude for the appearance of a new CD from vacuum in given quantum jump?

2. CDs have various moduli and one could assign to them quantum dynamics. The position of cm or either tip of CD in M^4 defines moduli as does also the point of CP_2 defining the origin of complex Eguchi-Hanson coordinates in which $U(2) \subset SU(3)$ acts linearly: these points are in general assumed to be different at the two ends of CD. If either tip of CD is fixed the Lorentz boost leaving the tip fixed, moves the other along constant proper time hyperboloid H^3 and the tessellations defined by the factor space H^3/Γ, where Γ is discrete subgroup of $SL(2,C)$, are favored for number theoretical reasons.

   Quantum classical correspondence inspires the question whether the boost is determined completely by the four-momentum assignable to the positive/negative energy part of zero energy states and corresponds to the four-velocity β defined by the ratio P/M of total four-momentum and mass for the CD in question. It seems that this kind of assumption can be justified only in semiclassical approximation.

3. In ZEO cm degrees of freedom of CD cannot carry Poincare charges. One can however assign the Poincare charges of the positive energy part of zero energy state to a wave function depending on the coordinate differences m_{12} defining the relative coordinate for the tips of the CD.

   The most general option is that the size scale of CD is continuous. This would allow to realize momentum eigen state as the analogs of plane waves as a function of the position m_{12} of the (say) upper tip of CD relative to the lower tip.

   The size scale of CD has been however assumed to be quantized. That is, the temporal distance T between the tips comes as an integer multiple of CP_2 time T_{CP_2}: this scale is about 10^4 Planck lengths so that this discretization has not practical consequences. Discretization is suggested both by the number theoretical vision, the finite measurement resolution, and by the general features of the U-matrix expressible in terms of S-matrix and hermitian square roots of density matrices forming orthonormal basis. U-matrix relates M-matrices associated with CDs with different size scales, which correspond to the Lorentz invariant temporal distance $T_n = nT_{CP_2}$ between the tips. The scaling up of the temporal distance would represent scaling of CD in the rest system defined by the fixed tip thus translating the second tip with integer multiple of T_{CP_2} from T_{n_1} to T_{n_2}.

   A further quantization would relate to the tessellations defined by the subgroups Γ. The counterparts of plane waves for the momentum eigenstates would be defined in a discretized version of Minkowski space obtained by dividing it to a sequence of discretized hyperboloids with proper time distance $a = nT_{CP_2}$ from the lower tip of CD.

4. There is evidence that one can assign a CDs with a fixed size scale to a given particle as secondary p-adic length scale: for electron this size scale would correspond to Mersenne prime M_{127} and frequency 10 Hz defining a fundamental biorhythm. This would give a deep connection between elementary particle physics and physics in macroscopic length scales. The integer multiples of the secondary p-adic length size scale would correspond to integer values of the effective Planck constant.

   A natural interpretation of this scale would be as infrared cutoff so that the wave functions approximating momentum eigenstates and depending on the relative coordinate m_{12} would be restricted in the region between light-cone boundary and hyperboloid $a = M_{127}T_0$. Similar restriction would take place for all elementary particles. For particle with effective Planck constant $\hbar_{eff} = n\hbar_0$ the IR cutoff would be n-multiple of that defined by the secondary p-adic time scale.

Could CDs allow to understand the simultaneous wave-particle nature of quantum states?

One of the paradoxical features of quantum theory is that we observe always particles - even with well-defined momentum - to have rather well-defined spatial orbits. As if spatial localization would occur in quantum measurements always and would be a key element of perception and state function reduction process. This raises a heretic question: could it be possible that the localized particles in some sense have a well-defined momentum. In standard quantum theory this is definitely not possible. The assignment of CD with particle - or any physical system - however suggests that this paradoxical looking assignment is possible. Particle would be localized with respect to (say) the lower tip of CD and de-localized with respect to (say) the upper tip and localization of the lower tip would imply de-localization of the upper tip.

It is indeed natural to assume that either tip of CD - say lower one - is localized in M^4 in state function reduction. Unless one is willing to make additional assumptions, this implies not only the non-prepared character of the state at the upper tip, but also a de-localization of the upper tip itself by non-triviality of M-matrix: one has quantum superpositions of worlds characterized CDs with fixed lower tip. The localization at the lower tip would correspond to the fact that we experience the world as classical. Each zero energy state would be prepared at the either (say lower) end of CD so that its lower tip would have a fixed position in M^4. The unprepared upper tip could have a wave function in the space of all possible CDs with a fixed lower tip.

One could also assign the spinor harmonics of $M^4 \times CP_2$ to the relative coordinates m_{12} and their analogs in CP_2 degrees of freedom. The notion of CD would therefore make possible to realize simultaneously the paricle behavior in position space (localization of the lower tip of CD) and wave like nature of the state (superposition of momentum eigenstates for the upper tip relative to the lower tip).

This vision is only a heuristic guess. One should demonstrate that the average dynamical behavior for coordinate differences m_{12} corresponds to that for a free particle with given four-momentum for a given CD and fixed quantum numbers for the positive energy part of the state.

The arrow of geometric time at the level of embedding space and CDs

In the earlier argument the arrow of geometric time at embedding space level was argued to relate to the fact that zero energy states are prepared only at the either end of CD but not both. This is certainly part of the story but something more concrete would be needed. In any case, the experienced flow of time should relate to what happens CDs but in the proposed model CDs are not affected in the quantum jump. Th is would leave only the drifting of sub-CDs as a mechanism generating the arrow of geometric time at embedding space level. It is however difficult to concretize this option.

Could one understand the arrow of geometric time at embedding space level as an increase of the size of the size of CDs appearing in zero energy state? The moduli space of CDs with a fixed upper/lower tip is without discretization future/past light-cone. Therefore there is more room in the future than in past for a particular CD and the situation is like diffusion in future light-cone meaning that the temporal distance from the tip is bound to increase in statistical sense. This

means gradual scaling up of the size of the CD. A natural interpretation would be in terms of cosmological expansion.

There are two options to consider depending on whether the embedding space is $M^4 \times CP_2$ or $M^4_+ \times CP_2$. The latter option allows local Poincare symmetry and is consistent with standard Robertson-Walker cosmology so that it cannot be excluded. The first option leads to Russian doll cosmology containing cosmologies within cosmologies in ZEO and is aesthetically more pleasing.

1. Consider first the $M^4 \times CP_2$ option. At each tip of CD one has arrow of geometric time at the level of embedding space and these arrows are opposite. What does this mean? Do the tips correspond to separate conscious entities becoming conscious alternately in state function reductions? Or do they correspond to a single conscious entity with memories?

   Could sleep awake cycle correspond to a sequence of state function reductions at opposite ends of personal CD? It would seem that we are conscious (in the sense we understand consciousness) only after state function reduction. Could we be conscious and have sensory percepts about the other end of CD during sleep state but have no memories about this period so that we would be living double life without knowing it? Does the unprepared and de-localized part (with respect to m_{12}) of zero energy state contribute to the conscious experience accompanying state function reduction? Holography would suggest that this is not the case.

   If CD corresponds to a spotlight of consciousness, the time span of conscious experience could increase in both time directions for the latter option. The span of human collective consciousness has been increasing in both direction all the time: we are already becoming conscious what has probably happened immediately after the Big Bang. Could this evolution be completely universal and coded to the fundamental physics?

2. If the embedding space is assumed to be $M^4_+ \times CP_2$, one obtains only one arrow of time in the long run. The reason is that the lower tip of any CD sooner or later reaches $\delta M^4_+ \times CP_2$ and further expansion in this direction becomes impossible so that only the expansion of CD to the future direction becomes possible.

Summary

The proposed vision for the dynamics of the moduli of CDs is rather general and allows a concrete understanding of the arrow of geometric time at embedding space level and binds it directly to expansion of CDs as analog of cosmic expansion. The previous vision about how the arrow of geometric time could emerge at the level of space-time level remains essentially un-changed and allows the increase of syntropy [J121] to be understood as the increase of entropy but for a non-standard correspondence between the arrows of subjective time and the arrow of embedding space time.

Embedding space spinor harmonics characterizing the ground states of the representations of symplectic group of $\delta M^4_\pm \times CP_2$ define the counterparts of single particle wave functions assignable to the relative coordinates of the second tip of CD with respect to the one fixed in state function reduction. The surprising outcome is the possibility to understand the paradoxical aspects of wave-particle duality in terms of bi-local character of CD: localization of given tip implies de-localization of the other tip.

13.4.5 The Arrow Of Geometric Time And The Arrow Of Logical Implication

If physics is mathematics in the sense that there is nothing behind quantum states regarded as purely mathematical objects, Boolean logic must have a direct manifestation in the structure of physical states. Physical states should represent quantal Boolean statements which get their meaning via quantum jumps. In TGD framework WCW ("world of classical worlds") spinor fields represent quantum states of the Universe and WCW spinors correspond to fermionic Fock states for second quantized induced spinor fields at space-time surface. Fock state basis has interpretation in terms of Boolean algebra. In positive energy ontology the problem is that fermion number as a

super-selection rule would allow very limited number of Boolean statements to be represented. In ZEO the situation changes.

The fermionic parts of positive and negative energy parts can be seen as quantum superpositions of Boolean statements with fermion number in given mode (equal to 0 or 1) representing yes/no or true/false. Also various spin like quantum numbers associated with oscillator operators have same interpretation. Zero energy state could be seen as quantum superposition of pairs of elements of Boolean algebras associated with positive and negative energy parts of the zero energy state.

The first - and incorrect - interpretation is that zero energy state represents a quantum superposition of equivalent statements $a \leftrightarrow b$ and thus abstraction $A \leftrightarrow B$ involving several instances of A and B. The breaking of time reversal invariance allowing localization to definite fermionic quantum numbers at single end of CD only however implies that quantum states can only represent abstraction of logical implication to $A \rightarrow B$ rather than equivalence. p-Adic physics for various primes pc [**?**]ould represent correlates for cognition and intentionality.

13.4.6 The Roles Of Sensory Perception And Motor Action In TGD Framework

The attempts to define consciousness rely on two basic approaches. The first approach emphasizes direct sensory awareness and formation of cognitive representations from it (phenomenal consciousness and reflective consciousness). Second approach emphasizes volition, motor plans, and motor actions.

The analogs of sensory representations and motor actions emerge at the fundamental level in quantum TGD without mentioning anything about brain. In ZEO state function reduction is replaced with a cascade of state function reductions corresponding to various scales for CDs forming a fractal hierarchy. State function reduction can take place to either of the opposite boundaries of CD in a given length scale. The reduction at given boundary of CD would always force de-localization of the opposite boundary of CD creating quantum superposition of CDs with various sizes. Also new sub-CDs (correlates for sensory mental images) within the resulting bigger CDs are naturally generated. This would explain the arrow of geometric time at embedding space level but the arrows are opposite at the opposite boundaries of CD.

The reduction to opposite boundaries of CD gives rise to zero energy states related by time reversal at the level of embedding space. If "my" conscious experience corresponds to reductions to either "upper" or "lower" boundary of CD of wake-up cycle defining me, I will experience that the arrow of geometric at the level of embedding space arrow is constant and would be basically due to the scaling up of the average size of "personal" CD. "Upper" "lower" can be fixed by the arrow of time assignable to large enough CD defining environment.

Standard quantum measurement theory assumes that a state function reduction followed immediately by a new one does not affect the reduced state [this gives rise to so called quantum Zeno effect: quantum monitoring of unstable particle prevents its decay (watched kettle does not boil)]. That repeated state function reduction at given boundary of CD does not affect the part of zero energy state at that boundary resulting in the reduction for given CD would generalize this hypothesis. Note that the the parts of zero energy states at the opposite boundary are affected: in particular, the size scale of CD increases.

If this assumption hold true, the subsequent reductions at the same boundary of CD would effectively correspond to single reduction at the passive boundary of CD, and one would effectively have an alternating sequence of cascades of state function reductions beginning from opposite boundaries of CDs. Note however that there a fractal cascade of reductions beginning from sub-CDs the CD is assumed changing the state in smaller scales.

In TGD framework the counterpart of quantum Zeno effect would be achieved by closing an unstable particle inside small enough CD so that the unitary time evolution restricted to CD would not affect the particle appreciably and state function reductions at boundaries of this CD very rarely would give rise to a final state of decay. Watchdog in this case would be the self to which this CD corresponds to.

Motor action as time reversal of sensory perception

In TGD framework motor action could be seen as a time reversal of sensory perception so that sensory-motor pairing could be seen as fundamental element of all conscious existence. This symmetry is very profound and strong prediction and forces to modify dramatically the beliefs about the arrow of geometric time and its relation to the subjective arrow of time. The variation of the arrow of time would be basic feature of living matter.

Just to fix conventions let us fix arrow of time as the arrow of the embedding space time for a very large CD, maybe of cosmic size scale, so that there is unique time direction corresponding to future.

1. All scales for CDs are possible. For sub-CDs of given CD the experiences associated with sub-CD define mental images of CD and the experience can be assigned with either boundary of sub-CD. Let us tentatively agree that for a given CD "lower" and "upper" boundaries are in future and past when seen from the center point of CD (past and future could be permuted in the convention).

   This choice would conform with the interpretation that motor "me" I_m makes a fuzzy prediction of future as superposition of space-time sheets extending from the lower boundary of CD and sensory "me" I_s generates memories represented by superposition of space-time sheets extending downwards from the upper boundary of CD. I do not quite have the courage to completely exclude the second option in which the roles of motor me and sensory me are changed.

2. With this assumption one can assign to a sub-CD near upper *resp.* lower boundary of sub-CD sensory mental images *resp.* their time reversals. In the interior they would represent memories *resp.* predictions. The larger CD would experience these sub-selves as mental images and interpret them in terms of ordinary sensory percepts *resp.* volitions, decisions, and plans. The primary sensory experience, phenomenal experience, involves generation of negentropic entanglement as the sensory mental image combines as a tensor factor with the existing sequence of mental images forming a sensory representation defining memory. The reading of this sequence of mental images using interaction free quantum measurement gives rise to a conscious memory about the mental image sequence.

3. A prediction, which looks rather strange at first glance, follows. "My" CD would be seat for two selves having their own phenomenal experiences seated at the opposite boundaries of my CD. They would be sensory me I_s assignable to sensory perception and motor me I_m assignable to motor action as time reversed sensory perception and assignable to the opposite boundaries of CD when they are localized in state function reduction. The time reversed sensory percept is interpreted in terms of predictions, volitions, and plans at least by larger CD having the CD as sub-CD. Sensory and motor "mes" would appear in all scales in the hierarchy of sub-CDs.

4. Since the scale of CDs increases quantum jump by quantum jump on the average and new sub-CDs emerge, the size scale of the largest CD in hierarchy increases and the perceptual fields of the two "me" s associated with it shift towards geometric future *resp.* past of the embedding space. The sub-CDs near the boundaries of largest CD give rise to sensory percepts of the two "me" s involved with the largest CD in the hierarchy. Those in the interior define memories. The flow of time would correspond to the gradual shifting of the upper/lower boundary of largest CD to future/past and generation of sensory mental images (sub-CDs) near the boundary. Same would of course occur for the smaller CDs. The time interval about which memories are about and also the time scale for predictions of future increases since the size of the personal CD is gradually scaled up.

Quantitative considerations

One can make also quantitative questions.

1. What is the average increase of the temporal distance between the tips of CD in a pair of state function reductions to opposite boundaries defining the chronon of subjective experience? The duration of this chronon can depend on the level of the self hierarchy.

For human sensory consciousness this chronon would naturally correspond to the time scale of about.1 seconds having interpretation as a duration of sensory mental image. Each pair of state function reductions would generate a layer of the sensory mental images at the lower and upper boundary of "our" CD.

This leaves open the size scale of "our" CD and lifetime would represent only the size scale for the increase of "our" CD during life cycle. This would mean that the durations of consciousness for the two "me" s assignable to "our" CD would be measured using.1 second as a natural unit.

2. What can one say about the size scales of CDs themselves? Since the memories are about the time interval, which is roughly the duration of life cycle at most, the first guess is that the size of personal CD is of the order of duration of life cycle. By the previous argument however only the increase of the distance between the tips of "personal" CD naturally corresponds to the duration of life cycle so that the size scale of personal CD could be much larger. Note that the conscious experiences of I_s and I_m assignable to sensory percepts and motor actions should correspond to sub-CD: s with size scale not much larger than.1 seconds. This is consistent with the interpretation of sensory percepts of I_m as plans, decisions, predictions, and volitions. The sub-CDs with time scale of say years are however possible and would correspond to memories and plans in time scales of years.

3. One can imagine also a fractal hierarchy for the increments ΔT_i of the temporal distance T_i between tips of CDs assignable to single pair of quantum jumps to opposite boundaries of CD in given length scale. $\Delta T = .1$ seconds would not be the only possible duration of chronon. This time scale is however very special since it corresponds to the Mersenne prime M_{127} assignable to electron which corresponds to largest Mersenne prime which does not correspond to completely super-astrophysical p-adic length scale. The smaller Mersenne primes - such as M_{107} and M_{89} could correspond to shorter time scales perhaps assignable to nerve pulse in the case of lightest quarks. All primes characterizing elementary particles could define chronons of this kind serving as clocks. The hierarchy of chronons could mean sensory percepts and motor actions have a fractal hierarchy of resolutions identifiable as kind of abstraction hierarchy.

   The clocks defined by these chronons of duration T_i should be synchronized in the sense that there would $N_{ij} = \Delta T_i/\Delta T_j$ quantum jumps with time increment T_j per single quantum jump with time increment T_i.

   Could various periodic phenomena such as diurnal period of 24 hours defining sleep-awake cycle, annual cycle, and various bio-rhythms such as EEG rhythms, define also chronons? Could cyclicity which seems to appear at the level of sensory and cognitive mental images relate to this kind of chronons: for instance, after images are a good example about mental images having analog of wake-up-sleep cycle.

Questions

There are also questions about the relation to the functioning of brain.

1. How sleep-awake cycle relates to this picture? The above argument suggest that.1 second time scale rather than 24 hour time scale defines the increase of CD scale assignable to single pair of state function reduction assignable to "me". Therefore the period assignable to single moment of human sensory conscious of the two "me" s would be of order.1 seconds.

   This strongly suggests that due to the lack of sensory input and absence of motor actions we are conscious during sleep but do not have memories from this period. Dreams generated by virtual sensory input to retina would produce memories during sleep state. Revonsuo indeed mentions that according to the reports of subject persons after awakenings sleeping period seems to involve either dreams or sleep mentation. Sleep mentation is very simple during nREM sleep: for instance, repetition of some word of internal speech. Sleep mentation would involve motor actions generating internal speech and in some cases also genuine speech. Also genuine motor actions such as sleep walking are possible.

2. Could the sensory-motor dichotomy have some relation to the right-left dichotomy at the level of brain? Right and left brain hemisphere could naturally correspond to parallel CDs of same size scale. Could right and left brain (or parts of them) organize their wake-up periods as in shift work: if left brain hemisphere is awake right hemisphere sleeps (sensorily perceives the opposite end of its CD) and vice versa, an alternating dominance by either hemisphere results, and one could understand sensory rivalry. The time scale of CDs possibly involved would be much shorter than that of sleep-awake cycle in this case. Interestingly, the duration of hemisphere dominance period in some disorders like schizophrenia is anomalously long.

   The CD containing both these CDs - "entire brain CD" - would be also present. The view of "brain CD" about world represented by entangled right and left negentropic mental images would be analogous to initial and final state and thus contain much more information than given by either right or left hemisphere. In the case of visual mental images this would give rise to stereo vision.

   Could this shift work between parts of right and left hemisphere be realized in several time scales of CDs? Even in the scale corresponding to sleep-awake rhythm? It is known that in case of some birds and mammals, which must be motorially and sensorily active all the time, the brain hemispheres have this kind of shift work in long time scale.

13.4.7 Trying To Understand The Relationship Between Subjective And Geometric Time

I am trying to improve my understanding about the relationship between subjective and geometric time. Subjective time corresponds to a sequence of quantum jumps at given level of hierarchy of selves having as correlates causal diamonds (CDs). Geometric time is fourth space-time coordinate and has real and p-adic variants. This raises several questions.

1. How the subjective times at various levels of hierarchy relate to each other? Should/could one somehow map sequences of quantum jumps at various levels to real or p-adic time values in order to compare them - as quantum classical correspondence indeed suggests?

2. Subjective existence corresponds to a sequence *of moments of consciousness*: state function reductions at opposite boundaries of CDs. State function reduction reduction localizes either boundary but the second boundary is in a quantum superposition of several locations and size scales for CD.

   There are two obvious problems related to the time experience.

   (a) If state function reductions occur alternately- one at time- then it is very difficult to understand why we experience same arrow of time continually: why not continual flip-flop at the level of perceptions. Some people claim to have actually experienced a temporary change of the arrow of time: I belong to them and I can tell that the experience is frightening. Why we experience the arrow of time as constant?

   One possible way to solve this problem - perhaps the simplest one - is that state function reduction to the same boundary of CD can occur many times repeatedly. This solution is so absolutely trivial that I could perhaps use this triviality to defend myself for not realizing it immediately! I made this totally trivial observation only after only after I had realized that also in this process the wave function in the moduli space of CDs could change in these reductions. Zeno effect in ordinary measurement theory relies on the possibility of repeated state function reductions. In the ordinary quantum measurement theory repeated state function reductions don't affect the state in this kind of sequence but in ZEO the wave function in the moduli space labelling different CDs with the same boundary could change in each quantum jump. It would be natural that this sequence of quantum jumps give rise to the experience about flow of time? This option would allow the size scale of CD associated with human consciousness be rather short, say.1 seconds. It would also allow to understand why we do not observe continual change of arrow of time. Maybe living systems are working hardly to keep the personal arrow of time changed and that it would be extremely difficult to live against the collective arrow of time.

(b) We experience time as a continuous flow rather than sequence of discrete jumps. Is this a problem or not? One could argue that it is not possible to be conscious about being unconscious so that gaps would not be experienced. But is this so simple? We are indeed able to experience the gap in sensory consciousness caused by sleeping over night (this does not mean we have been unconscious: we just do not remember).

3. Subjective time is certainly not metricizable whereas geometric time is and defines a continuum. But are moments of consciousness well-ordered as the values of real variant of geometric time are? This relates closely to the relationship of subjective time to geometric time. Certainly subjective time does not allow any continuous measure in real sense as geometric time does. One can however map moments of consciousness to integers.

   (a) It would seem natural to be able to say about two moments of consciousness - call them A and B, - whether A is before B or vice versa. Moments of consciousness would be well-ordered and could be mapped to *real* integers. But is this the case always? There is experimental evidence for the fact that consciously experience time ordering does not always correspond to the physical one. This was observed already by Libet (see `http://tinyurl.com/yathqkzv`) for my first attempt to understand these findings [K133]).

   (b) What about p-adic integers as labels for moments of consciousness as suggested by the vision about p-adic space-time sheets as correlates for cognition. Given p-adic integers m and n, one can only say whether the p-adic norm of m is larger than, smaller than, or equal to that of n. One can say that p-adic integers are weakly ordered.

p-Adic integers form a continuum in p-adic topology. Could one map the infinite sequence of quantum jumps already occurred to p-adic integers and in this manner to p-adic continuum instead of real one? Could the p-adic cognitive representations allow to achieve this? If so, the experience about conscious flow of time could be due to the p-adic topology for cognitive representation for the sequence of quantum jumps!

Could p-adic integers label moments of consciousness and explain why we experience conscious flow of time?

Next arguments give a more precise formulation for the idea that p-adic integers might label the sequence of quantum jumps at the level of conscious experience, or rather reflective consciousness involving various representations realized as "Akashic records": NMP and ZEO considerably modify the standard quantum measurement theory).

1. Most p-adic integers expressible as $n = \sum_k n_k p^k$ are infinite in real sense and in p-adic topology they form a continuum. Suppose that the infinite sequence of moments of consciousness that have already taken place can be labelled by p-adic integers and look what might be the outcome.

2. Sounds very strange in ears of real analyst but is true: the integers n and $n + kp^N$, for N large are very near to each other p-adically. In real sense they are very far. This allows to fill the gaps between say integers $n = 1$ and 2 by p-adic integers which are very large in real sense.

3. The p-adic correlate of the sequence of discrete quantum jumps/moments of consciousness would define p-adic continuum which in turn can be mapped to real continuum by canonical identification.

This map sequence of moments of consciousness to p-adic continuum would be nice but maybe tricky for any-one accustomed to think in terms of real topology!

This raises two questions.

1. p-Adic integers are not well-ordered. Could one induced the well-ordering of real time to p-adic context by mapping p-adic time axis to real one in a continuous manner and in this manner achieving mapping of moments of consciousness to real time axis?

2. Could canonical identification $\sum_k n_k p^k \to \sum_k n_k p^{-k}$ map (or its appropriate modification) allow to map p-adic integers to real numbers and in this manner induce real well ordering to the p-adic side. The problem is that real number with finite pinary expansion has second infinite expansion (1=.9999... is example using decimal expansion) so that two p-adic time values correspond to any real time value with finite pinary digits. Should one restrict the consideration to integers with finite number of pinary digits (finite measurement resolution) and select either branch? Could the two branches correspond to real time coordinates assignable to the opposite boundaries of CD defining two conscious selves in this scale?

What happens when I type letters in wrong order?

One can speak about sensory and cognitive orderings of events corresponding to reals and p-adics (for various values prime p or course). The cognitive ordering of events would not be well-ordering if cognition is p-adic. Is there any empirical support for this besides Libet's mysterious looking findings?

Maybe. For instance, as I am typing text I experience that I am typing the letters of the word in the correct order but now and then it happens that the order is changed, even the order of syllables and sometimes even that of short words can change. It is probably easy to cook up a very mundane explanation in terms of neuroscience or even electric circuits from keyboard to computer memory, or computer itself. One can however also ask whether this could reflect the fact that p-adic ordering of the intentions to type letter is not well-ordering and does not always correspond to the real number based order for what happened ?

In TGD Universe writing process involves a sequence of transformations of p-adically realized intention to type a letter to a real action (doing it). At space-time level it is therefore a map from p-adic realm to real realm by a variant of canonical identification crucial in the definition of p-adic manifold concept (see `http://tinyurl.com/ydxw3zvm`) assigning to real preferred extremal of Kähler action a p-adic preferred extremal in finite measurement resolution [K140]).

The variant of canonical identification in question defines chart maps from real to p-adic realm and vice versa, and is defined in such a manner that discrete and rationals in a finite subset of rationals are mapped to themselves and defining intersection of real and p-adic realms.

1. In the case of p-adic integers this subset is characterized by a cutoff telling the power of p below which p-adic integers and real integers correspond to each other as such. For the corresponding moments of consciousness (now intentions to type letter) one has same ordering in both realms. For integers containing higher powers of p a variant of canonical identification mapping p-adics to reals continuously is applied. In this case ordering anomalies can appear.

2. Another pinary cutoff comes from physics: real preferred extremals are mapped to p-adic preferred extremals and vice versa: without the cutoff the p-adic image of real extremal would be continuous but non-differentiable so that field equations would not make sense. The cutoff tells the largest power of p up to which the variant of canonical identification is performed for p-adic integers. Also now ordering anomalies appear if one regards p-adic integers as ordinary integers.

3. For the remaining integers the map is obtained by completing the discrete set of points to a preferred extremal of Kähler action on both real and p-adic sides so that physics enters into the game. This assignment need not be unique and the most natural manner to handle the non-uniqueness is to form quantum superposition of all allowed completions with same amplitude: this effective gauge invariance would be very natural from the point of view of finite resolution and conforms with the vision about inclusions of hyper-finite factors (see `http://tinyurl.com/yaye9z3w`) as a representation for finite measurement resolution giving rise to the analog of dynamical gauge symmetry [K138].

Could the strange inconsistencies between cognitive (sequences of intentions) and sensory time orderings (sequence of typed letters) reflect the fact that the ordering of p-adic integers as real integers is not the same as the ordering of their real images under canonical identification? Could it be possible to test this and perhaps deduce the prime p characterizing p-adic topology of cognitive representation in question?

13.5 In What Sense The Flow Of Time Could Correspond To The Increase Of The Effective Planck Constant?

I like answering questions. It gives a lot of meaning to the life of a theoretician who is not allowed to enjoy the pleasures of academic existence. Career builder would of course argue that writing again and again similar answers is a waste of time: I should be building social networks to important people instead. This activity however allows to make important observations and little discoveries. This time I answered to the questions relating to non-determinism of Kähler action. How this non-determinism relates to quantum non-determinism? How the non-determinism in elementary particle scales relates to that in biology?

The unexpected fruit was a little might-be discovery: the mechanism generating the arrow of geometric time in zero energy ontology might rely in crucial manner to a sequence of phase transitions increasing the value of Planck constant $h_{eff}/h = n$ and hence the size of the causal diamond (CD) characterized by quantum average temporal distance. Since the second boundary of CD is fixed, the second one moves to future in average sense: hence the flow of experienced time and its arrow. Conscious entities become more intelligent as they age! It became also clear that large h_{eff}/h characterizes many-particle system rather than single particle. This leads to view in which intelligent consciousness involving the experienced about the flow of time emerges as the complexity of the systems measured by the number of fundamental particles increases.

The guess was wrong as such. It seems that the time evolution by repeated state function reductions leaving the state at passive boundary of CD invariant should correspond to localizations in the moduli space for causal diamonds with second boundary fixed. It cannot affect the value of h_{eff} since this would scale up the size of CD and affect also the state at the passive boundary by scaling up the sizes of 3-surfaces.

Rather, this time evolution should be analogous to a sequences of time shifts: the time would be the integer valued proper time distance between the tips of CD and the operator acting on zero energy state would be exponent of energy. Each shift would be followed by a localization in the modular degrees of freedom of CD but no state function reduction would occur since this would change the arrow of time and opposite boundary of CD would become the passive boundary.

The scaling of h_{eff} by integer would define the scaling of CD in the first state function reduction to the opposite boundary. This reduction would be preceded by a unitary time evolution defined by exponent of conformal scaling generator. Of course, this scaling could be also trivial! If one considers only these discrete moments of time one obtains a time evolution consisting of discrete time and it is kind if jumping forth and back with increasing amplitude. The repeated birth and death of mental image could corresponds to this kind of evolution at the level of conscious experience.

13.5.1 Background

Quantum classical correspondence suggests that the non-determinism of Kähler action could be correlated for quantum non-determinism. An alternative but not exclusive interpretation is as a correlate for quantum criticality.

The non-determinism of Kähler action and quantum non-determinism

The first question was about the relationship between non-determinism of preferred extremals and quantum non-determinism. As a matter of fact, I like to use the phrase "partial failure of determinism for Kähler action" rather than "non-determinism of Kähler action".

A possible interpretation could be as a correlate for quantum non-determinism. Second interpretation would be in terms of quantum criticality implying non-determinism. I do not know whether the interpretations are actually equivalent.

I certainly do not believe that one could get rid of quantum non-determinism and there is no need for it. The generalisation of quantum-classical correspondence is however natural in ZEO, where basic objects are 4-D surfaces- classical time evolutions serving as space-time correlates for quantal evolutions.

The origin of the failure of classical determinism is following.

1. Kähler action has a huge vacuum degeneracy. For instance, for space-time surfaces, which are maps from M^4 to at most 2-D Lagrangian manifold of CP_2 having by definition vanishing induced Kähler form (configuration space and momentum space are Lagrangian manifolds in the context of classical mechanics) induced Kähler form of course vanishes. These vacuum extremals define an analog of gauge degeneracy of Maxwell action for vacuum extremals. For non-vacuum externals it is expected to be lifted at least partially. Hence 4-dimensional spin glass degeneracy is more appropriate analogy. One could say that classical gravitation breaks the analog of gauge invariance for non-vacuum extremals.

2. For CP_2 type vacuum externals one has also non-determinism, which corresponds directly to Virasoro conditions expressing the light-likeness of 1-D M^4 projection of the CP_2 type vacuum extremal. Now induced Kähler form does not vanish.

3. Zero energy ontology (ZEO) and causal diamond (CD) are essential notions concerning the interpretation but leave these notions as an exercise for the reader. The ends of the vacuum extremal at light-like boundaries of CD are connected by infinite number of vacuum extremals.

   One expects that some of the vacuum degeneracy is present also non-vacuum externals. Part of this degeneracy must be analogous to gauge degeneracy since by strong form of general coordinate invariance implying strong form of holography, only the partonic 2-surfaces and their 4-D tangent space data fix the physics since WCW metric depends only on this data. Hence the interiors of 3-surfaces carry very little information about quantum states.

Identification of gauge degeneracy as hierarchy of broken conformal gauge invariances

The conjecture is that conformal symmetries acting as partially broken gauge symmetries realize this vision. TGD allows several kinds of conformal symmetries, and a huge generalisation of string model conformal symmetries (including Kac-Moody) [K30] but I will not go to this here. Suffice it to say that the generalization of conformal symmetries means replacement of AdS/CFT correspondence with a correspondence which looks intuitively much more realistic [K116], [L37].

Classical conformal charges would vanish for sub-algebra for which the conformal weights are multiples of some integer n, $n = 1, 2, \ldots$. These conditions would give the long-sought-for precise content to the notion of preferred extremal. These conditions would be the classical counterparts of corresponding quantum conditions and define a Bohr orbitology. This hierarchy would correspond to the hierarchy of Planck constants $h_{eff} = n \times h$ and to the hierarchy of dark matters [K44]. There would be infinite number of hierarchies $(1, n_1, n_2, ...n_i, ...)$ such that n_i would divide n_{i+1}. They would correspond to the hierarchies of inclusions of hyper-finite factors of type II_1 (HFFs) [K138]. Included algebra defines measurement resolution, which would thus realized as generalized conformal gauge symmetries. Evolution would correspond to a sequence of symmetry breakings: this is not a new idea but emerges naturally if n serves as a quantum "IQ".

The proposal is that that there is a finite number $n = h_{eff}/h$ of conformal equivalence classes of four-surfaces with fizxed 3-D ends at the opposite boundaries of CD so that the non-determinism with gauge fixing would be finite and would correspond to the hierarchy of Planck constants and hierarchy of conformal symmetry breaking defined by the hierarchy of sub-algebras of various conformal algebras with weights comings as integer multiples of integer $n = 1, 2, , \ldots$. These n surfaces would be analogous to Gribov copies for gauge conditions in non-Abelian gauge theories.

13.5.2 The Non-Determinisms Of Particle Physics And Biology

There was also a question about the non-determinism of partcle physics contra that of biology, where it manifests itself as partially free will.

NMP

Before continuing it is good make clear that a new principle is involved: Negentropy Maximization Principle (NMP) [K73]. Also a new kind of entanglement entropy based p-padic norm is involved. This entanglement entropy is negative unlike ordinary entanglement entropy and characterizes

two-particle system rather than single particle system. By consistency with quantum measurement theory it corresponds to identical entanglement probabilities $p_i = 1/n$.

Negentropic entanglement is assumed to be associated with pairs of n-sheeted coverings (at least these) defined by the space-time surfaces in n conformal equivalence classes associated with $n = h_{eff}/h$ and connecting same 3-surfaces at the ends of space-time surface. Two systems of this kind can entangle negentropically. The entanglement matrix associated with quantum computation proportional to a unitary matrix gives rise to negentropic entanglement. Also n-partite negentropic entanglement makes sense. Note that for hyper-finite factors of type II_1 the entanglement matrix is strictly unitary.

What could be common for particle physics and biology?

Basically the non-determinism of particle physics and of biology could be essentially the same thing but for living matter whose behave is dictated by dark matter the value of $h_{eff}/h = n$ would be large and make possible macroscopic quantum coherence in spatio-temporal scales, which are longer by factor n. Note that n could characterize macroscopic quantum phase rather than single particle system: this distinction is important as will be found.

The hierarchy of CDs brings additional spatio-temporal scale identified as secondary p-adic scale characterising the minimal size of CD. This size scales like $h_{eff}/h = n$ and one can think of a superposition of CDs with different values of n and that the average value of n measuring the age of self increases during the sequence of quantum jumps. Since n is kind of IQ, NMP says that conscious entities should become wiser as they get older: maybe this is too optimistic hypothesis in the case of human kind but maybe electrons are different! I swear that this interpretation is not due to the fact that I have passed the magic threshold of 60 years when one begins to feel that the aging means growing wisdom. I must confess that the interpretation of experience time flow in terms of increasing h_{eff}/h charactering CD scaling has not come into my mind earlier. One could even consider the possibility that there is no superposition - just a sequence of h_{eff}/h increasing (in average sense) phase transitions, kind of spiritual growth even at the level of elementary particles - or rather, the macroscopic quantum phases.

For instance, for electron characterised by Mersenne prime $M_{127} = 2^{127} - 1$ the minimal CD time scale is .1 seconds (note that it defines a fundamental biorhythm of 10 Hz) and thus macrotemporal. Corresponding size scale is of the order of Earth circumference. This size scale could characterize quite generally the magnetic body of the elementary particle or the magnetic body at which macroscopic quantum phase of particles resides. In both cases there would be a direct connection between elementary particle physics and macroscopic physics becoming manifest in living matter via alpha rhythm for instance.

What distinguishes between particle physics and biology?

There are essential differences between elementary particle physics and biology. The first differences comes from quantum measurement theory in ZEO.

1. The repeated state function reduction does nothing for the state in standard ontology. In TGD the state is invariant only at the second boundary at which the reduction occurs. For second boundary of CD the average value if n increases. This gives rise to the experienced flow of geometric time and the arrow of time. Self exists as long as reductions take place on same boundary of CD and dies as the first reduction to opposite boundary is forced by NMP.

2. In particle physics context one expects that the duration of self identified as a sequence of state function reductions at the same boundary of CD is much shorter than in living matter. Otherwise one would have too strong breaking of reversibility in elementary particle time scales. One could also argue that for visible matter the value of h_{eff} should not change in the first state function reduction to the opposite boundary.

   Here one must be very cautious. The flux tubes connecting the wormhole contacts serving as building bricks of the elementary particle could have very large h_{eff} having the p-adic prime characterizing the elementary particle as a factor and that the dynamics of elementary particles corresponds to the ordinary value of Planck constant as long as this flux tube is not involved. If the flux tubes mediate gravitational interaction scaling the size of the

gravitational bound state from the naïvely expected Planck scale to Compton length, the effects on other particle interactions would be negligible as gravitational interactions.

Objections usually help to make the formulations more precise. Now the objection is that the increase of average h_{eff}/h so that particles darken gradually, should have been observed long time ago since reaction rates are independent of Planck constant only the lowest order in h_{eff} that is in classical approximation. The attempt to circumvent this objection leads to two crucial questions?

1. Does h_{eff} characterize elementary particle (or fundamental fermion) or a magnetic/field body of physical system which could be also many-particle system.

   If $h_{eff}/h = n$ corresponds to n-sheeted covering which becomes singular at the ends of space-time surface so that sheets coincide at partonic 2-surfaces representing particles, it seems that large h_{eff} is a phenomenon assignable to the field/magnetic body inside CD rather than particle identified as partonic 2-surface or 3-surface at the end of CD. If so large h_{eff} effects would relate to the dynamics associated with the magnetic/field bodies carrying dark matter.

2. Is darkness single particle phenomenon or many-particle phenomenon? For the latter option elementary particle physics would not be any challenge so that it looks the reasonable option. Note that negentropic entanglement requires at least one pair of (say) electrons and suggests macroscopic quantum phase - say high-T_c super-conductivity or super-fluidity.

   The idea about evolution of many-electron systems at dark magnetic body generating increasing value of h_{eff} makes sense, and would conform with the observation that electrons secondary p-adic time scale defines fundamental bio-rhythm. Dark magnetic bodies carrying dark particles are indeed in key role TGD inspired quantum biology. Bose-Einstein condensates and spontaneously magnetized dark phases at magnetic bodies would conform with the idea that dark matter is many-particle phenomenon.

   Large h_{eff} would not be seen in elementary particle physics. This does not seem to support the idea that sparticles in TGD SUSY might have same p-adic mass scale as particles but be more stable in dark phase (this would be due to the scaling up of the size of CD) [K110]. Note however that in TGD already elementary particles are many-fermion systems so that it might be possible to circumvent this objection.

3. The original formulation for darkness was at single particle level so that h_{eff} characterizes elementary particles rather than many-particle systems. In elementary particle reactions the particles in the same vertex would always have the same value of h_{eff}/h. It was assumed that h_{eff} can change only in 2-vertex analogous to mass insertion vertex.

   The previous arguments suggest that darkness makes sense only for many-particle systems so that mass insertion vertex becomes phase transition. These phase transitions would occur routinely in living matter but as phase transitions involving large number of particles. For instance, bio-photons would result from dark photons in this manner. This picture seems to make sense at least at the level of many-particle systems but not necessary for Feynman graphs.

   This many-particle aspect would explain at very general level why the search for dark particles has been fruitless.

Could one regard elementary particle as a conscious entity?

The previous considerations support the view that it is macroscopic quantum phases of particles at magnetic flux tubes which can be seen as conscious and intelligent evolving entities experience the flow of time. In the case of single elementary particle previous arguments would suggest that only single state function reduction occurs at given boundary of CD so that the lifetime of elementary particle self would have zero duration! This in accordance with the absence of the arrow of time at elementary particle level. Strictly speaking this does not exclude consciousness but excludes intelligence and experience of time flow.

Could already systems with small particle number, be conscious entities and develop - not necessarily large - $h_{eff}/h > 1$. Hadrons consist of quarks and I have considered the possibility that valence quarks and gluons at the color magnetic body are dark. Also nuclei as many-nucleon systems could be dark. In TGD even elementary particles consist of fundamental fermions so that one can ask whether elementary particles possess some elementary aspects of consciousness identified as the possibility of non-vanishing "biological" life-time. This kind of picture would conform with the idea about consciousness as something emerging as the complexity of the system increases.

The average lifetime of elementary particle as a conscious entity cannot be longer than the life-time of particle in the sense of particle physics. In the case of electron having infinite lifetime as elementary particle the "biological" lifetime must be finite since otherwise the irreversibility would manifest itself as a breaking of time reversal invariance in electron scale. The temporal time scale of CD characterising the dimensions of the magnetic body of the elementary particle is the first order of magnitude estimate for the lifetime of elementary particle self. The "biological death" of electron means state function reduction in the sense of ordinary quantum measurement theory implying for instance localization of electron or giving eigenstate of spin in given quantization direction and these quantum jumps meaning re-incarnations of electron certainly occur.

This time scale could give an idea about the geometric duration of elementary particle self (the growth of the temporal distance between tips of CD during the sequence of reductions or equivalently the increase of n). One expects that Δn is by NMP rather small for single particle systems.

Could thermodynamical breaking of time reversal symmetry relate to the CP/T breaking in particles physics?

Could the "thermodynamical" breaking of time reflection symmetry (T) correspond to the breaking of T as it is observed for elementary particles such as neutral kaon? I think that most colleagues tend to be skeptic about this kind of identification, and so do I.

The point is that particle physicist's T breaking could be purely geometric whereas thermodynamical breaking of T involves the notion of subjective time, state function reduction, and consciousness. One could however ask whether the particle physicist's T could serve as space-time correlate for thermodynamicist's T and whether systems showing CP breaking could be seen as conscious entities in very primitive sense of the word ($n_f/n_i > 1$ but small). An important point is that the time evolution for CDs corresponds to scaling so that usually exponential decay laws are replaced with their hyperbolic variants. Hyperbolic decay laws become an important signature of consciousness. For instance, bio-photon intensity decays in hyperbolic manner.

Consider neutral kaon as example.

1. The mean lifetimes are of long-lived and short lived neutral kaon are $\tau_L = 1.2 \times 10^{-8}$ seconds and $\tau_S = 8.9 \times 10^{-11}$ seconds: the ratio of the time scales is roughly 2^7. This does not conform with the naïvest guess that the size of CD gives estimate for the duration of elementary particle self (increase of the temporal distance between tips of CD): the estimate would be $_L = 10^{-7}$ seconds from the fact that the mass of neutral kaon is roughly 10^3 times electron mass.

2. This is not too far from the lifetime of K_L^0 but is about 2^7 times longer than the life-time of short-lived kaon. Why K_S would be so short-lived? Could the lifetime be dictated by quark level: the longer time scale could be assigned as secondary p-adic time scale with the p-adic prime $p \simeq 2^k$, $k = 104$, characterising b quark. Could the short life-time be understood in terms of loops involving heavier quarks with shorter lifetimes as conscious entities: they indeed appear in the description of CP/T breaking?

13.6 Time For Time

I was very happy to find that Sean Carroll in Cosmic Variance (see `http://tinyurl.com/p9pvefz`) gave links to really interesting talks in Time conference arranged by fQXI. I have not been too happy for the elitistic nature of these conferences making impossible the communication of really new

theoretical ideas. By listening the brilliant talk [J61] by neuroscientist David Eagleman (see `http://tinyurl.com/credoxs`), I however learned that this conference made possible communication of extremely interesting experimental findings about the relation of the time of physicist to the subjective time. I sincerely hope that my colleagues would listen this talk and realize that there are fascinating problems to be solved. There is simply no theory and therefore no list of dead theories among which graduate student is allowed to choose as in theoretical physics.

Eagleman together with other neuro scientists make distinction between time and subjective time and the experimental work has revealed that this relationship looks very complex and is poorly understood. One of the key realizations forced by TGD inspired theory of consciousness - in a well-defined sense a generalization of quantum measurement theory - is that geometric time (the time of field equations) and subjective time (experienced time) are two different notions. The challenge is to understand how they relate and under what conditions and in what approximation their identification performed routinely my the naïve colleagues is possible. This was an excellent reason for continuing listening and I warmly recommend this for the reader. Also the other lectures might be equally rewarding. In the following I just represent TGD based interpretation of the findings and suggest that the reader would not take it too seriously and would try to build his or her own interpretation.

Eagleman talks about what he calls relativity of subjective time. This has of course nothing to do with the relativity of the geometric time. At the basic level subjective time need not even allow any metric measure (as is the case in TGD where subjective time corresponds to a sequence of quantum jumps).

13.6.1 Flash-Lag Effect And Its Modification

Eagleman tells first about very simple visual illusion known as flash-lag effect. One rotates a small circle around a circular orbit. As the circle passes the horizontal line there is a flash of light in the middle of the circle. If our perception were ideal the flash would be perceived in the middle of the circle. The circle is perceived to be 5 degrees ahead of the flash.

The first explanation to come in mind is that brain anticipates the motion of the flash and represent it to us in a position in which it would be in nearby future. Eagleman decided to test this proposal and studied three different situations. Two of them correspond to a circle rotating in opposite directions and the third one to a situation in which the circle stops at the position of the flash. The theory predicts that the circle is perceived to be ahead in all situations since the perveiver should not know anything about what happens in future. The surprise was that there was no flash-lag when the circle stopped. As if the brain would know what happens in the nearby future.

This kind of observation is not new. I remember more than a decade old experiment studing the galvanic response created by emotionally very provocative picture appearing as an odd-ball in a series of neutral pictures. This kind of response was observed. The mystery was that it was observed before the picture was seen! The result was of course not taken seriously by serious scientists. When a serious scientist associates something with the word "parapsychology" he loses totally ability to rational thinking and begins to rage.

The conclusion is that our moment of subjective time seems to have a finite duration about 80 ms and all events that occur in this time interval are associated with one and same moment of subjective time. This time interval would correspond to 12.5 Hz frequency. In TGD framework the interpretation could be in terms of the time scale assignable to causal diamond (CD) identified as intersection of future and past directed light-cones, which serves as embedding space-correlate for the moment of consciousness: this time would be the temporal distance between the tips of CD.

The fractal hierarchy of quantum jumps within quantum jumps (identifiable as with a hierarchy of selves withing selves) has the hierarchy of CDs as an embedding space correlate. For electron the time scale of CD is 100 seconds. What is troubling is that 80 ms corresponds to a time interval which is by 20 per cent shorter. One could of course assign this time scale to some cyclotron frequency in TGD framework but I would be very happy if it would correspond to a time duration of electron's CD.

As Eagleman tells, perception involves gaps. For instance, during saccadic motion necessary for visual consciousness (the explanation in TGD framework is that the conscious experience is associated with nondeterministic change, quantum jump) visual system is not on. We do not

however perceive these gaps although we perceive the gaps created by putting lights off. Could it be that the gaps are absent because the 100 ms CDs in the sequences have overlap producing on the average 80 ms intervals without overlap? Could the absence of gaps also tell us that it is retina and various sensory organs which build the fundamental qualia and that brain only constructs a cognitive representation about it decomposing the world to objects with certain properties and names and also builds all kinds of useful associations? This picture applies to all sensory qualia in TGD Universe and one can circumvent various objections against it in terms of TGD view about time.

13.6.2 We Live In The Past: But In What Sense?

One surprising fact about consciousness is that we live in the past. The justification for this in terms of standard neuroscience, where brain builds both sensory and cognitive representations of the external world, does not require refined arguments.

Neural communications are extremely slow using light-velocity as the standard. The velocities of nerve pulses are between 1-100 m/s as compared with the light velocity 3×10^8 m/s. The communication of the sensory data to brain takes time which can be of order second. The data coming from various sensory organs with varying velocities must be processed and combined to single view about external world at associative cortex. This takes time since it is the slowest signalst that determine the time used for the processing. Eagleman gives a humorous example: tall people should live father in past than the short ones since it takes longer time for neural signals from feet to arrive from cortex to the brain! Different sensory inputs must be also combined together in a realistic manner.

Is the brain really able to meet this enormous challenge? The representation about the external world is not enough: this representation must be also realistic and 80 ms seems to represent the maximum duration of moment of sensory consciousness. Is the velocity of nerve pulses quite too slow to achieve this? And is information processing based on nerve pulse conduction really fast enough?

1. These questions could have been motivation for TGD proposal (or almost-prediction) that sensory organs are seats of primary sensory qualia experienced instantanously.

2. They could have also motivated what proposal that quantum entanglement is needed to bind various parts of the body and brain to form single coherent conscious unit. Quantum entanglement makes possible effective signalling with infinite velocity. Of course, genuine signals are not in question. It is better to speak about macroscopic system behaving like an elementary particle. Dark matter realized as a hierarchy of macroscopic quantum phases with a larger value of Planck constant is what would make this possible.

3. Light velocity is ideal for the communication purposes in the scale of biological body. Could it be that biology might have been stupid enough to miss this kind of an opportunity? Could it be that neuroscientists are the stupid one and simply on a wrong track? In TGD inspired model dark photons with large value of $\hbar$ (bio-photons would be dark photons transformed to ordinary photons) define a central element both in the communications from sensory organs to brain and to magnetic body and from magnetic body to biological body. At the level of body the communications would be practically instantaneous.

4. Even in Earth length scale the time taken by EEG photons to travel from biological body to the corresponding layear of the magnetic body would still be be of order.1 seconds and the experiments of Libet demonstrate among other things that our sensory data is a fraction of second old. This has nothing to do with the conduction velocity of nerve pulses. The purpose of nerve pulses would be quite different: they would create fundamental memory representations and the model for this is based on DNA as topological quantum computer vision.

   Explaining this would however require TGD based view about memory as 4-D perception: causal diamonds are 4-D objects and our conscious experience is always about 4-D space-time region. For sensory perception the scale of this region is.1 seconds. For the perceptions that

we call memories the scale is often years or even decades. Our conscious experience is 4-dimensional. Also our motor actions are essentially 4-dimensional: moment of consciousness replaces 4-D world (or quantum superpositions of them) with a new one: also our geometric past is changed in every moment of consciousness. This view resolves many puzzles related to memory but time is far from mature for the revolution. My hope is that the talks of Time conference could open the minds of at least some young colleagues.

5. The communications with light velocity make possible feedback from brain to sensory organs making possible the building of standardized mental images by using the virtual sensory input from brain to create a charicature. Our brain would be an artist using primary sensory input as a raw material.

13.6.3 Kublai Khan's Problem And Three More Surprises

Eagleman tells about the problem of emperor Kublai Khan. At that time people did not have internet and being a head of an empire of the size of Asia posed many problems. Kublai Khan used emissars travelling around the empire and bringing news about what happened. The problems was the correct integration of these data: the news about ending of some local war somewhere could arrive before the news telling that it had begun! Brain is faced with a similar problem. When the television came, one of the big problems was thought to be the synchronization of pictures and sound. It however turned out that brain takes care of this problem if the picture and sound to be associated with each other are withing 80 milliseconds. The moment of subjective time has this duration.

That we live in past was the first surprise of neuroscience already discussed. Eagleman tells about three more big surprises of neuroscience.

Time perception recalibrates

The brain must build a logical story about sensory data coming through different sensory channels. To achieve this time perception recalibrates. When one comes from bright sunlight to a dim room, the response function of retina gets slower. This does not however happen at the level of conscious experience. A simple test is a sequence of button clicks causing a flash of light. Experimenter can cheat the subject person by producing the light flash with a delay. Surprisingly, the subject person notices nothing. What is even more surprising that when one adds to the sequence of click-flash pairs an odd-ball for which flash is not delayed, the flash is experienced to take place earlier than clicking! Again a direct evidence for the TGD prediction that our perceptive field is 4-dimensional.

In this kind of situation the natural conclusion of subject person would be that it was not me who did the click. Some other agent caused the flash whereas my own attempt fails. Eagleman suggests that schizophrenia might be a disorder of time perception. Person would attribute his own thoughs sometimes heard as internal voices to some external subjects since the time order is pathological. Maybe. What is known that schizophrenics have very sharp sensory perception which cannot be cheated and that there might be no re-calibration. Eagleman talks about temporal inflexibility. This is of course just a suggestion as Eagleman emphasizes. I am not enthusiastic about this kind of interpretation: the bicameral views of Jaynes fit much better with the idea that magnetic body uses biological body as sensory receptor and motor instrument.

Time is not one thing

Time perception is much more complex than one might think: it involves many aspects such as duration, simultanety, flicker rate, time ordering. What brain does is the analysis of the sensory imput, and its reconstruction from the resulting small pieces. This is very much what is done in the processing of the raw sound (and also pictures) in movies. This applies also to time perception. In TGD framework also the feedback from brain is essential and basic communications would take place using light. Nerve pulse patterns would serve quite different purpose and are also hopelessly slow for building the percept.

The rate of time flow correlates with the rate of neural metabolism

There is large number of findings supporting the few that the experienced rate for the flow of subjective time correlates with the rate of neural metabolism and therefore with the intensity of consciousness.

1. Slowing down of the subjective time

Slowing down of subjective time flow is familiar to anyone. This can happen in troublesome situation or in so called flow state. Interestingly, also in very boring situations (say waiting for someone to come) the same can happen. From my own experience I would say that the slowing down of subjective time characterizes very intense conscious experiences involving intense concentration. But why it would occur when you are bored: perhaps just because you are so intensely conscious about how boring your life is just now. You are not drowsy: you are inpatient and irritated.

Various explanations have been proposed. The proposal that the slowing down of time is analogous to the slowing down of the magnetic tape reducing the frequencies of sounds fails. Another explanation could be in terms of increased time resolution and also I have proposed this explanation. This explanation was tested.

Eagleman did an experiment which could be also seen as a tongue-in-cheek variant of Galileo's famous experiment in which he dropped various objects from the tower or Pisa and measured the time of fall and observed that it does not depend on the weight of the material object. Eagleman dropped subject persons instead of stones!

First of all Eagleman constructed an instrument which he calls perceptive chronometer producing random sequence of digits. In the simplest situation only single digit appeared alternatively as its positive or negative. As the rate of digits exceeds certain critical rate -presumably rather near to 12.5 Hz under normal circumstances- it becomes impossible to distinguish between subsequent digits: one sees only single fuzzy digit. The critical duration for the digit defines a natural unit of subjective time. The idea is to calibrate the rate of the chronometer in such a way that the subject person is not able to distinguish between digits but that only a small reduction of the digit rate makes this possible. In this kind of situation it is enough to make the person scared and see whether he becomes able to distinguish between subsequent digits.

What Eagleman wanted to test was whether this time resolution increases when a person is really scared. If so, the subjective time measured using this critical unit would be longer in scaring situations. The method of really scaring was ingenious: drop the person from quite high a tower! During the free fall the person first found the critical time resolution of his visual perception which became the time unit used to measure the time of fall. The rate for Person reported his time resolution in two cases: when another person was falling and during own fall. The resolution increased during own fall: the falling time was estimated to be about 36 per cent longer for own falling down using the resolution as a unit.

What does this mean? It seems that the rate of the experienced time flow depends on the level of neural activity. In TGD framework the proper measure of subjective time is single quantum jump (recall that they form fractal hierarchy): this would be the tick of subjective clock. The larger the number of these ticks in a given interval of geometric time, the longer the experienced time duration is. More abstractly: the number of sub-CDs within CD representing mental images of self would provide a measure for the number of ticks during single CD.

Since metabolic energy is the necessary prerequite for the build-up of sensory and cognitive representations (mental images), the prediction is that the rate with which metabolic energy is used by brain correlates directly with the rate of the experienced time flow. When the subject person is falling from a tower, the rate of brain metabolism is higher than normally so that the observations can be understood in terms of the theory. As a matter fact, the correlation of the subjective duration with neural activity is well-known in neuroscience and Eagleman gives a long list of examples.

2. Odd ball effect

In this experiment the subject person perceives a series of figures. The figures are identical apart from some odd-balls between the repeating ones. The duration of odd-ball is experienced to be longer than that of the repeating picture although it is the same. The explanation would be that brain wants to save energy. Less metabolic energy for repeating items and nore metabolic energy

for odd-balls, which literally wake-up the partially sleeping brain. The rate of neural metabolism correlating with the intensity of conscious experience (and number of quantum jumps per unit of geometric time/density of sub-CD: s within CD) seems to correlated directly with the experienced slowing down of time.

To sum up, the findings discussed by Eagleman are not easy to understand in the standard conceptual framework of neuroscience. The basic assumptions of TGD inspired theory of consciousness make the explanation trivial. In particular, the hierarchy of quantum jumps containing quantum jumps (of selves having sub-selves with sub-selves interpreted as mental images of self) and having as an embedding space correlate the hierarchy of CDs within CDs, explains the correlation of neural metabolic energy consumption with the experienced rate for the flow of subjective time. The higher the density of sub-CDs within CD representing mental images, the higher the intensity of conscious experience, the higher the consumption of metabolic energy to build mental images, and the shorter the average time interval taken by given mental image and serving as a natural unit of subjective time and the longer the experienced duration of time interval.

13.7 Some comments related to quantum measurement theory according to TGD

In the following some comments on quantum measurement theory inspired by FB discussions. The TGD view about time is involved because measurement theory in TGD relies crucially on zero energy ontology (ZEO).

13.7.1 Does the analog of repeated second quantization take place at the level of WCW?

The world of classical worlds (WCW) is the basic structure of quantum TGD. It can be said to be the space of 3-surfaces consisting of pairs of (not necessarily connected 3-surfaces) at the boundaries of causal diamond (CD) and connected by a not necessarily connected 4-surface. 4- surface defines the interaction between the states associated with the 3-surfaces. The state associated with given 3-surface correspond to WCW spinor and one has modes of WCW spinor fields. WCW decomposes to sub-WCWs assignable to CDs and effectively the universe reduces to CD.

The key idea is that the WCW spinor fields are purely classical spinor fields. No second quantization is performed for them. Second quantization of induced spinor fields at space-time level is however carried out and gamma matrices of WCW anticommuting to its Kähler metric are linear combinations of fermionic oscillator operators.

The classicality of WCW spinor fields looks somewhat problematic.

1. The classicality of WCW spinor fields has implications for quantum measurement theory. State function reduction involves reduction of entanglement between systems at different points of space-time and therefore also many-particle states and second quantization are involved. However, second quantization does not take place at the level of WCW and it seems that entanglement between two 3-surfaces is not possible. Therefore measurements at WCW level should correspond to localizations not involving a reduction of entanglement. Measurements could not be interpreted as measurements of the universal observable defined by density matrix of subsystem. This looks problematic.

2. At the space-time level second quantization is a counterpart for the formation of many-particle states. Particles are pointlike and one of the outcomes is entanglement between point like particles. Since the point of WCW is essentially point-like particle extended to 3-surface, one would expect that second quantization in some sense takes place at the level of WCW although the theory is formally purely classical.

3. Also the hierarchy of infinite primes suggests an infinite hierarchy of second quantizations. Could it have counterpart at the level of WCW: can WCW spinor field be second quantized and classical simultaneously?

Could the counterpart for the hierarchy of infinite primes and second quantization be realized automatically at WCW level? One can indeed interpret the measurements at WCW as either localizations or as reductions of entanglement between states associated with different points of WCW. The point is that the disjoint union of 3-surfaces X^3 and Y^3 can be regarded either as a pair (X^3, Y^3) of 3-surfaces in $WCW \times WCW$ or as a 3-surface $Z^3 = X^3 \cup Y^3 \subset WCW$. The general identity behind this duality $WCW = WCW \times WCW = ... = WCW^n = ...$

One could think the situation in terms of $(X^3, Y^3) \in WCW \times WCW$ in which case one can speak of entanglement between WCW spinor modes associated with X^3 and Y^3 reduced by the measurement of density matrix. Second interpretation as a localization of wave function of $Z^3 = X^3 \cup Y^3 \in WCW$.

13.7.2 About the notion of observable

In ordinary quantum theory observables are hermitian operators and their eigenvalues representing the values of observables are real.

In TGD using $M^4 \times CP_2$ picture the gauge coupling strengths are complex and therefore also classical Noether charges are complex. This should be the case also for quantum observables. Total quantum numbers could be still real but single particle quantum numbers complex. I have proposed that this is true for conformal weights and talked about conformal confinement.

Also in ordinary twistor approach virtual particles are on mass shell and thus massless but complex. Same is expected in TGD for 8-momenta so that one obtains particles massive in 4-D sense but massless in 8-D sense: this is absolutely crucial for the generalization of twistor approach to 8-D context. Virtual momenta could be massless in 8-D sense but complex but *total* momenta would be real. This would apply to all quantal charges, which for Cartan algebra are identical with classical Noether charges.

I learned also a very interesting fact about normal operators for which operator and its hermitian conjugate commute. As the author mentions, this trivial fact has remained unknown even for professionals. One can assign to a normal operator real and imaginary parts, which are commuting as hermitian operators so that - according to the standrd quantum measurement theory - they can be measured simultaneously.

For instance, complex values of various charge predicted by twistor lift of TGD would therefore in principle be allowed even without the assumption that the total charges are real (*total* charges as hermitian operators). Combining the two ideas one would have that single particle charges are complex and represented by normal operators and total charges are real and represented by hermitian operators.

13.7.3 What does amplification process in quantum measurement mean?

Quantum measurement involves an amplification process amplifying the outcome of state function reduction at single particle level to a macroscopic effect. This aspect of quantum measurement theory is poorly understood at fundamental level and is usually though to be unessential concerning the calculation of the predictions of quantum theory.

The intuitive expectation is that the amplification is made possible by criticality - I would suggest quantum criticality - and involves the analog of a phase transition generated by seed. This is like the change for a direction of single spin in magnet at criticality inducing change of the magnetization direction.

Quantum criticality [K31, K32, K33, K34] involves long range fluctuations and correlations for which $h_{eff}/h = n$ serves as a mathematical description in terms of adelic physics in TGD framework. Long range correlations would make possible the classical macroscopic state characterizing the pointer. This large $h_{eff}/h = n$ aspect would naturally correspond to the presence of intelligent observer: h_{eff} indeed closely relates to the description of not only sensory but also cognitive aspects of existence and has number theoretic interpretation as a measure for what might be called IQ of the system.

If this is tge case, one cannot build proper quantum measurement theory in the framework of standard quantum mechanics, which is unable to say anything interesting about cognition and observer. A theory of consciousness is required for this and ZEO based quantum measurement theory is also a theory of consciousness.

13.7.4 Zero energy ontology and Afshar experiment

Afshar experiment [D10] challenges Copenhagen and many-universe interpretations (see `http://tinyurl.com/ycsttpb9`) and it is interesting to look how it can be understood in ZEO.

Consider first the experimental arrangement of Afshar.

1. A modification of double slit experiment is in question. One replaces the screen with a lense, which reflects from slit 1 to detector 1' and from slit 2 to detector 2'. Lense thus selects the photon path that is the slit through which the photon came.

   The detected pattern of clicks at detectors consists of two peaks: this means particle behavior. One can say that at single photon level either detector/path/slit is selected.

2. One adds a grid of obstacles to the nodes (zeros) of the interference pattern at imagined screen behind the lense. The photons entering the points of grid are absorbed. Since grid is at nodes of the interference pattern this does not affect the detected pattern, when both slits are open but affects the pattern when either slit is closed (grids points are not nodes anymore). This in turn means wave like behavior. This conflicts with principle of complementary stating that either of these behaviors is realized but not both.

Consider the analysis of the situation in the usual positive energy ontology and assuming that state function reduction occurs at the detectors.

1. Photon wave function Ψ in the region between slits and lense is superposition of two parts: $\Psi = \Psi_1 + \Psi_2$ with Ψ_i assignable to slit $i = 1, 2$. The lense guides Ψ_1 to detector 1 and Ψ_2 to detector 2. State function reduction occurs and Ψ is projected to Ψ_1 or Ψ_2. Either detector 1 or 2 fires and photon path is selected.

   It however seems that state function reduction - choice of the path/slit - can occur only in the region in front of the grid. In the region between slits and grid one should still have $\Psi 1 + \Psi_2$ since for Ψ_i the grid would have effect to the outcome. This effect is however absent. This does not fit with Copenhagen interpretation demanding that the path of photon is selected also behind the grid. This is the problem.

2. What about the interpretation in ZEO? After state function reduction - detection at detector 1 say - the time evolution between opposite boundaries of CD is relaced with a time reversed one. To explain the observations of Afshar (no deterioration of the pattern at detector caused by grid), one must have time evolution in which the photons coming from the detectors in reversed time direction have wave functions which vanish at the points of grid. This determines the "initial" values for the reversed time evolution: they are most naturally at grid so that grid corresponds naturally to a surface at boundary of CD in question. This is of course not the only choice since one can use the determinism of classical field equations to choose the intersection with CD differently. If time reversal symmetry holds true, the final state in geometric past corresponds to a signal coming from slit 1 (in the case considered as example). There would be no problem! Afshar experiment would be the first laboratory experiment selecting between Copenhagen interpretation and ZEO based quantum measurement theory.

13.8 Maxwell's demon from TGD viewpoint

In Facebook I received a link to an interesting popular Science News article titled "*A New Information Engine is Pushing the Boundaries of Thermodynamics*" (see `http://tinyurl.com/y74bfrpu`). The article told about the progress in generalizing the conventional second law of thermodynamics to take information as an additional parameter.

Carnot engine is the standard practical application. One has two systems A and B, both in thermal equilibrium but with different temperatures T_A and $T_B \geq T_A$. By second law one has heat flow Q from A to B the two systems, and Carnot's engine transforms some of this heat to work. Carnot's law gives an upper bound for the efficiency of the engine as $\eta \equiv W/Q \leq (T_2 - T_1)/T_2$. The possibility to transform information to work forces to generalize Carnot's law.

Since information is basically conscious information, this generalization is highly interesting from the point of view of quantum theories of consciousness and quantum biology. Certainly the generalization is highly non-trivial. Especially so in standard physics framework, where only entropy is defined at fundamental level and is regarded as ensemble entropy and basically has very little to do with conscious information. Therefore the argumentation is kind of art work.

13.8.1 Maxwell's demon in its original form

Maxwell's demon (see `http://tinyurl.com/q829my5`) is a thought experiment in which one considers a system consisting of two volumes A and B of gas in thermal equilibrium at same temperature. At the boundary between A and B having a small hole sits a demon checking whether a molecule coming from A has velocity above some threshold: if so it allows the molecule to go to B. Demon monitors also the molecules coming from B and if the velocity is below the threshold it allows the molecule to continue to A. As a consequence, temperature and pressure differences develop between A and B. Pressure difference can do work very much voltage between the cathode and anode of battery. One can indeed add a tube analogous to wire between ends of the entire system and pressure difference causes a flow of mass doing thus work: one has pump.

The result is in conflict with the second law and one can ask what goes wrong. From the Wikipedia article one learns that a lot of arguments have been represented con and pro Maxwell's demon. Biologist might answer immediately. Demon must measure the states of molecules and this requires cognition and memory, which is turn require metabolic energy. When one takes this into account this, paradox should disappear and second law should remain true in a generalized form in which one takes into account the needed metabolic energy.

13.8.2 Experimental realization of Maxwell's demon

The popular article describes an experiment actualizing Maxwell's demon carried out by Govind Paneru, Dong Yun Lee, Tsvi Tlusty, and Hyuk Kyu Pak (see `http://tinyurl.com/y9sn9j7o`). Below is the abstract of the article *Lossless Brownian Information Engine* published in Phys Rev Letters.

We report on a lossless information engine that converts nearly all available information from an error-free feedback protocol into mechanical work. Combining high-precision detection at a resolution of 1 nm with ultrafast feedback control, the engine is tuned to extract the maximum work from information on the position of a Brownian particle. We show that the work produced by the engine achieves a bound set by a generalized second law of thermodynamics, demonstrating for the first time the sharpness of this bound. We validate a generalized Jarzynski equality for error-free feedback-controlled information engines.

Unfortunately, the article is behind paywall and I failed to find it in arXiv. The popular article uses notions like "particle trapped by light at room temperature" and photodiode as "light trap" without really defining what these expressions mean. For instance, it is said that the light trap would follow particles moving in definite direction (from A to B in Maxwell's thought experiment). I must admit that I am not at all sure what the precise meaning of this statement is.

13.8.3 TGD view about the situation

TGD inspired theory of consciousness can be regarded as a quantum measurement theory based on zero energy ontology (ZEO) and it it is interesting to try to analyze the experiment in this conceptual framework.

TGD view about the experiment

The natural quantum interpretation is that the photodiode following the photon is performing repeated quantum measurements, which in standard quantum theory do not affect the state of the particle after the first measurement. From the viewpoint of TGD inspired consciousness, which can be regarded as a generalization of quantum measurement theory forced by zero energy ontology (ZEO), the situation could be as follows.

1. Photo-diode following the particle by would be like conscious entity directing attention its to the particle and keeping it in focus. In TGD Universe directed attention has as classical space-time correlates flux tubes connecting attendee and target of attention: in ER-EPR correspondence the flux tubes are replaced with wormholes, which suit better to GRT based framework. Flux tubes make also possible entanglement between attendee and target. The two systems become single system during the period of attention and one could say that the attention separates the particle from the rest.

2. Directed attention costs metabolic energy. Same would be true also now - photo-diode indeed requires energy feed. Directed attention creates mental image the conscious entity associated with the mental images can be regarded as a generalized Zeno effect or as a sequence of weak measurements.

   Tracking would thus mean that particle's momentum is measured repeatedly so that the particle is forced to continue with the same momentum. Gradually this would affect the thermal distribution and generate temperature and pressure gradients. Directed attention could be also seen as a mechanism of volition in quantum biology.

3. This looks nice but one can ask what about the collisions of the particle with other molecules of gas: don't they interfere with the Zeno effect? If the period between repeated measurements is shorter than the average time between the collisions of particles, this is not a problem. But is there any effect in this case? The directed attention or a sequence of quantum measurements could separate the particle from the environment by de-entangling it from the envirobment. Could it be that collisions would not occur during this period so that attendee and target would form a subsystem de-entangled from rest of the world?

ZEO variant of Maxwell's demon

Zero energy ontology (ZEO) [L72] forces to consider different arrangement producing energy somewhat like in perpetuum mobile but not breaking the conservation of energy in any obvious manner. The idea pops into my mind occasionally and I reject it every time and will do so again.

1. Zero energy states (ZESs) are like physical events: pairs of positive and negative energy state with energy E and $-E$: this codes for energy conservation.

2. One can have quantum superposition of ZESs with different values of energy E and with average value $\langle E\rangle$ of energy. In state function reduction $\langle E\rangle$ can change and in principle this does not break conservation of energy since one has still superposition of pairs with energies E and $-E$.

3. For instance, the probabilities for states with energy E could be given by thermal distribution parameterized by temperature parameter T: one would have "square root" of thermodynamic distribution for energies. "Square root" of thermodynamics is indeed forced by ZEO. One would have essentially entanglement in time direction. Single particle states would realize square root of thermodynamical ensemble, which would not be a fictive notion anymore.

   The coefficients for the state pairs would have also phases and these phases would bring in something new and very probably very important in living matter. System characterized by temperature T would not be so uninteresting as we think, there could be hidden phase information.

If T increases in reduction then $\langle E\rangle$ increases in state function reduction. Reduction could also measure the value of E. Could the system increase its $\langle E\rangle$ in state function reductions? My proposal for an answer is "No".

In ordinary thermodynamics energy should be fed from environment to increase $\langle E\rangle$: how environment would enter into the game now?

1. State function reduction always reduces the entanglement of system S with environment, call it S_{env}. Could the increase of $\langle E\rangle$ be compensated by compensating change of $-\langle E\rangle$ in S_{env}. Indeed, the conservation of energy for single state is expected have statistical counterpart: energy would come from environment as a kind of metabolic energy. Therefore also the "square root" of thermodynamics would prevent perpetuum mobile.

2. This would be the case if the reduction measures the energy of the entire system $S_{tot} = S + S_{env}$ - so that S_{tot} is always in energy eigenstate with eigenvalue E_{tot} and E_{tot} does not change in reductions and in unitary evolutions between them. Can one pose this condition?

Time reversal and apparent breaking of second law in zero energy ontology (ZEO)

ZEO based theory of consciousness [L72] forces to consider also a genuine breaking of the second law.

1. In ZEO self as a conscious entity corresponds to a generalized Zeno effect or equivalently a sequence of analogs of weak measurements as "small" state function reductions. The state at passive boundary of CD is unaffected as also the members of state pairs at it.

   Second boundary of CD (active boundary) shifts farther away from the passive one and the members of state pairs at it change giving rise to the conscious experience of self. Clock time time identified as temporal distance between the tips of CD increases. This gives rise to the correspondence between clock time and subjective time identified as sequence of weak reductions.

2. Also "large" state function reductions are possible and also unavoidable. The roles of active and passive boundary are changed and time reversal occurs for the clock time. One can say that self dies and re-incarnates as a time-reversed self.

   At the next re-incarnation self with the original arrow of clock time would be reborn and continue life from time value shifted towards future from the moment of death: its identity as a physical could be however very different. One can of course wonder whether sleep could mean a life in opposite direction of clock time and wake-up a reincarnation in the usual sense.

   The time-reversed self need not have conscious memories about its former life cycle: only the collections of un-entangled subsystems at passive boundary carry information about this period. A continuation of conscious experience could however take place in different sense: the contents of consciousness associated with the magnetic body of self could survive the death as near-death-experiences indeed suggest.

3. The time reversed system obeys second law but with opposite time direction as normally. Already Italian physicist Fantappie proposed that this occurs routinely in living matter and christened the entropy for time reversed systems syntropy [J121]. Processes like spontaneous assembly of complex molecules from their building bricks could be controlled by time reversed selves.

   In TGD inspired biology motor actions could be seen as generation of signal propagating backwards in time and defining sub-system with revered arrow of time and inducing the activity preceding motor activity before the conscious decision leading to it is made: this with respect to geometric time. There are many effects supporting the occurrence of these time reversals.

4. How the possibility of time reversals relates to the second law? One might argue that second law emerges from the non-determinism of state function reduction alone. Second law would transform to its temporal mirror image when one looks the system from outside with unchanged arrow of clock time.

   But does the second law continue to hold in statistical sense as one takes average over several incarnations? One might think that this is the case since generalized Zeno effect generalizes ordinary Zeno effect and at the limit of positive energy ontology one would effectively have a sequence of ordinary state function reductions leading leading to second law.

Negentropy Maximation Principle (NMP)

TGD also predicts what I call Negentropy Maximization Principle (NMP) [K73] [L72].

1. Entanglement coefficients belong to extension of rationals allowing interpretation as both real and p-adic numbers in the extension of p-adics induced by the extension of rationals defining the adele.

One can assign ordinary entanglement entropy to the real sector of adele and entanglement negentropy with the p-adic sectors of adelic physics: for latter the analog of ordinary Shannon entropy is negative and thus the interpretation as conscious information is possible. The information is assigned with the pairing defined by entanglement whereas entropy is associated with the loss of precise knowledge about the state of particle in entangled state.

2. One can also consider the difference of sum of p-adic entanglement negentropies and real entanglement entropy as the negentropy. This quantity can be positive for algebraic extensions of rationals and its maximal value increases with the complexity of the extension and with p-adic prime.

   Also the information defined in this manner would increase during evolution assignable to the gradual increase of dimension of algebraic extension of rationals, which can take place in "large" state function reductions (re-incarnations of self): if the eigenvalues of density matrix are algebraic numbers in an extension of the extension of rationals, the "large" state function must take place.

3. NMP would hold true in statistical sense - and mathematically very much analogous to second law - and would relate to evolution. In particular, one can understand why the emergence of intelligent systems is - rather paradoxically - accompanied by the generation of entropy. To have large entanglement negentropy in p-adic sectors one must have large entanglement entropy in real sector since same entanglement defines both.

Dark matter as phases of matter labelled by the hierarchy of Planck constants

The hierarchy of Planck constants $h_{eff}/h = n$ [K31, K32, K33, K34, K90] is a further key notion in TGD inspired quantum biology.

1. The hierarchy of Planck constants $h_{eff}/h = n$ implied by adelic physics as physics of both sensory experience (real numbers) and cognition (p-adic number fields) is basic prediction of TGD [L70]. Planck constant characterizes the dimension of the algebraic extension of rationals characterizing the cognitive representations, and is bound to increase since the number of extensions with dimension larger than given dimension is infinite whereas those with smaller dimension is finite.

2. The ability to generate negentropy increases during evolution. System need not however generate negentropy and can even reduce it. In statistical sense negentropic resources however increase: things get better in the long run. In biology metabolic energy feed brings to system molecules having valence bonds with $h_{eff}/h = n$ larger than that for atoms [L65], and this increases the ability of the system to generate negentropy and in statistical sense this leads to the increase of negentropy.

The most recent ZEO based view about demonic activities in TGD Universe

Maxwell's demon is at the boundary of the region which can be seen as physics disregarding totally the observer. Maxwell's demon allows only particles with velocity above threshold to travel from A to B. This leads to generation of pressure gradient in conflict with the second law.

The basic objection against Maxwell's demon is that the demon is an intelligent living being which thinks and although there is no mainstream physical theory about cognition, the empirical fact is that this requires metabolic energy feed. This must be taken in account also and means that the development of the gradient requires metabolic energy.

In zero energy ontology (ZEO) one must reconsider the situation since time reversal occurs in ordinary state function reductions (BSFRs) [L108]. This means time reversed dissipation and forces a generalization of the second law [L104]. For the observer with the standard arrow of time, this shows itself as a generation of various gradients, demonic activity.

Living matter is full of examples of self-organization in which such this seems to happen and the explanation is in terms of non-equilibrium thermodynamics and thermodynamical fluctuations basically. Essential is that energy flows are involved as in the example of Maxwell demon and metabolic energy feed explains this partially. But eventually the energy flows are gradients and

eventually disappear and heat death of the Universe occurs. The emergence of life therefore seems very implausible: England [?] would be thus incorrect [L35].

Usually the energy flow to the system is taken as passive - arranged from outside. In ZEO the opposite arrow of time makes it active. System extracts energy from the environment, "eats" rather than waiting for the food to flow into its mouth spontaneously and to creep to the stomach without help. This leads to what I call remote metabolism or credit card mechanism as a way to extract radiative energy from the environment or from systems analogous to population inverted lasers able to provide it.

Living matter is also full of examples about self-organized criticality (SOC) very difficult to understand in standard thermodynamics. System manages to stay near a critical state which is by definition unstable. This is nothing but homeostasis [L194]. What in standard biology looks like extremely tightly planned programs involving endlessly various biochemical pathways is unplanned spontaneous dissipation with a reversed arrow of time: this simplifies enormously the biological modelling. In time reversed direction critical state is an attractor rather than repeller and time reversal would be the basic mechanism of homeostasis.

There are specific molecules - stress proteins (SPs) specialized to act as coolers, heaters, and heat engines using the thermal energy at their magnetic body (MB), whose temperature has maximum - presumably near physiological temperature - by the fact the number of degrees of freedom is infinite [L194]. SPs a near this maximal temperature known as Hagedorn temperature and have very large heat capacity. Stress molecules provide in the case of cold shock energy to DNA and basic proteins to heat them so that they remain functional. In the case of heat shock they reduce the temperature of the environment by sucking thermal energy by time reversal for their magnetic body serving as an energy reservoir. They can act also as heat engines driving molecular motors.

13.9 Why the outcome of an event would be more predictable if it is known to occur?

I learned from Reza Rastmanesh about highly interesting findings of Armor and Sackett, and this section is essentially the article [L199] written together with him about the topic.

Past research in experimental psychology has brought evidence showing that certain changes in internal neurocognitive environments of human subjects can influence their predictions of near future events. In the series of experiments published in a recognized psychological Journal of Personality and Social Psychology, Armor and Sackett [J39] examined how the nature of future events influence the participants´ predictions about their future performance in different tasks.

In Study 1, half of participants were informed that they will complete a scavenger hunt task, i.e. finding particular objects at the university campus during 30 minutes, whereas the second half of participants were not informed. Thus, the expectations of participants were manipulated in terms of real versus hypothetical future events and this manipulation also causes different changes in internal neurocognitive environments in each half of participants. The participants were asked "How well will you do on the scavenger hunt?" or "How well would you do, if you were asked to complete the scavenger hunt?". After that, all the participants completed the scavenger hunt task and their predictions were compared with their real performance in this task. Strikingly, participants who did expect to complete the task predicted their own performance quite accurately. In contrast, participants who believed that the task is only a hypothetical future event showed much higher prediction-performance discrepancy, i.e. they were not able to predict their future performance accurately.

These findings were replicated also in Study 2, where another kind of task was used (a completion of test used for Graduate Record Examination). One may ask how it is possible that participants that were informed about their future life event predicted their real performance in the task better than non-informed participants. The authors of this study were quite surprised by obtaining these results and labeled them as "seemingly anomalous findings". If this finding is real it provides a difficult challenge for model builders.

In the context of Minkowski spacetime, several possible explanations can be theoretically conceptualized:

1. In classical GRT, the causal structure is the structure of light cones of the space-time metrics. As the matter-energy degrees of freedom determine the metric through Einstein's equations, the causal structure of a region of space-time is dynamical: it depends on the state of the matter energy in its past light cone. If one identifies the causality of human actions experienced as acts of free will with the deterministic causality of field equations, the ability to predict the near future is theoretically possible. This applies also to person's own behavior if it does not involve free will: if this is the case, the two causalities cannot be identified.

2. Also a general quantal explanation may be considered. Quantum measurement provides information. In the context of the above-outlined experiments, the participants who were told about the purpose of the experiment gained information. Could this action have involved state function reduction of some kind improving the ability to predict their own future? Also this option would assume that HOs are passive inspectors of their own fate and does not conform to the direct experience of having (partially) free will.

3. One can consider also an explanation in terms of precognition based on future-to-past communications requiring change of the arrow of time and therefore also violation of standard thermodynamics. Precognition is classified as belonging to the field of parapsychology by materialists accepting only a single arrow of time. Also this explanation fails if one accepts free will: precognizing of own unpredictable acts of free will is impossible.

In the sequel the problems of various physicalistic explanations are discussed in more detail and the TGD based model relying on zero energy ontology (ZEO) [L108] replacing the standard ontology of quantum theory in TGD framework and solving the basic paradox of quantum measurement theory. The basic prediction is that the arrow of time changes in "big" (ordinary) states function reductions (BSFRs) but is preserved in "small" SSFRs as analogs of "weak" measurements. This forces to distinguish between geometric and subjective time.

This leads to an understanding of the findings of Libet [J44] about active aspects of consciousness challenging the reality free will: in BSFR the arrow of causality changes and the outcome of BSFR causes the neural activity rather than vice versa. Also the findings of Armor and Sackett seem to give direct support for the physicalistic picture: the members of group A would be passive inspectors of their own future actions and therefore would have not free will. Precognition, which is not accepted in the physicalistic framework, is however required, which suggests that BSFRs transforming precognition to memory recall might be involved.

In the sequel the findings of Armor and Sackett are taken at face value and an explanation based on TGD inspired theory of consciousness relying on zero energy ontology (ZEO) allowing to get rid of the basic paradox of quantum measurement theory is proposed. There are 2 new elements essential for the explanation.

1. There is a hierarchy of magnetic bodies carrying dark matter as $h_{eff} = nh_0$ phases of ordinary matter and defining a self-hierarchy.

2. The time reversal in BSFRs makes memory recall in reversed time direction possible: these memories need not be personal and it is possible to get information about the memories of MB at a higher level of hierarchy with a reversed arrow of time after BSFR.

In the scavenger hunt BSFR at higher level would be assignable to the experiment which had already occurred with respect to subjective time at a higher level of the hierarchy in the geometric future of participants. This BSFR would be followed by a cascade of BSFRs proceeding to shorter scales in subjective future but located in the geometric past.

The subject persons who were told that that they will participate a scavenger hunt would have received non-personal memories about those abstract aspects of the scavenger hunt at higher level of hierarchy, which they could not affect by BSFRs: the number of objects found by the participant would have been this kind of aspect and already determined by a BSFR at a higher level of hierarchy. Ordinary motor action would be very similar process involving communications to lower levels of self hierarchy in the geometric past.

This explanation is akin to the earlier TGD based explanation [L32] [K125] for psychedelic experiences in which subject persons experience meeting of representatives of advanced civilizations of outer space. That these encounters could be actual telepathic contacts was proposed in

a book about psychedelic induced experiences titled as "Inner paths to outer space" (http://tinyurl.com/gnb4bp9) written by Rick Strassman, Slawek Wojtowicz, Luis Eduardo Luna and Ede Frecska [J93]. In ZEO the arrow of time is not fixed so that instantaneous communications over arbitrarily long distances become possible by what might be called time reflection involving BSFR.

The explanation relies on sending a signal, which is reflected back as a time reversed signal (involving BSFR): this allows to circumvent the barrier caused by finite speed of light. In principle this would make signalling with arbitrarily distant civilizations possible.

13.9.1 Why the standard physics based explanation for the findings of Armor and Sackett looks implausible?

What seems clear to me is that it is very difficult to understand the findings of Armor and Sackett [J39] - if real - in the standard physics framework.

1. Standard physics excludes precognition: the thermo-dynamical arrow of time is fixed and also the quantization procedure of quantum field theory fixes the arrow of time. Creation operators create states and annihilation operators destroy them. The change of arrow of time would change the roles of these operators. Classically this corresponds to the fact that signals propagate in preferred direction only. It is difficult to see how quantum effects according to standard QM could help. State function reductions happen in standard physics only in very short scales and have no effect in macroscales. They do not make possible effective precognition.

2. The idea that the persons in group A got bored after they had found the number of objects that they had estimated to find does not work since the same should have happened in group B.

3. The experimenter effect [K69] is encountered in parapsychology experiments and also in experiments involving living subjects (testing of drugs). There are extremely successful parapsychology experimenters and often their findings cannot be replicated. Could the experimenters somehow affect the subject persons so that the outcome of the experiment is what the experimenter would regard as desired? Physicalists deny the possibility of this kind of effect so that fraud or bad experimentation remains the only explanation. The reality of Placebo effect cannot be denied and suggests that the state of mind of the patient affects the healing in conflict with the physicalistic expectations. These effects are discussed from the TGD point of view in an article [K69] prepared in the project organized by Lian Sidoroff. Experimenter effect leads to ask whether the strong belief of experimenter on the expected result could induce the result also in the experiment of Armor and Sackett. This hypothesis could be tested by replicating the experiment sufficiently many times by other experimenters.

4. The causal reference frame model of Guerin and Bruckner [J39] involves a rather speculative proposal that classical GRT could allow anomalies in which the order of events is different for different observers modelled in terms of lightcones. One can ask whether it could differ in the recent experiments between participants a in group A and participants b in group B. For persons in group A it would have been changed and they could "remember" their performance whereas the participants in B only estimated it since they did not know that effective memory recall is possible! The information would have entered as classical signals in reversed time direction to the participants in group A. Somehow the information about the participation to the actual experiment would have made possible this effective change of arrow of time.

   Classical Relativity predicts that gravitation is extremely weak interaction so that the explanation does not look plausible to me. There are however some black-hole like solutions of Einstein's equations known as Kerr-Newman metrics [B24] describing rotating objects having opposite arrows of time in near-field and far-field regions but these solutions do not seem relevant in the recent case.

   It is difficult to see how standard quantum physics could help. One must however notice that there is no generally accepted quantum theory of gravitation.

13.9.2 A model for the findings of Armor and Sackett based on the notions of magnetic body (MB) and zero energy ontology (ZEO)

TGD based explanation of the findings relies on the notions of magnetic body (MB) and zero energy ontology (ZEO).

The notion of magnetic body (MB)

The notion of classical field differes from that it classical field theories. Gauge potentials - in particular electromagnetic gauge potential - are induced from the spinor connection of embedding space $M^4 \times CP_2$ as defining static and non-dynamical gauge potentials. Sama applies to gravitational field as deviation from flat metric of Minkowski space. The dynamics of space-time surface makes the induce gauge potentials and metric dynamical. Locally the dynamics is however extremely simple since only 4 field like variables are involved. Even approximate superposition of fields is lost and possible only for massless modes propagating in the same direction and is replaced with superposition of effects.

This extreme local simplicity is compensated by the extremely complex topology of the many-sheeted space-time distinguishing TGD from standard model plus General Relativity. Many-sheeted space-time prevailing in long length scales means that there is very large number of space-time sheets parallel in the sense that they intersecting 4-D M^4 projections. This is crucial for all applications. Any system the induced gauge fields at space-time sheets characterizing the system and since these sheets are separate for separate system, these induce fields do not interfere. One can say that the system has field body, in particular magnetic body (MB). In gauge theories this is not the case.

How does this picture relate to ordinary field theoretic description. Particle like entity as a small 3-surface touches all space-time sheets with 4-D M^4 projection and therefore experiences the sum of induced gauge fields associated with the space-time sheets. Effects superpose and this superposition corresponds basically to a set theoretic union of space-time surface with intersection M^4 projections. In ordinary field theory this is used as justification for the assumption that fields superpose. Field theory limit of TGD is defined by replacing the many-sheeted space-time with single regions of M^4 with gauge fields and gravitational fields defined as superpositions of the induced fields.

Also brain has MB. Quite generally MB is assumed to contain dark matter identified as ordinary matter characterized by extension of rationals with dimension $h = h_{eff}/h_0 = n$ measuring algebraic complexity and having interpretation as a kind of universal IQ. Also the scales of quantum coherence increase with h_{eff}. The layers of MB characterized by the value of n form naturally a slaving hierarchy in which ordinary matter with smallest Planck constant is at the bottom and controlled by higher levels. The energies of systems increase with h_{eff} and since h_{eff} tends to be spontaneously reduced, energy feed is needed to preserve the distribution of h_{eff}: the interpretation is as metabolic energy feed.

In the TGD framework the onion-like hierarchical structures of MB of brain would correspond to brain regions. The structure of MB with levels labelled by extensions of rationals characterized partially by $n = h_{eff}/h_0$ measuring the scale of quantum coherence, would also reflect the geometric and topological structure of the brain. There is evidence that functionally similar neurons can be modelled using statistically determined hyperbolic geometry [J76]. Functionally similar neurons not necessarily near to each other physically would be near to each other in the effective hyperbolic geometry.

In TGD framework MB could realize this hyperbolic geometry quite concretely as an abstract representation of the hierarchical functional structure of brain [L129]: functionally similar neurons and also higher level structures would be connected to nearby points at MB by flux tubes. Classification experienced as putting similar things to the same box is one of the basic cognitive functions and hierarchy of MBs could realize classification geometrically: functionally similar neurons would be connected by flux tuges to points near each other at MB - they would belong to the same box.

There is an astonishing finding supporting the notion of MB. The neurons of the brain of salamander were shuffled like a pack of cards. The salamander however recovered and preserved its memories (identified as learned behaviors) [J146]. In [K93, K95] this finding was considered

as a support for the view about the brain as an analog of hologram (for the idea about TGD Universe as a conscious hologram see [K18]). It is however clear that a single neuron cannot represent the information content of the entire brain. However, if memories are represented by the images of neurons at the level of MB, the shuffling of neurons has no effect on memories as indeed found. Neurons would represent the analog of RAM in computer science.

What does ZEO mean?

The TGD based explanation would be based on ZEO allowing to solve the basic paradox of quantum measurement theory. First a brief summary of ZEO [L108].

1. In ZEO quantum states are not 3-dimensional but superpositions of 4-dimensional deterministic time evolutions connecting ordinary initial 3-dimensional states. By holography they are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced with a new superposition. Classical determinism of individual time evolution is not violated and this solves the basic paradox of quantum measurement theory. There are two kinds of quantum jumps: ordinary ("big") state function reductions (BSFRs) changing the arrow of time and "small" state function reductions (SSFRs) (weak measurements) preserving it and giving rise to the analog of Zeno effect [L108].

2. To avoid confusion it is good to emphasize some aspects of ZEO.

   (a) ZEO does not mean that physical states in the usual 3-D sense as snapshots of time evolution would have zero energy state pairs defining zero energy states as initial and final states have same conserved quantities such as energy. Conservation implies that one can adopt the conventions that the values of conserved quantities are opposite for these states so that their sum vanishes: one can think that incoming and outgoing particles come from geometric past and future is the picture used in quantum field theories.

   (b) ZEO implies *two* times: subjective time as sequence of quantum jumps and geometric time as space-time coordinate. These times are identifiable but are strongly correlated.

3. In BSFRs the arrow of time is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. BSFRs can occur in all scales since TGD predicts a hierarchy of effective Planck constants with arbitrarily large values. There is empirical support for BSFRs.

   (a) The findings of Minev *et al* [L99] in atomic scale can be explained by the same mechanism [L99]. In BSFR a final zero energy state as a superposition of classical deterministic time evolutions emerges and for an observer with a standard arrow of time looks like a superposition of deterministic smooth time evolutions leading to the final state. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution in which case the process does not lead to anywhere: the interpretation would be that BSFR back to the initial state occurs!

   (b) Libets' experiments about active aspects of consciousness [J44] can be understood. Subject person raises his finger and neural activity starts before the conscious decision to do so. In the physicalistic framework it is thought to lead to raising of the finger. The problem with the explanation [J34] is that the activity beginning .5 seconds earlier seems to be dissipation with a reversed arrow of time: from chaotic and disordered to ordered at around .15 seconds. ZEO explanation is that macroscopic quantum jump occurred and generated a signal proceeding backwards in time and generated neural activity and dissipated to randomness.

(c) Earthquakes involve a strange anomaly: they are preceded by ELF radiation. One would expect that they generate ELF radiation. The identification as BSFR would explain the anomaly [L101]. In biology the reversal of the arrow of time would occur routinely and be a central element of biological self-organization, in particular self-organized quantum criticality (see [L104, L194].

Some implications of ZEO

ZEO has profound implications for understanding self-organization [L104] and self-organized quantum criticality [L194] in terms of dissipation with non-standard arrow of time looking like a generation of structures. ZEO could also allow understanding of what planned actions - like realizing the experiment under consideration - could be.

1. Second law in the standard sense does not favor - perhaps even not allow - realization of planned actions. ZEO forces a generalization of thermodynamics: dissipation with a non-standard arrow of time for a subsystem would look like self-organization and planned action and its realization.

   Could most if not all planned action be like this - induced by BSFR in the geometric future and only apparently planned? There would be however the experience of planning and realizing induced by the signals from geometric future by a higher level in the hierarchy of conscious entities predicted by TGD! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than agents with completely free will.

2. The notion of magnetic body (MB) serving as a boss of ordinary matter would be central. MB carries dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n serving as a measure for algebraic complexity of extension of rationals as its dimension and defining a kind of universal IQ. There is a hierarchy of these phases and MBs labelled by extension of rationals and the value of n.

   MBs would form a hierarchy of bosses - a realization for master slave hierarchy. Ordinary matter would be at the bottom and its coherent behavior would be induced from quantum coherence at higher levels. BSFR for higher level MB would give rise to what looks like planned actions and experienced as planned action at the lower levels of hierarchy. One could speak of planned actions inducing a cascade of planned actions in shorter time scales and eventually proceeding to atomic level.

3. This interpretation is actually not new. I proposed in [L191, L193] that motor actions could correspond to BSFRs and sensory percepts to their time reversals. It took still some time to realize that sensory perceptions naturally correspond to SSFRs ("weak" measurements), and that both BSFRs and SSFRs can occur with both arrows of time. Motor action would be a cascade of BSFRs with each BSFR inducing sensory perceptions as SSFRs at lower level inducing in turn motor actions as BSFRs in shorter time and length scales. The above model is a generalization of this picture.

The model

Could one apply ZEO also to the experiment under consideration?

1. Could one think that the experiment involving BSFR had in some sense already occurred (with respect to subjective time) when the experimenters got the idea to perform the experiment as a control signal from the geometric future? Experimenters and participants would have been like neurons in the brain of participants of Libet's experiment demonstrating that neural activity precedes experience about act of free will [J44]. They did what the already occurred experiment forced them to do. They of course had a lot of free will but not at this level of hierarchy of conscious entities but in shorter time scales and this made possible the needed preparations.

2. Experimenter informed the members of group A about the arrangement of the experiment. Therefore the members of group A concentrated on a process which was actually an attempt

to remember in a reversed time direction and they were successful. The participants in group B did not know that the experiment would be arranged and made only guesses.

3. The objection is that in applications to atomic systems, Libet's experiments and earthquakes, one speaks of what an outsider with the standard arrow of time observed. Now one however talks about the participants of experiments and BSFR would now affect them. Does this really make sense?

   Here the notion of MB could come in rescue. BSFR would occur at the level of a collective MB of the system involving participants and experimenters and induce the outcome of BSFR and would change the arrow of time only at this level of MB. The participants at lower levels of hierarchy would receive information from the collective MB as time reversed control and communication signals. The signals would be received if the participant tunes herself to the correct wavelength - that is performs a memory recall, which would become possible after learning that the experiment will be actually performed.

13.9.3 How could the higher levels of MB use the brain to realize their free will?

The proposed model assumes that the experienced long terms goals (in the recent case the goal of experimenter to perform the experiment) correspond to SFRs that have already occurred at some higher layer of MB controlling the brain.

Neuroscience supports the view that frontal lobes are responsible for long term planning and decision making. They are involved also with the self model. This suggests that the highest layers of MB control frontal lobes. There would be a hierarchy of layers of MB having frontal lobes at the bottom.

Model for the coupling of MB with frontal lobes in terms of cognitive entanglement

A natural assumption is that the control of biological body by MB involves entanglement. Since frontal lobes are associated with high level cognition, this entanglement could be cognitive entanglement discussed in [L134]. Cognitive entanglement is a hierarchical entanglemen between wave functions in hierarchy of sub-groups in the factorization of Galois group to a product $G_1G_2...G_n$ of sub-groups reflecting directly the representationof extension as extension of extensions of .... of rationals.

What is special is that entanglement is directed like attention and hierarchical just like for the slaving hierarchy. The entanglement between states in group algebras of G_1 and $G_2...G_n$ is directed from boss G_1 to slave $G_2..G_n$. Cognitive SFRs are cascades proceeding downwards and reducing entanglement. Negentropy Maximization Principle can however prevent the cognitive measurement cascade from proceeding down to G_n [L157] if it does not give rise to negentropy gain.

Long term goals could involve this kind of cognitive entanglement assignable to directed attention and motor actions as BSFRs at this layer of MB would produce what is experienced by the levels of the hierarchy with the standard arrow of time as a behavior with long term goals. This would produce what could be regarded as analog of precognition [L191] and identifiable as sensory perception of signals propagating to non-standard direction of time. Precognitive dreams would be an example of this.

What happens when frontal lobes are damaged?

This vision conforms with what happens when frontal lobes are damaged. Although intellectual abilities are not lost, long term planning is not possible and the patient loses the ability to initiate actions. Damage can also lead to idiot savant phenomenon [J65]. Although the person seems to lack conceptual thinking completely, he/she can possess miraculous looking mathematical skills [L49] [K106] or artistic gifts [L36] [L36]. In some poorly understood sense idiot savants can be extremely intelligent.

Is the character of the cognitive entanglement changed or replaced with something totally different in these situations? TGD predicts two kinds of information related to two different

representations of genetic code which relate to each other like function represented by its local values to its Fourier transform as a non-local and holistic representation [L132, L154]. The local representation of the genetic code is in terms of bits and using sequences of genetic codons as units of 6 bits. The second representation is in terms of 3-chords of light defining the allowed chords of a bio-harmony. Music expresses and induces emotions and bio-harmony would characterize a mood. Emotional intelligence would relate to this representation. Could it be that for idiot savants non-verbal emotional intelligence dominates.

The duality of these two representations of genetic code is highly analogous to the duality of momenta and position coordinates in wave mechanics. In quantum TGD this duality has as an analog $M^8 - H$ duality [L127, L128] stating that space-time surfaces can be regarded as 4-surfaces in $H = M^4 \times CP_2$ or in M^8. $M^8 - H$ duality relates these representations. H corresponds to ordinary differential geometric space-time representation involving also the notion of field. M^8 identifiable as 8-D momentum space corresponds to non-local algebraic and number theoretic representation, which is non-local and holistic since the momenta are analogous to frequencies. Scattering amplitudes in particle physics provide an example of this representation.

Both representations can be used and it depends on the situation which representation is more appropriate. Could it be that for ordinary *resp.* emotional intelligence H *resp.* M^8 representation is more appropriate? Could one exaggerate and say that not only idiot savants but also people in timeless meditative state and experiencing no separations (produced by cognitive SFRs), and maybe also children "live" in M^8 whereas the ordinary people with their tight time schedules and busily performing comparisons "live" in H? Momentum eigenstates are delocalized.

Are meditative states labelled by finite simple groups?

What could be the counterpart of meditative state without cognition be at the level of cognitive representations? Could it correspond to a situation in which it is not possible to create separations as decompositions to unentangled system pairs by reducing the entanglement between the factors of the Galois group G?

This is certainly the case if G is simple, that is does not allow this factorization at all. Simple finite groups are the basic building bricks of finite groups: the classification theory for simple groups [A2] (`https://cutt.ly/Pj2i2Nx`) states that simple finite groups is cyclic and of prime order, alternating group consisting of even permutations of n objects, group of Lie type or one of the 26 sporadic groups or Tits group. The meditative states of pure consciousness would correspond to finite simple groups!

A question about possible classification of meditative states definitely raises eyebrows. But the power of mathematics is miraculous: if one agrees that thinking means SFRs (thought generates separations and comparisons) and that in meditative states thinking ceases, this is the conclusion. Rather paradoxically, the "idiot savant state" would be cognitively irreducible in the same sense as the states of Hilbert space with prime dimension do not allow a representation as entangled states. They would represent elementary particles of cognition - fundamental ideas - from which more complex thoughts are composed by performing repeated extensions. The basic advice of meditative practices is to stop thinking: maybe this is indeed the manner to achieve the state of understanding.

Chapter 14

Quantum Model of Memory

14.1 Introduction

The ideas related to the quantum model of memory have developed gradually from very general ideas to reasonably concrete models and a connection with biological quantum computer type systems has emerged. It is good to list the basic ideas and notions briefly to get and idea about this process which is still continuing.

14.1.1 ZEO And Self

Zero energy ontology (ZEO) allows a rigorous formulation of earlier vision about memories as something involving communication with geometric past using negative energy signals.

1. In ZEO unitary M-matrix between positive and negative energy parts of zero energy state defines particular zero energy state. M-matrices characterize zero energy states and are square roots of density matrices reducing to a product of real and diagonal hermitian matrix and unitary S-matrix S common to al of them. M-matrices can be assumed to be orthogonal and form effectively orthogonal basis of matrices.

2. Self corresponds to a sequence of repeated state function reductions in which neither the passive boundary of CD nor states at it is changed. The state function reduction sequence corresponds at the active boundary to a sequence of U-processes each followed by a localization in the moduli of the active boundary but without any state function reduction at it.

   This sequence of state function reductions gives rise to the experienced flow of time and the contributions to consciousness from passive boundary give rise to the experience about static observer, the self and to varying contribution to the experience representing sensory input. Figure-background separation is clearly involved.

   The first state function reduction to the active boundary means death of self and its reincarnation at formerly active boundary. Self experiences time reversal, and for mental images of self (sub-selves) this change is certainly highly non-trivial and must have effect on how self experiences the sub- self.

This chapter was written much before the emergence of ZEO based view about self and I have kept the text almost as such trying to add some comments about how the ZEO based view simplifies the situation. For instance, the considerations related to the life-time of self reduce to few lines if ZEO based view is applied.

14.1.2 Geometric And Subjective Memories

The identification of moment of consciousness as quantum jump between histories suggest two kinds of time developments, subjective and geometric, and therefore also two causalities and memories. By the 4-dimensional general coordinate invariance (GCI) of quantum TGD, geometric memories

contain information about entire quantum and classical histories. This means that there is no absolute need to store memories of the geometric past to the geometric now. This has dramatic implications for the modelling of brain and allows to get rid of the basic problem of the memory models, namely the fact that the storage of new memories unavoidably tends to destroy the old memories whereas it seem that childhood memories are actually the most stable ones.

Strong form of holography allows to make more this picture more precise. Information about memories is coded by data assignable to string world sheets and partonic 2-surfaces and the partonic 2-surfaces and strings connecting them would appear as carriers of the basic data. Even more, at the this level only the strings carry the data about Yangian Noether charges of super-sympelectic generating the zero energy states.

To remember geometrically means sending signal to the geometric past and receiving it. In ZEO this means that some sub-self (mental image) dies (or falls a sleep) and re-incarnates so that signals traverse to the direction of geometric past. After than death and re-incarnation (wake-up) occurs again and this means positive energy signal to the geometric future possibly creating the mental image about memory becoming conscious after wakeup of sub-self.

Subjective memories could result from time-like entanglement between sub-selves defined by M-matrix. In this case the square root of the matrix appearing in M-matrix would reduce to a projection operator multiplied by S-matrix having no elements beween the sub-space defined by projection operator and its orthogonal complement. Therefore one would have negentropic entanglement (NE) with a unit density matrix. This kind of memories would be interpreted as sharing of mental images of future and past selves. It is somewhat questionable whether this mechanism is mathematically feasible.

14.1.3 Spin Glass Model Of Memories

One of the relatively early ideas was that the 4-dimensional quantum spin glass property of TGD universe must have fundamental role in the realization of memories. Spin glass property predicts fractal energy landscape in which there are valleys inside valleys inside valleys and memories correspond to self-organization patterns associated with sub-self having interpretation as processes leading to bottoms of various valleys. In TGD framework energy minima are replaced by the maxima of Kähler function defining configuration space geometry as a function of zero modes which are effectively classical variables in the sense that in each quantum jump a complete localization occurs in these variables. One can also consider the interpretation of "energy" as binding energy of bound states as function of zero modes. The higher the value of the binding energy, the deeper the valley, and the higher the probability that system ends up to the bound state and the longer the time spent in the bound state.

Four-dimensionality means in ZEO that 3-surfaces are pairs of 3-surfaces at opposite boundaries of CD connected by a preferred extremals for which classical Noether charges in quantum critical sub-algebra of super-symplectic algebra vanish. This means very strong correlations between 3-surfaces at the boundaries of CD implying that they are analogous to Bohr orbits. This also implies that self-organization can be regarded as occurring for the superpositions of space-time surfaces analogous to representations of behaviors or functions in the sense of biology.

One can also regard life as a process of carving a 4-dimensional statue gradually quantum jump by quantum jump. The longer the extension of the valley in the temporal direction and the larger the number of copies of the valley is, the more reliable the memory recall is. The best way to learn to remember is to remember. The depth of emotion determines how deep and long in temporal direction the valleys representing memories are.

14.1.4 Mirror Mechanism

MEs provide a mechanism of long term memory which differs from ordinary sensory perception only in that the ME giving rise to a geometric memory has much longer duration with respect to the geometric time than the ME giving rise to ordinary sensory perception. To remember something at temporal distance T in the past is to look at a mirror with length $L = cT/2$. The mirrors in question must have astrophysical sizes measured in light years typically and this of course raises obvious objections against the model. Although this mechanism as such is too strong an idealization, it can serve as a starting point. For instance, MEs can be also curvilinear and

could propagate along closed magnetic flux loops of the personal magnetic body serving effectively as wave cavities and suffer few reflections: this would make possible high precision targeting.

At quantum level remembering means sharing of mental images: this corresponds to the quantum entanglement between the sub-selves of the geometric now and of the geometric past. The classical non-determinism of Kähler action is essential in making possible entanglement between systems having time-like separation. This would be the mechanism of episodal memory, For non-episodal memories only the mental image representing the desire to remember would be shared, and the answer from the geometric past could be realized as classical communications using MEs. Commmunication would be based on some code, perhaps memetic code, and would generate a conscious experience in the receiving end, typically verbal memory. Positive energy MEs would propagate with ultra low effective phase velocity inside brain or along magnetic flux tubes of astrophysical size with sub-luminal effective velocity (say alpha wave effective velocity). The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

In this framework synaptic strengths code only cognitive representations and learned associations, not genuine information about the events of the geometric past. Brain can be seen as kind of a collection of standardized features serving as building blocks of sensory and memory representations. Long term memory is coded in the classical em/gravitational fields associated with and in coherent light/gravitons generated by MEs in hologram like way. Any finite space-time region receiving the classical em field of coherent light/gravitons generated by it gets hologram like picture containing info about entire geometric time interval spanned by ME. If vacuum current is localized to some restricted space-time region (it can be!), the hologrammic information is about this region and receiver anywhere along the ME gets more or less the same information since hologram is in question. Note also that the light-likeness of the boundary of ME implies that ME selves have temporal extension defined by the length of ME.

14.1.5 Third Person Aspects Of Memory

Topological quantization implies the notion of field body: field body accompanies any system be it molecule or human body. Field body serves as kind of a manual providing higher level abstract representations about the quantum aspects of the physical body. The model of sensory representations realized at personal magnetic body and at Earth's magnetic body explains both the first and the third person aspects of our sensory experience. Also memories should have third person and transpersonal aspects realized at the magnetic body of Earth. This prediction is testable: moon traveller consciousness should have different third person aspect or this aspect could be even absent. Third person aspect should be crucial for the generation of social structures and the rapid weakening and reversal of Earth's magnetic field predicted to occur within next 2 millenia might have dramatic effects for the future of the civilization.

The sharing of mental images is crucial for the model of the third person aspect of memories. What happens is that sub-self of brain entangles with with the sub-self of the magnetic sensory canvas in the geometric past. One could perhaps interpret spontaneous episodal memories as a basic example of memories communicated by some sub-self of magnetic Mother Gaia to us.

14.1.6 Symbolic And Cognitive Representations Of Memories

Most of our memories are not direct re-experiences. In fact, it would be difficult to tell whether memory is really in question if this were the case. Rather, memories are highly conceptual and based on symbolic representations making possible huge filtering and compression of information. Only in some special cases direct re-experiencing occurs. The inherent nondeterminism of the p-adic field equations and the classical non-determinism of Kähler action make possible to represent sequences of quantum jumps determining the contents of consciousness of self at space-time level in terms of p-adic or real space-time sheets, that is cognitively and symbolically. Symbolic representations are crucial for memories whereas cognitive representations are crucial for intentions. Symbolic representations allow to store information about geometric past to geometric now: history writing

is just this kind of activity. Also brain is doing history writing: to remember is also to form a new memory representation.

It is highly plausible that memory representations are highly abstracted and that the signals from the geometric past do not recreate directly the experience but serve as names for standardized self-organization patterns of neuronal activity, "features" giving charicature of the experience. This means that it is not easy to distinguish between TGD based model and standard model of memories.

14.1.7 Bio-Supercomputers And Memories

The most recent but certainly not the last step in the development of ideas was the realization of a connection between macrotemporal quantum coherence, quantum spin glass property of the TGD universe, classical and quantum gravitation, and the mirror model of geometric memories.

The interpretation of quantum jump as a creation of a totally entangled holistic state $U\Psi_i$ which is then analyzed to pieces allows to interpret self measurement cascade as a conscious analysis. The temporal fractality of consciousness suggest that the lifecycle of any self can be seen as a generation of multiverse of potentialities followed by analysis (and decay) process. One can see the situation also differently. The conscious experience of self is average over moments of consciousness and the eventual thermalization induced by the quantum jump sequence destroys all conscious information. There must be some mechanism hindering this and making macrotemporal quantum coherence possible.

To achieve macrotemporal quantum coherence self must be irreducible self for which self measurements and analysis do not occur. The self must also have large number of zero modes transformed to quantum fluctuating degrees of freedom and this is achieved if self corresponds at space-time level to a join along boundaries condensate. In this process the zero modes of the condensing space-time sheets become quantum fluctuating degrees of freedom. In this "state of oneness" self is able to carry out quantum computer like information processing which is the diametrical opposite of analysis. The decay of this bound state to its components corresponds to the analysis period at the level of self.

Macrotemporal quantum coherence is possible by the quantum spin glass property of TGD universe making the lifetimes of bound states much longer than in the universe obeying standard physics. Different almost degenerate vacuum space-times differ only because they have different classical gravitational energies. The quantum transitions between these almost degenerate states involve emission of MEs representing gravitons. These topological graviton rays are reflected from the curved almost vacuum space-time sheet acting as a gravitational mirror and self energy diagrams involving emission and absorption of the gravitonic ME have interpretation as correlates for the geometric memory recall. The time scale of human memories is between millisecond and 100 years and this time scale characterizes the gravitational energies for systems having sizes between cell size and cell membrane thickness (the number theoretical miracle is that all p-adic length scales in this range correspond to Gaussian Mersennes). Microtubules are excellent candidates for realizing long term declarative memories at bit level so that a connection with Penrose-Hameroff views emerges.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L29].

14.2 Different Types Of Memories

TGD predicts two kinds of memories corresponding to two different time developments. There is deterministic (in generalized sense) time development with respect to the geometric time and the nondeterministic time development by quantum jumps with respect to the subjective time. The memories with respect to subjective time are about previous conscious experiences and "real" whereas geometric "memories" are prophecies giving simulations of the geometric past and future assuming that quantum jumps do not alter the macroscopic properties of the space-time surface. A good visualization is following: each quantum jump represents particular geometric memory whereas the heap of these memories gives rise to subjective memory. The comparison between expectations and reality is obviously a central part of mentality and the heap structure implies

that this comparison is a basic function of conscious mind not reducible to anything simpler. It is well-known that our memories involve a lot of construction and are more like stories consistent with what we actually have experienced than actual documents of what happened. Perhaps geometric memories constrainted by subjective memories give rise to the "story".

One can distuinguish between several memory types such as short term memory and long term memory, episodal memory, procedural memory, implicit memory and associative memory, and it is interesting to try to find whether these memories could be understood in the proposed conceptual framework. In the discussion below concrete mechanisms for the realization of geometric memory are not discussed: the reader interested on this aspect of geometric memory can consult [K50].

14.2.1 Geometric And Subjective Memories

There are two times in TGD: subjective and geometric. In accordance with this there are also two kinds of memories: subjective and geometric[1].

1. The temporal binding of the experiences associated with quantum jumps occurred after the last "wake-up" of the self gives rise to subjective memory defined as memory about earlier conscious experiences and is identifiable as an immediate conscious memory, "psychological now", presumably of duration of fraction of second in case of sensory experiences. There is infinite hierarchy of subjective memories and if long term memories are genuine subjective memories (this need not be the case!), they could correspond to conscious short term memories of higher level selves somehow communicated to the lower level. An essential element is the possibility of sub-selves inside self having much shorter lifetime and organized in a subjecto-temporal sequence: without them the average over the quantum jumps would destroy the information and it would not be possible to remember the digits of a phone number. Various rhythmic actions (such as micro tremor of eyes at 80 Hz frequency and muscle tremor) could generate a sequence of sub-selves with constant duration and thus a clock measuring subjective time.

2. Geometric memories are like a classical physics based model for the universe. They are memories with respect to geometric rather than subjective time and predict what must have happened in the geometric past and what will happen in the geometric future assuming that world is classical (no quantum jumps). The temporal extension of the mind-like space-time sheets and the notion of the association sequence (3-surfaces consisting of a sequence of space-like 3-surfaces with time-like separations providing a simulation of classical history) make possible geometric memories. A natural hypothesis is that the macroscopic space-time associated with the final state of the quantum jump represents the geometric memory. Of course, only part of it becomes conscious and temporal binding implies that self experiences kind of temporal average of the geometric memories associated with the quantum jumps. An attractive possibility is that our long term memories, which have narrative character and are unreliable, correspond to geometric memories. This would mean that there is no need for memory storage mechanisms, four-dimensional brain would take automatically care of memory storage.

Intentionality manifests itself in many ways: as expectations of the future, planning, goals, desires, fears, imagination, intuition etc.. It seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to identify all aspects of intentionality with the predictions of the expected geometric future provided by the mind-like space-time sheet. Geometry as such contains nothing intentional. Rather, the intentional aspects of the conscious experience reflect the attitudes towards the expectations provided by the geometric memory.

[1]The attribute "subjective", as it is used in TGD context, does not have quite the same meaning as it usually has as something non-objective and unreliable: "subjective" derives its meaning from "subjective time" as consciously experienced time as opposed to the geometric time of physics.

"Memories" with respect to geometric time as simulations

Geometric memories are predictions/simulations for what would happen if no further quantum jumps would occur and what would have happened if no quantum jumps had occurred in the past. Simulations and expectations rather than real memories are in question. Geometric memories become reliable in the classical limit, when the effect of quantum jumps becomes negligible. In the deterministic world of classical physics geometric memories would be absolutely reliable. It is indeed possible to predict rather reliably what will happen in the solar system during the next decade. Geometric memories are a prerequisite of the intentionality often regarded as a basic characteristic of conscious mind: beliefs, expectations, plans, etc. involve geometric memory in an essential manner. The computational approach to mind assumes only geometric memories.

The memory with respect to geometric time is possible even assuming that single quantum jump determines the contents of conscious experience completely. However, if the contents of conscious experience are determined completely by the initial and final quantum histories of single quantum jump, it is in principle impossible to have genuine memories about previous conscious experiences. This does not make it impossible to have a model for the most probable subjective life history through simulation. Quantum statistical determinism could make these simulations possible. One must however admit that the hypothesis about subjective memory, naturally identifiable as a short term immediate memory defining the duration of psychological moment, makes things extremely simple and natural. One could also argue that in a universe without subjective memory it would not be possible to discover the notion of quantum jump so that internal consistency of the theory of consciousness requires genuine memory about earlier conscious experiences.

Mindlike space-time sheets and simulations

It is a fact that we can plan future in the time scale of life time. We can also quite reliably extrapolate to the past without direct memory of what happened. The simplest explanation is that the time extension associated with those mind-like space-time sheets, which we have access to, is of the order of lifetime or perhaps even longer. The simplest model for the simulation would be based on an ensemble of thoughts scattered around entire material space-time history defined by, say, my body. Quark sub$-CD$s could realize thoughts as Boolean algebra of statements and could be present everywhere in condensed matter, in particular in water, which is expected to have very rich hierarchy of space-time sheets. Self would experience the sum of the abstracted experiences of ensemble members and experience a simulation about what happens in future and what happened in past assuming that quantum jumps will not occur in future and did not occur in past.

Of course, selves could also do what computers do, namely mimic other selves by building cognitive representations about them at their own space-time sheets. This would make it unnecessary to jump between the levels of the self hierarchy. These representation could have quite different temporal and spatial scales and the presence of the time scaled versions about time development of other selves would realize the fractality aspect related to the idea about Universe as a hologram. DNA could be an example of this kind of simulation of the entire lifespan of individual in molecular length and time scales. Monte Carlo simulation of elementary physics experiment could be also regarded as a simulation of this kind.

The difference between intentions and geometric memories

Intentionality, understood here as time-directedness, manifests itself in many ways: as expectations of future, planning, goals, desires, fears, imagination, etc.. The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. The temporal extension of the mind-like space-time sheet makes possible expectations of what happens in the future assuming that no quantum jumps occur or at least that quantum jumps do not change the macroscopic space-time. Single quantum jump contains information about this kind of expectations. Subjective memory in turn tells what happened actually. Therefore it seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to identify the predictions of the expected geometric future provided by the mind-like space-time sheet as a basic prerequisite of intentionality.

Subjective memory makes it possible to compare the expectations with what really occurred since subjective memory is kind of a heap of predictions of future arranged with respect to the value of the psychological time. The origin of at least some emotions, which often involve a comparison of what happened and what was expected to happen, is perhaps here. It is quite well possible that all comparisons must be realized as comparisons of the subjective and geometric time developments. It seems that self can also compare its sub-selves, which correspond to simultaneous mental images.

The possibility of this comparison provide a solution to the paradox raised by the innocent question "How do I know that the me of today is the same as the me of the yesterday? How do I even know that I existed yesterday?". The solution might be simple: mind-like space-time sheets have extension which can be much longer than the duration of the subjective memory. Therefore subjective memories contain information about the geometric me of the yesterday and geometric me of today and since these me's resemble each other quite a lot, the conclusion is that also the yesterday's me was a conscious self living in this same body. It is however quite possible that temporal entanglement with higher selves still remembering my past wake-up states is also involved and realized as a formation of join along boundaries bonds between the mind-like space-time sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

What is the temporal extension of mind-like space-time sheets?

With respect to subjective time self and its sub-selves can be characterized by the typical durations of the wake-up state. With respect to the geometric time self (or rather, mind-like space-time sheet) can be characterized by its own duration and the durations of the mind-like space-time sheets which it contains. The time span for the predictions and memories provides an estimate for the duration of mind-like space-time sheets. mind-like space-time sheets can have time-like separations. Mind-like space-time sheets of geometric past could represent memories so that conscious memories could be regarded as multitime experiences and the distances between mind-like space-time sheets could be quite large, of order lifetime.

Zero energy ontology allows to answer this question quantitatively. Space-time surfaces correspond to surfaces inside causal diamonds (CDs) having space-like ends at the boundaries of CDs and the size scale of CD characterized the size scale of self as a geometric entity. The order of magnitude for the size scale is expected to be of the same order of magnitude as duration of life cycle of self.

In ZEO based view about self, the size of CD is not equal to the life-time of self. Rather, the increase of the size scale of self during state function reduction sequences taking place at same boundary of CD and not changing state at it defines the life-time of self.

Life-spans of sub-selves

Sensory experiences seem to correspond to a well defined geometric now having perhaps duration of order .1 seconds. Thus it seems that mind-like space-time sheets representing my sensory sub-selves have rather short time extension, of order .1 seconds. "Ontogeny recapitulates phylogeny principle" (ORP) suggests that the extension is of same order as the duration of the immediate subjective memory, something like .1 seconds. This prediction is certainly consistent with the typical resolution of the sensory experience, say the ability of the visual system to discriminate subsequent pictures as separate pictures. Quite generally, the p-adic time scale $T_p = L_p/c$ characterizing the mind-like space-time sheets gives the first guess for the duration of the mind-like space-time sheet and duration of geometric memory provided by it. Note that .1 seconds gives for the p-adic length scale L_p and estimate which is about circumference of Earth!

The fact is that we have childhood memories, plan future and make reliable predictions. This is not in contradiction with the duration of the mind-like space-time sheets associated with sensory sub-selves. The mind-like space-time sheets representing sub-selves (mental images) can be located in geometric past or future so that multitime experiences with mind-like sheets of past and future contributing to the experience are possible.

The duration of .1 seconds is the duration of typical sub-selves representing our mental images. The geometric duration of the mind-like space-time sheet representing our "main self"

should be much longger since it contains mind-like space-time sheets distributed along entire life span.

The sub-selves which have fallen asleep, wake-up again generating new wave of sensory experience. For instance, mental images (after images) typically re-appear periodically. We are also mental images of larger self in the hierarchy and the periodical appearenc e of of our mental images suggests that also we appear periodically as mental images of this larger self. This would mean reincarnation in the geometric past so that our life would be lived again and again. Entire trains of mind-like space-time sheets could wander through time again and and experience what it is to live in a particular body. Therefore my body could live again and again: by p-adic evolution each life would tend to be slightly better than the previous one. The civilizations of past could be still well and alive and even more civilized! This picture could perhaps explain why persons in their old age sometimes begin to live their childhood again.

As already noticed, the ZEO based view about self allows a precise identification for the life-time of self.

What is the subjective duration of "our" self?

Our conscious experience is some kind of an averaged sum over all conscious experiences associated with the quantum jumps occurred after the last "wake-up". If the averaging is completely democratic, the only possibility is that our sensory sub-selves have duration not much longer than the the time resolution of the sensory experience of order .1 seconds. Contrary to the original beliefs, this does not in principle pose any limitation to the duration of "our" self.

There are thus several options concerning the duration of our self.

1. Our self could have duration not much longer than the duration of immediate short term memories of order .1 seconds. The ability to remember digits of a phone number requires that the duration is indeed longer. For this option it is not at all obvious how the subjective experience of personal continuity is possible.

2. The duration could also correspond to the wake-up period. Also now the problem is how we know that this self existed already yesterday. Note that the gradual thermalization of sub-selves means that subjective memories represented by sub-selves get gradually fuzzy so that the digits of a phone number are forgotten even if our self has duration of order wake-up time.

3. Our self has a duration of order lifetime, or even longer and only the mental image representing our physical body has duration of order lifetime. A possible objection is that the mental image representing our self becomes gradually more and more entropic unless it manages to fight against second law. This might of course correspond to ageing.

Third option deserves a more detailed consideration.

1. The geometric duration of our "main" mind-like space-time sheet should be of the order of life span if geometric memory explains long term memories. "Ontogeny recapitulates phylogeny" principle would suggest that also the subjective duration of our "main" self is of order life time. This option would explain elegantly the fact that we possess subjective identity: this kind of subjective identity would be a logical deduction in case that our main self has duration shorter than life time.

2. This option would mean that we are not actually unconscious during sleep but are only unable to remember anything about what happened during sleep. This would be rather natural since various sensory and cognitive sub-selves are not conscious during sleep periods so that also multitime experiences in which sensory sub-selves wake-up in night time are rare! It might be also possible to remember events occurred during sleep state only during sleep.

3. Note that the claims about near death experiences in which entire life is experienced as a kind of film, could be interpreted as very intensive experiences in which mind-like space-time sheets along the entire life span "wake-up" and give rise to multitime geometric memories. Alternatively, if bodily self with a duration of order lifetime is a sub-self of our self (perhaps

identifiable as the self associated with our magnetic body), the bodily self representing entire life cycle could be experienced as a mental image. Also shorter bodily sub-selves forming a subjectotemporal sequence, "film", could be experienced in the absence of the ordinary sensory input.

ZEO based answer is that our life-time corresponds to the increase of the size scale of CD serving as correlates for us. The simplest expectation is that this size scale is of same order of magnitude as our CD.

14.2.2 Habits, Skills, Associations

The universe of TGD is quantum spin glass [K103]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/ associations are formed.

1. Mental images (in particular memories) correspond to sub-selves undergoing self-organizing time development by quantum jumps leading to self-organization patterns selected by dissipation. Thus both memes and genes, in particular long term memories, can be regarded as winners in the fight for survival in which dissipation is the ultimate Darwinian selector. Inhibitory and excitatory nerve pulses might physically realize "frustrations" which make possible large number of almost degenerate energy valleys.

2. The universe of TGD is quantum spin glass characterized by a fractal "energy" landscape having valleys inside... inside valleys (directories inside...inside directories). This structure is ideal for a hierarchical representation of memories. Memories must correspond to valleys of the spin glass "energy" landscape into which dissipation takes the system. Memory formation is active process and memories are charicatures rather than photos and deep valleys of the energy landscape represent these charicatures. Hippocampus, known to be involved with the formation of the long term memories, could control the rate of motion in these control variables. The plastic regions of the brain are the most spin-glassy ones and are the most probable seats of the long term memories.

3. System has some territory in the energy landscape. The motion in the zero modes serving as control variables causes a slow shift of the entire territory. Synaptic strengths corresponds naturally to the slow control variables characterizing the position of the territory. In the presence of a metabolic energy feed and sensory input system moves around this territory.

ZEO and NMP provide powerful additional tools, which were not available when the first version of this chapter was written. In ZEO self-organization can be seen as self-organization of 4-dimensional patterns having as space-time correlates space-time surfaces (preferred extremals of Kähler action) connecting space-time 3-surfaces at opposite boundaries of causal diamond. One can say, that basic objects are not 3-D time=constant snapshots but entire time evolutions. Behavioral patterns, functions, habits are the natural basic notions. This has especially interesting implications to morphogenesis, where the notion of magnetic body as kind of morphogenetic field and template for the self-organization of matter around it, becomes the key notion [K69]. Equally interesting are the applications to genetics and neuroscience [**?**]

14.2.3 Is Genuine Subjective Memory Really Necessary?

For a long time the basic hypothesis of TGD inspired theory of consciousness was that the contents of conscious experience are determined totally by the initial and final states of *single* quantum jump. A heavy objection against this assumption is that the hypothesis makes it impossible to have genuine memories about previous conscious experiences. The concept of self however allows the possibility that the connected series of sequential quantum jumps performed by self after its last "wake-up" integrates to single conscious experience. This hypothesis realizes self as an extended object in subjective time allowing it to have memories about previous conscious experiences rather than only memories with respect to geometric time. An attractive additional assumption is that the conscious experiences of self are kind of subjecto-temporal statistical averages. This would make experiences reliable. In particular, sensory experiences can give objective reliable knowledge

despite the fact that the outcomes of individual quantum jumps are not predictable. The undesired implication is that for long sequences of quantum jumps averaging leads to a total loss of information.

The original vision was that geometric memory is made possible by the finite temporal duration of the what I called mind-like sheets. The emergence of zero energy ontology led to the conclusion that all space-time sheets are mind-like since one can assign them to the interior of CDs. Depending on one's tastes one could of course refer to p-adic space-time sheets as mind-like (or cognitive). p-Adic space-time sheets are identified correlates of intentions, plans, desires, ... whereas real space-time sheets would correspond to sensory experience and sensory memories. Geometric memories are about geometric past and serve as prophecies telling what would have happened if quantum jumps were not constantly replacing macroscopic space-time with a new one. Precognitions which can be only geometric tell what would happen if no further quantum jumps take place. Subjective memory makes it possible to compare what actually happened with what was expected to happen. It might be that this comparison is one of the fundamental irreducible mental acts. There is a sharp difference between ordinary memories on one hand and precognition and memories about time before birth (the region in the geometric past of the CD assignable to the 4-dimensional biological body) since the interior of "personal" CD is in a preferred position. Interestingly, the CD corresponding to a life time of order 100 years corresponds to a primary p-adic length scale of order 10^{-7} meters and the age of the universe to 10^{-4} meters, the size scale of a large neuron.

A natural identification of the subjective memory is as immediate short term conscious memory, or actually a hierarchy of short term memories corresponding to the hierarchy of selves. This identification requires that the subjective durations of our sensory selves are typically of a fraction of second, .1 seconds is suggested by various arguments relating to the ability to experience subsequent stimuli as separate ones and corresponds to the duration of psychological moment. This time scale corresponds to the temporal size scale of the CD of electron. The narrative character of the long term memories suggests their identification as geometric memories: long term memories could correspond to multitime experiences with contributions coming also from the geometric past (say childhood). It turns out that this identification explains basic facts about long term memories. Declarative memories are assumed to involve negative energy signals suffering a time reflection from the brain of the geometric past. The condition that the energies of the corresponding photons are above thermal threshold can be satisfied if the value of Planck constant is large enough. The emergence of long term memory and planned action would involves in an essential manner the emergence of large values of Planck constant [K44].

14.2.4 Spin Glass Model Of Learning And Long Term Memories

The universe of TGD is quantum spin glass [K103]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/associations are formed.

1. Mental images (in particular memories) correspond to sub-selves undergoing self-organizing time development by quantum jumps leading to self-organization patterns selected by dissipation. Thus both memes and genes, in particular long term memories, can be regarded as winners in the fight for survival in which dissipation is the ultimate Darwinian selector. Inhibitory and excitatory nerve pulses might physically realize "frustrations" which make possible large number of almost degenerate energy valleys.

2. The universe of TGD is quantum spin glass characterized by a fractal "energy" landscape having valleys inside... inside valleys (directories inside...inside directories). This structure is ideal for a hierarhical representation of memories. Memories must correspond to valleys of the spin glass "energy" landscape into which dissipation takes the system. Memory formation is active process and memories are charicatures rather than photos and deep valleys of the energy landscape represent these charicatures. Hippocampus, known to be involved with the formation of the long term memories, could control the rate of motion in these control variables. The plastic regions of the brain are the most spin-glassy ones and are the most probable seats of the long term memories.

3. System has some territory in the energy landscape. The motion in the zero modes serving as control variables causes a slow shift of the entire territory. Synaptic strengths corresponds naturally to the slow control variables characterizing the position of the territory. In the presence of a metabolic energy feed and sensory input system moves around this territory.

One can consider two general models of learning and memory recall in this framework, the TGD version of the neural network model and the genuinely TGD based mechanism on the notion of the geometric memory. Consider first the TGD based version of the neural network model of memory.

1. The possible memories of the system correspond its territory in the "energy" landscape. Learning means slow change of the shape of the territory so that memory valleys get gradually deeper and system ends up to them with larger probability in future.

2. Repeated simulated annealing provides a promising memory recall mechanism. The feed of energy from metabolism kicks the system into a motion and dissipation leads it into some valley. If the valley is quite not correct (correct subdirectory but wrong subsubdirectory), a smaller kick leads the system to the bottom of some nearby valley which might be correct. By applying a sequence of increasingly smaller kicks system finally finds the correct memory valley. The conscious attempt to remember corresponds naturally to an external force forcing the system to move in a correct direction.

There are several objections to this scenario. The first mystery is how system knows that the experience is a memory: there seems to be nothing which would distinguish memory from the experience occurring for the first time. Second problem is that the formation of the new memories tends to destroy the old ones: the new territory is simply not the old one. Even if one could circumvent this paradox, it is difficult to understand why the lively episodal memories of childhood are the most stable ones.

If long term memories are geometric memories then memory recall mechanism corresponds to multitime experiences involving generation of mind-like space-time sheets in both geometric now and past.

1. Learning by repetition means keeping some subsystem in some deep valley for a long period of geometric time (system is still in that valley in the geometric past!). This corresponds to reverberating patterns in neuronal circuits generated automatically or by learning by repetition. In this picture the modification of synaptic strengths is not learning of memories but just what it seems to be: a modification of responses to sensory inputs necessary for survival.

2. The attempt to remember creates mind-like space-time sheets located in the geometric past. The probability that a newly created mind-like space-time sheet is located in the memory valley of long time duration is high and thus conscious memory recall becomes probable. Also very emotional and "catchy" experiences generating long lasting memory valleys are easily remembered. Childhood memories are often very emotional ones and therefore also the most stable ones.

No final vision about what memories are in TGD framework exists yet. What is certain is that one can distinguish between geometric and subjective memories. The idea that episodal memories are ordinary sensory experiences with the object of the perceptive field in the geometric past is very attractive and speculative hypothesis which might work in TGD Universe, but more conventional explanation sounds more realistic in the context provided by the standard neuroscience. What is lacking still is a clear vision about the precise physical realization of long term memories.

14.2.5 Long Term Memories

An important question is whether our long term memories correspond to either geometric or subjective memories or whether they involve both aspects somehow.

Long term memories as geometric memories?

The unreliability and narrativeness of the long term memories would support strongly the interpretation of at least episodal long term memories as geometric memories, that is multitime experiences involving active mind-like space-time sheets scattered along entire life span. This option is consistent with the short duration of subjective memories, which can be even of order .1 seconds characterizing the duration of immediate sensory memories.

Geometric memories could be realized as multitime experiences involving mind-like space-time sheets located around several moments of the geometric time, provide the simplest realization for the long term memories.

1. The model solves the basic difficulties of the neural net models of long term memory. In the neural net models long term memories are represented by synaptic strengths. The problem is that the learning of new memories destroys old memories. In particular, the stability of the childhood memories is difficult to understand. It is also hard to understand how brain knows that the experience represents memory. One cannot avoid the difficulty by saying that novelty detection tells that experience occurs for the first time since the notion of novelty does not make sense if conscious experience contains only information from single moment of geometric time.

2. TGD model is consistent with neural net models and actually generalizes them. Neural net in the spirit of TGD corresponds to brain as system moving in spin glass energy landscape. Self-organization by quantum jumps leads the system to a bottom of an energy valley representing memory. This model is consistent with the fact that there is no upper bound for autobiographical memory. One can also understand how learning occurs. The repetition of an experience means that energy valley becomes a canyon in time direction so that mind-like space-time sheets in the geometric past have a large probability to end up to the region representing memory. In particular, reverberating nerve pulse patterns are ideal for representing long term memories.

3. Highly emotional experiences generate deep valleys and increase the probability of the system of the geometric past to stay at the bottom of valley. This explains why cildhood experiences are so stable. In fact, one could identify primitive emotions of pleasure and pain as related to the motion in the spin glass energy landscape. Pleasure and pain could even directly correlate with the sign of the increment of the Kähler function in the hopping motion in the spin glass energy landscape. Note that primitive pleasure and pain are are very much like sensory experiences and one could regard them as sensory experiences of brain about its own motion in spin glass energy landscape. This leads to the generalization of the notions of sensory experience and motor action to include the motion in spin glass energy landscape and to a considerably new insight about the meaning of the brain architecture.

There are also perinatal experiences, memories about previous lives and transpersonal experiences having natural explanation in terms of geometric memory realized as multitime experiences associated with mind-like space-time sheets located at different values of the geometric time. Transpersonal experiences suggests that self is dynamical: if prenatal experiences, memories about previous lives and transpersonal experiences are really what they seem to be, the geometric time extension of self should dramatically increase during these experiences.

If "our" self has duration of order lifetime, also subjective memories can contribute to our long term memories. As already found, this option does not exclude the possibility that our long term memories correspond to subjective memories.

Geometric memories as sensory experiences with the object of the perceptive field in the geometric past?

The general theory of qualia to be developed in [K50] leads to the conclusion that geometric memories could be regarded as special kind of sensory experiences for which some objects of the perceptive field located in the geometric past. One also ends up with a concrete models for the mechanism making long term memories possible by "waking up" sub-selves of the geometric past in selective manner by EEG frequencies. The unavoidable conclusion is that massless extremals

(MEs) with durations of order lifetime, and hence with sizes which are measured in light years, are necessarily involved. Needless to say, one must give up the idea that we are nothing but our brains.

The fact that the light-like boundaries of MEs serve as quantum holograms and have gigantic information storage capacities by the almost degeneracy of the states fits nicely with view. Lightlikeness means that 3-dimensional time=constant slice of Minkowski space is replaced with a slice which can have arbitrary long temporal duration so that memories become indeed possible. The fact that at least vision represents directly information about outer surfaces of 3-dimensional objects rather than objects themselves but contains information about time development over an interval of order .1 seconds fits nicely with this view.

The realization of long term memories in terms of magnetic quantum phase transitions induced by ME frequencies requires incredibly high frequency resolution. The resolution is of order $\Delta f/f \sim \Delta T/T$ giving $\Delta f/f \sim 10^{-9}$ for time resolution of about $\Delta T = 1$ seconds. An unrealistically high frequency resolution is required if temporal coding by EEG frequencies is assumed. There is also another problem: if the signal to the geometric past and back is between parts of brain, one cannot avoid zigzag type MEs effectively representing a repeated reflection between two mirrors. In the p-adic context these zigzag MEs are allowed by conservation laws (this might relate with the fact that long term memories are mostly cognitive) but not in the real context.

These observations suggests that one should allow MEs and magnetic flux tube structures with length scales of order light lifetime and try to invent a more elegant mechanism of long term memory. One might start from the mirror idea and consider the possibility that memory recall involves a question sent to the geometric past as a classical signal reflected back to brain in a mirror formed by a magnetic flux tube: perhaps passive MEs are involved at this stage. Thus MEs with lengths of order of light lifetime ($L = cT$) would be required. The answer could involves a transformation of passive MEs to active em MEs and the generation of quantum entanglement unless it is present already: the recalled experience is shared by the experiencer now and experiencer in the geometric past. The mechanism involves several purely TGD based features: the light-like character of the boundaries of MEs making possible light-like selves; space-time sheets with a negative time orientation allowing classical signals to propagate backwards in time; the magnetic flux tube structures associated with brain having sizes of order light years making possible MEs to form mirrors. Precognition is the temporal mirror image of this mechanism.

If long term memories are in some sense sensory experiences with the object of the perceptive field in the geometric past, the notion of the magnetic canvas should work also in these astrophysical length and time scales. Consider first the constraints on this mechanism.

1. The sensory experiences at different levels of the magnetic hierarchy cannot be identical. This means that standard sensory representation using magnetic canvas must be applied to realize the episodal memory. This leaves only two possibilities. Either the experience is coded to a light-like vacuum current and this information, when sent into future, regenerates the sensory experience there. Alternatively, future self could entangle with the self of the geometric past and share its experience.

2. Since MEs correspond to 3-surfaces moving with light-velocity, the only possible realization of the communications between geometric past and geometric now is in terms of "laser mirrors" connected by MEs representing geometrically the light reflected in the mirror. The length of ME is given by $L = cT$: $2T$ is the moment of the geometric past which gives rise to the memory. Interestingly, Peter Gariaev has suggested that laser mirrors are involved also with DNA [I28]. This means that a ME extending from the brain of the geometric now to the geometric past and the ME from the brain of the geometric past fuse with the same magnetic flux tube to form a representation for light reflected in a cosmic mirror. The MEs and magnetic flux tube structures associated with the relevant parts of brain must form pre-existing, tightly correlated structures since the probability for the formation of this kind of mirrors accidentally is extremely small and there is no guarantee that they connect parts of the same brain. Second mirror would be obviously defined by the join along boundaries contact/flux tubes of ME with the magnetic flux tube. Hippocampus is a natural candidate for the brain structure, at which the first mirror is located. The fact that MEs represent channelled energy means that distance is not a problem as far as energetics is considered.

3. Active memory recall must involve a question sent to the geometric past followed by an answer communicated to future in some manner. There must be some difference between precognition and memory recall so that the question and answer cannot be realized in the same manner. This serves as an important guideline. Various arguments lead to the view that the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

   Sharing of mental images if time-like quantum entanglement is generated between the selves of the geometric past and geometric now. This is possible in TGD framework, thanks to the non-determinism of Kähler action making also MEs quantum holograms in quantum gravitational sense. The fact that MEs represent light-like selves, would be essential for this realization. The beauty of this realization is that the information need not be transferred classically. This realization is actually a special case of the realization in terms of zigzag ME in much shorter length scale: in this case a huge number of reflections in the mirror pair would be required and it is difficult to understand how one could control the temporal position of the self of the geometric past in this kind of situation.

This picture deserves some further comments.

1. If the higher levels of the magnetic self hierarchy are intelligent as one might expect (and even more intelligent than us), one can also consider the possibility that the step in which the interaction of ME representing a question sent to the geometric past with the magnetic flux tube at the higher level of the hierarchy is far from a mechanical interaction. Rather, the magnetic flux tube structure could act as an intelligent conscious system rather than a mechanical relay station.

2. The process could also have interpretation as an exchange of two virtual MEs between brain and magnetic flux tube structure: kind of a very low frequency counterpart of self energy Feynman diagram realized as a generalized Bohr orbit. The Feynman diagrams for the emission of parallel photons are infrared divergent. This encourages the expectation that the probability for the presence of MEs parallel to the magnetic flux tubes is very high and increases with the increasing length of ME. The spontaneity of the episodal memories is in accordance with this view. An interesting question is how these MEs relate to $1/f$ noise.

3. The assumption that the lengths scales of MEs and magnetic structures are identical implies that the frequency of EEG ME equal to the magnetic transition frequency f_m fixes the length of the two MEs involved and thus the temporal location of the long term memory in the geometric past:

$$T = \frac{2}{f_m} \quad .$$

   This represents a frequency coding for the temporal location but in a way different from the one proposed originally. In particular, this coding does not require ME frequencies to be in EEG range and defined with a relative accuracy of order $E-9$. In standard physics the idea about brain generating MEs with a frequency scale of the order of the inverse of lifetime does not make sense: in TGD context situation is different since this process occurs in subjective time.

If this picture has captured something essential from the nature of the long term memories, the conclusion is that we are not at the top of the magnetic sensory hierarchy. Human body and brain generates extremely weak magnetic fields and the corresponding magnetic flux tube structures could serve as a sensory canvas making possible long term memories. Near death experiences [K23] could be understood in this framework if the weak magnetic fields associated with the higher levels of the fractal hierarchy of magnetic structures utilize brain and body as kind of sensory and motor organs. Note that there is flux tubes inside flux tubes structure so that ordinary sensory experiences can be associated also with these flux tubes.

Long term memories as memories of higher level self?

The natural identification of the immediate short term memory as subjective memory predicts that the life time of a human sensory self cannot be much longer than .1 seconds, the duration of psychological moment of time. Our long term memories correspond to much longer time interval and cannot thus correspond to our subjective memories. Entire hierarchy of subjective memories is however predicted and a possible model for *genuine* long term memories is as resulting from temporary entanglement with selves belonging to the higher level of the hierarchy. Also this identification is consistent with the fact that there seems to be no upper bound on autobiographical memory. Summation hypothesis implies that our genuine long term memories would be sums over a large number of wake-up periods of self in the subjective past of the self. Therefore one could perhaps understand how aging self gains gradually wisdom from experience: also the identification of the long term memories as geometric memories explains this.

Higher level selves could communicate their subjective and geometric memories as well as the emotions generated by their comparison to us. The first idea to come into mind is that communications occur during totally entangled state, sleep or trance. For this option it is not at all clear how the experiences of the higher level selves during entangled state could be ours! In fact, we should lose our selves during entanglement with self characterized by larger p-adic prime. For instance, during sleep without dreams entanglement with some higher level self should occur and we do not remember anything about this. Trance is a second example of this: subject person does not remember anything about the trance state. Thus it seems that this mechanism cannot give rise to conscious long term memories. This does not however exclude the possibility that cognitive representations are formed during the communication and lower level self experiences them later as memories. One function of sleep might be the generation of the entanglement with higher selves making in turn possible the communication of genuine memories of subjective past to our mind. This communication could realize these memories as thoughts about the experiences of past realized as nerve pulse patterns regenerating these thoughts.

The so called semitrance mechanism [K107] avoids the objections against communications occurring in totally entangled state. During semitrance parts of brain are entangled with some higher level self. These selves can communicate their memories to that part of brain which is awake (communication means generation of mental images). Ancient men received these communications as sensory hallucinations ("God's voice"), very much like schizophrenics, whereas modern man experiences them as thoughts and emotions which are often "hallicinatory" in the sense that they are not automatic reactions to the sensory input. The TGD based vision for the development of language and civilization modifies Jaynes's vision about bicameral man as a schizophrenic of modern society and relies on the notion of semitrance. Semitrance mechanism is extremely general and could be present in all length scales. For instance, semitrance could provide the inhabitants of cell societies (organisms) and protein societies (cells) with a personal self narrative (genetic determination of cell as self narrative!).

Semitrance mechanism survives the most obvious counter arguments.

1. The general objection is that the memories of the higher level selves are rather abstract. The assumption communication mechanism is restricted to thoughts and emotions is however consistent with the abstract nature of the non-episodal long term memories. The most natural identification of episodal memories is indeed as personal geometric memories or possibly as artificially generated sensory hallucinations stimulated by higher level self during semitrance.

2. Since semitrance mechanism is only a communication method, geometric and subjective memories remain the fundamental memory mechanisms. Therefore the nice features of the geometric memory are not lost. For instance, one can understand learning and the role of emotions and repetition in learning.

More complicated scenarios

One can consider also more complicated scenarios for realizing long term memories.

1. Ensemble of mind-like space-time sheets could generate continuously cognitive representations remaining in ideal case unchanged and memories as ability to re-experience would be

carried by mind-like space-time sheet when it wanders to the direction of future. This would require that mind-like space-time sheets replicate just as material space-time sheets (DNA, cells, members of species) do. If mind-like space-time sheets responsible for memories of this kind have finite lifetime, say of order one second, short term memories could be realized in this manner without cognitive population explosion. In fact, cell division might realize long term memories in cell populations. Perhaps also DNA replication might be regarded as this kind of memory.

2. The realization of long term memory and communication relying on replication is rather primitive and the fact is that neurons do not replicate. A natural explanation is that neurons have discovered procedural memory, which means that long term memories could be realized dynamically: standardized nerve pulse patterns generate standardized temporal patterns of quark magnetization. This implies ability to regenerate the thought stimulated by the primary experience and associative learning would associate memories to experiences as thoughts. This picture would correspond to that of ordinary associative nets and is subject to the standard counter arguments such as the loss of old memories caused by the learning of the new ones.

3. Sustainment of the mental images is indeed one of the basic mechanisms behind human intelligence and can be also seen as a way to enhance the probability that a geometric memory in the past is recalled. Sustained mental images are analogous to the icons of the computer screen, which in fact supports the idea that the evolution of computers mimics in many respects the evolution of the brain. At program level icons correspond to program loops. At neural level to periodic neural process generating again and again the same mental image (not necessarily directly conscious to us).

4. Written language and symbols are the next step to the internal sustainment and make possible to achieve a given sensory and cognitive experience in a controlled manner. Program files are obviously analogous to the written language (the electronic control systems preceding the computer era were effectively computer programs but were not written as computer code, externalized). DNA could be seen also as ROM type memory of living systems.

14.2.6 Implicit Memories

A possible definition of implicit memories is as memories which exist but are not created in conscious experience of the subject person. Also implicit learning could be defined in this manner. A good example of implicit memory is provided by a situation in which unaesthetized patient can quite accurately remember what has been said during the operation [J137]. An example of implicit learning is the learning of grammatical rules without any explicit (conscious) representation for them. The status of the implicit memories and learning is not established. A possible reason for this is that it is not easy to understand them in computational paradigm of consciousness. Connectionism explains implicit learning and memories as unconscious formation of associations and mathematically modelled by the dynamics of the neural networks.

In TGD framework implicit learning and memories could correspond to learning and memories at the lower levels of the self hierarchy not usually conscious to us. In case that the mind-like space-time sheet corresponding to our sub-self forms flux tube with a lower level self so that lower level self fuses with the sub-self in question, its memories can become our conscious memories. ORP suggests that this process involves also the formation of quantum entanglement and this indeed must occur. Biofeedback could be understand as a special case of this process. In the TGD based model for the quantum correlates of the sensory qualia this process is key role. The memories communicated by semitrance mechanism can indeed be and probably often are implicit.

One can consider also formation of flux tubes between our sub-selves and sub-selves of other persons. This is quite possible if our sub-selves indeed correspond to topological field quanta representing ELF photons associated with the EEG frequencies having size of even size of Earth. Formation of flux tubes between topological field quanta of this size would make for us to experience the memories of other persons. This kind of mechanism could explain the memories of anesthetized patient about what happened during the operation as memories of sub-selves of the persons participating the operation. An open question is whether the mechanism could also explain

also out-of body experiences, in which patient looks himself from outside, sometimes involved with this kind of situations.

Implicit learning could also correspond to the development of various cognitive skills realized as self-organized self cascades so that no explicit representation of the skill is needed: when initial value self wakes up, the cascade proceeds with highly predictable manner due to quantum statistical determinism. Even the ontogeny could be regarded as this kind of skill implicitely coded in DNA!

14.2.7 Procedural Memories

Procedural memories seem to be mostly stabilized sequences of thoughts and mental images and the proposed model for cascade like generations of selves provides therefore a model for procedural memory. Procedural memories could be simple cognitive acts occurring again and again as a reaction to some specific stimulus. mind-like space-time sheet would carry them while drifting into the future. For an ensemble of selves with each self initiating cognitive acts is in question, reliability of memories would result.

Quantum spin glass model of brain explanains for formation of the procedural as resulting from quantum self-organization. Dissipation caused by quantum jumps would automatically select skills, habits and eigen behaviours as surviving self-organizing patterns. These patterns would correspond to deep valleys in the fractal energy landscape of the spin glass landscape, which is effectively four-dimensional. Repetition would automatically lead to the learning of procedural memories since it would extend the valleys in time direction so that mind-like space-time sheets would have larger probability to enter to the valley and give rise to memory. For instance, reverbrating nerve pulse patterns in the memory circuits of brain would realize this repetition.

14.3 Model For Long Term Memories

In the following an attempt is made to understand how long term memories could be realized at neuronal level. I hope that my fragmentary knowledge about the details of brain science would not mask from the reader the beauty and simplicity of the general mechanism. The model is constructed first at general level and then basic facts about long term memory are discussed in the framework of the model.

14.3.1 General Ideas

In TGD framework one can make a precise distinction between genuine memories and apparent memories such as procedural and implicit memories, associations, feature recognition, and standardized neuronal "features" serving as building blocks of memories. The basic question is whether the representations of the long term memories are realized in the brain geometrically now or in the brain of the geometric past. In TGD the latter option is allowed by time-like quantum entanglement made possible by the non-determinism of Kähler action. The very fact that the memory storage of past memories to the geometric now is not needed, means that there is no need to carve long term memories to associative structures so that geometric now would contain representations about moments of the geometric past. Only the representation of the event at time when it occurred is needed. For example, this implies that long term potentiation (LTP) is just learning and adaptation to a new situation and can only be related to the modification of memory representations and possibly the construction of new standardized features.

Mirror mechanism

Mirror mechanism is the simplest quantum mechanism of episodal memories and involves only a sharing of mental images by time-like entanglement. p-Adic physics suggests that the entanglement should be negentropic. Negentropic time-like entanglement is indeed possible and would correspond to density matrix which is projector. The corresponding entanglement matrix would be unitary.

Another mechanism is based on communications in time direction giving rise to the analog of reflection in time direction. The brain hemisphere sends a negative energy ME to the geometric past reflected at a large distance and returning back to the hemisphere and induces a sharing of mental images. The desire to remember something and the memory of the past fuse to a single

mental image shared by the brains of the geometric past and now. The desire to remember would be communicated to the geometric past also in case of non-episodal memories whereas memory itself would be communicated classically by positive energy MEs.

In a more realistic situation multiple reflections for a curvilinear negative energy ME along a closed magnetic flux loop would occur and guarantee precisely targeted communications to the geometric past. The sizes of these loops would be measured in light years. MEs and magnetic flux loops associated with the personal magnetic body are the most realistic candidates since in this case the interaction with matter is minimized.

The notion of memory field supports this idea. Retrograde amnesia leads to a selective loss of memories in some time interval, and the notion of memory field provides a possible explanation. This means that brain structures with a given memory field entangle with those events of the geometric past which are located in some time interval ΔT at temporal distance T in the past. A closed magnetic flux tube with a given length $L(T)$ would obviously be a correlate for a memory field with a given time span T.

The sharing of mental images mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/sharing.jpg` or **Fig. ??** in the appendix of this book) requires only that gravitational MEs take care of only quantum entanglement and because it allows arbitrary kinds of episodal long term memories. The electric stimulation of neurons can induce complex episodal memories. This can be understood if the episodal memory recall involves only the entanglement by the negative energy ME and the field pattern associated with ME does not matter at all. The unique experimental signature of the quantum entanglement mechanism is that no direct correlates for the memories themselves are necessary in the brain geometrically now. One can wonder what distinguishes the resulting experience from precognition by the self of the geometric past: could it be that to precognize now is to remember in the geometric future?

The direct sharing of sensory experience is non-economical in the sense that the amount of the irrelevant information is very high. The conceptualization involved with the symbolic representation allows to represent only the absolutely essential aspects. In case of classical communications symbolic representations is of course the only practical possibility. Since the brain of the geometric past serves as a passive entangler and does not have the possibility to process the communicated information, the sharing of the mental images is not flexible enough and does not allow an active precisely targeted memory recall. It is also very difficult to tell whether sensory experience represents memory or a genuine experience.

Classical communications and non-episodal memories

For non-episodal memories classical communication mechanism suggests itself as a more appropriate mechanism. Classical signalling requires the coding of the data to the shape of the field pattern propagating along positive energy ME, which could be curvilinear and analogous to a radiation propagating in a wave cavity defined by a magnetic loop of the magnetic body.

MEs are indeed optimal for the coding of the classical signal since the vacuum current for given moment of geometric time is non-deterministic. Classical communications would allow and also require the minimization of the data communicated. These memories would not be sensory unless back-projection to the sensory organs is involved at the receiving end. The formation of the symbolic representation is subject to errors: for instance, temporal order of events can change. It is known that declarative memories can often involve changes of the temporal order. It must be emphasized that declarative need not be synonymous with non-episodal. Declarative memories could be also episodal and correspond to sharing of a symbolic mental images of the geometric past. The "features" of Freeman [E2] having during of about.1 seconds are good candidates for the representation of the classical signals and the time scale suggests that electron's causal diamond is involved as also quark CDs with time scale of 1 ms. If EEG MEs are involved, the modulation of hippocampal theta frequency is a candidate for the representations of classical signal.

In ZEO this mechanism corresponds to a process in which sub-self representing mental image dies and re-incarnates at the opposite boundary of CD. This corresponds to a negative energy signal travelling to the geometric past. Also this self dies and re-incarnates at original boundary of CD: this corresponds to the positive return signal from the geometric past. Mental image simply falls asleep and wakes up and after that represents the memory as a conscious information.

There are are two basic options for how the classical communication could occur.

1. Positive energy ME would not leave brain at all and would therefore have ultra slow effective phase velocity along the brain structure in question, say axon, so that it would not leave brain during its travel to the geometric future.

2. Positive energy ME would be curvilinear and parallel with magnetic flux loop of the personal magnetic body serving effectively as a wave guide. In this case the reduction of the phase velocity to EEG wave phase velocity would be enough. For instance, for the phase velocity of alpha waves propagating along loops with the size of the order of the Earth's circumference, the time span of the memory would be of the order of one year. In this picture one of the functions of the part of EEG representing evoked responses could be classical communications making possible non-episodal memories. Only part of these memories would be conscious to us. The length of the magnetic loops is expected to directly correlate with the period of EEG frequency involved with the classical communication via the relationship $L = vT$ would provide a second correlate for the notion of the memory field. There are indeed reasons to expect that the structures communicating signals to the geometric future are specialized to communicate signals to a certain distance.

The most plausible neurophysiological excitations associated with the received signal are Ca^{++} waves known to have extremely wide velocity spectrum. For the option a) the required velocity would be of order neuronal sizes per year, and this is perhaps unrealistically low velocity. It is also difficult to see how the neuronal noise would not spoil the signal. For the option b) the positive energy ME entering brain at the moment of memory receival would induce Ca^{++} waves in turn inducing neural activity.

For classical signalling the transformation of the classical signal to a conscious experience is needed. MEs could directly generate membrane oscillations and nerve pulse patterns via the general mechanism of nerve pulse and EEG discussed in [K97]. EEG MEs could in turn induce cyclotron transitions at the magnetic flux tubes of the Earth's magnetic field in turn affecting nerve pulse generation. Also a transformation of the signal to Ca^{++} waves could be possible. The conscious experience does not involve sensory component unless there is back-projection to the level of sensory organs involved.

Interesting questions relate to the interpretation of the ultraslow effective phase velocity of MEs acting as bridges connecting two space-time sheets.

1. The classical fields from a larger space-time sheet A can be transferred to a smaller space-time sheet B topologically condensed on A by inducing the motion of the wormhole contacts, which in turn generate classical fields at the smaller space-time sheet. The fields can also penetrate along flux tubes connecting the boundaries of two space-time sheets.

2. Quite generally, the "topological" half of Maxwell's field equations implies that tangential component of E and normal component of B are continuous at the junctions connecting the boundaries of two space-time sheets. One could assume that quantum effects can be modelled phenomenologically by introducing the phenomenological D and H fields introduced also in the Maxwell's theory. In the Maxwell's theory the discontinuity of the normal component of the D field equals to the density of the free surface charges and the discontinuity of the tangential component of the H field equals to the free surface current. These conditions can be assumed also now, at least as the first approximation.

3. One could model the propagation of MEs topologically condensed at a space-time sheet labelled by a p-adic prime $p \simeq 2^k$, k prime or power of prime, by introducing the di-electric constant $\epsilon(k)$ and the relative permeability $\mu(k)$ satisfying the condition $\epsilon(k)\mu(k) = 1/v^2 > 1/c^2 = 1$, where v is the effective phase velocity of ME depending in general on its fundamental frequency. The fields D and H would be defined as $D = \epsilon(k)E$, $H = B/\mu(k)$: this condition generalizes to that for the Fourier components of the fields. The reduction of the effective velocity for the propagation of the topologically condensed MEs to say alpha wave phase velocity does not seem plausible.

4. The propagation of MEs which serve as bridges between boundaries of two space-time sheets (say cell membrane space-time sheet and cell exterior space-time sheet) must be modelled differently. One could introduce a generalized di-electric constant $\epsilon(k_1, k_2)$ and permeability

$\mu(k_1, k_2)$ characterizing the pair of space-time sheets such that the effective phase velocity $v(k_1, k_2)$ of MEs acting as bridges satisfies $\epsilon(k_1, k_2)\mu(k_1, k_2) = 1/v^2(k_1, k_2)$, and also now depend on the fundamental frequency of ME. A very large value of $\epsilon(k_1, k_2)$ implying the needed very small value of the effective phase velocity would mean that the orthogonal component of the electric field does not appreciably penetrate inside ME from either space-time sheet. Since MEs are the fundamental topological field quanta, this looks a natural assumption. The extremely low effective phase velocity should be due to the replacement of the wormhole contact coupling with the join along boundaries coupling causing the "sticking" of MEs. Note that the join along boundaries coupling is topological sum coupling for boundaries whereas wormhole contacts represent topological sum coupling for interior. Furthermore, join along boundaries contacts can have a macroscopic size whereas wormhole contacts are CP_2-sized: this could explain the huge reduction of the effective phase velocity for the boundary MEs.

Negative energy MEs as ideal entanglers with the geometric past?

MEs with negative energies are especially favoured for quantum communications. The reasons are many-fold. The interaction with the matter is very weak in long length scales but strong in cellular length scales, negative energy implies that ME is identifiable as a virtual particle and analogous to a part of a Feynman diagram so that no dissipation is involved and quantum communication is possible. The reversal of the arrow of geometric time means also that there is not macroscopic dissipative dynamics which would spoil the quantum coherence.

The requirement that the entanglement process is highly selective suggests a resonance mechanism. This requires that receiving and sending structures are similar and generate ULF MEs with fundamental frequencies measured typically in cycles per year. If negative energy energy ME is in question, as suggested by the idea that a classical communication to the geometric past is involved, it cannot be emitted unless there exists a receiver absorbing the negative energy and in this manner providing energy for the sender by buy now-let others pay mechanism. For negative energy MEs resonance mechanism plus a simple classical signal serving as a a password could also guarantee that correct part of the brain receives the signal.

Negative energy MEs represent time reversed level of the p-adic length scale hierarchy so that the dissipative effects associated with the space-time sheets with the normal arrow of time should not interfere with the quantum communication. This at least, when the energy of the negative energy ME has a magnitude larger than the thermal energy associated with the space-time sheets with which it interacts: there is simply no system which could make a transition to a lower energy state by the absorption of a negative energy ME. Furthermore, since the systems with reversed arrow of geometric time are expected to have extremely low density, the dissipative effects in the reversed direction of time are expected to be small.

Since the generation of negative energy MEs does not require energy feed, the memory recall to the geometric past occurs more or less spontaneously, and the scanning of the geometric past becomes possible. The intentionality of the memory recall would be realized as generation of a p-adic ME transforming to a negative energy ME, when the real system jumps to a higher energy state. This process makes possible precisely targeted intention also in the case of memory recall since the transitions in question cannot occur spontaneously. In the case of precognition precognizer must intentionally receive negative energy MEs from the geometric future so that energy feed is needed. This perhaps explains why precognition is so rare. Note that p-adic variant of pre-cognition having interpretation as intentionality occurs easily since p-adic energy is conserved only in a piecewise manner.

The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

14.3.2 Could Gravitation Have Something To Do With Long TermMemories?

Penrose has proposed that quantum gravitation might be crucial for understanding consciousness. In TGD framework the hierarchy of Planck constants labelling a hierarchy of quantum criticalities and the prediction that quantum gravitation gives rise to quantum coherence in astrophysical scales replaces this vision [K112, K87].

The quantitative formulation is in terms of the gravitational Planck constant characterizing the flux tubes of two-body system and having the expression $\hbar_{gr} = GMm/v_0$, where v_0 corresponds to a characteristic velocity associated with the system. The hypothesis $h_{eff} = n \times h = h_{gr}$ relates h_{gr} to the large Planck constant h_{eff} characterizing the cyclotron condensates of charged particles in living matter.

Gravitational Compton length does not depend on the mass of the particle and cyclotron energy spectrum proportional to h_{eff} is universal (no dependence on the mass of charge particle) and in visible and UV range. The dark photons in question can transform to ordinary photons identifiable as bio-photons and defined fundamental communication and control tools in living matter. This implies that they are crucial also for the memory. This vision is discussed in [K90, K31, K32, K33, K34, K15].

The text below was written much before this vision but I have left it essentially as such.

Could classical gravitation stabilize irreducible bound state entanglement?

Bound state entanglement gives rise to a "state of oneness", in which quantum computing system is totally bound-state entangled and does not decay into sub-selves in self measurement process and can thus behave effectively as a non-dissipating system and quantum compute. The estimates for the duration of this kind of bound states tend to be much shorter than required [J134]. The question is whether classical gravitational interaction could somehow stabilize these bound states.

The extremely low value of the gravitational binding energy is an objection against the view that gravitational interaction could help to stabilize the bound states. The huge degeneracy of the bound states could however change the situation.

1. Suppose that spin glass degeneracy gives rise to a huge number of almost degenerate bound states for which only the classical gravitational energy is different and that for non-bound states this degeneracy is much smaller. The dominant part of the binding energy is of course something else than gravitational. If this is the case, the number of the bound states is so large as compared to the number of unbound states that the branching ratio for the decay to unbound state is very small and bound state entanglement can last for much longer time as usually. Although the lifetime of an individual bound state need not increase, the time spent in bound states and defining de-coherence time become much longer than predicted by standard physics.

2. If the flux tubes are sufficiently near to vacuum extremals, they indeed allow immense spin glass degeneracy with slightly different gravitational interaction energies and the desired situation can be achieved.

3. This argument can be refined by using unitarity. If the net rate for the transitions to bound states is enhanced by the degeneracy of the bound states, probability conservation implies that the probability for the occurrence of de-cohering decays is reduced correspondingly.

A rough order of magnitude estimate for the gravitational binding energy for a cubic blob of water (that is living matter) having size given by p-adic length scale $L(k)$ is

$$E_{gr}(cubic,k) \sim \frac{GM^2}{L(k)} = G\rho^2 L^5(k) \sim \frac{Gm_p^2}{L(137)}\frac{L^5(k)}{L^5(137)} \simeq 2^{-127}2^{5/2(k-137)}\frac{1}{L(137)} \quad .$$

Gravitational binding energy is larger than the p-adic energy $2\pi/L(k)$ for $L(k = 179) \simeq .169$ mm. In the range $L(163) = 640$ nm and $L(167) = 2.56$ μm gravitational binding frequency varies between 1 Hz and 1 kHz, that is over EEG range up to the maximal frequency of nerve pulses. If

the binding energy gives estimate for the lifetime of the gravitationally bound states, this might fit nicely with EEG energies in typical cell length scales!

For $k = 157$ and $k = 151$ (the range from cell 10 nm-80 nm, microtubules are at the lower end of this range) the gravitational binding frequency corresponds to a time scale of 8.5 hours and 32 years respectively so that the time scales relevant for life are spanned by the Gaussian Mersennes. What sounds paradoxal is that short length scales would correspond to long time scales but this indeed follows from the inverse square law for the gravitational force.

One can perform a similar estimate for linear structures. Parametrizing the microtubular transversal area to be $d = x^2L^2(151)$, $L(151) = 10$ nm, one has

$$E_{gr}(lin, k) = x^5 \times E_{gr}(cubic, 151)\frac{L(k)}{L(151)} \quad .$$

This gives for $L(k) \sim 1$ meter, the frequency of $.1 \times x^5$ Hz. The time scale varies between $10/x^5$ seconds and $32/x^5$ years and certainly covers the time scale for human long term memories. Of course, this rough estimate involves numerical factor which can increase the upper bound.

Note that the increments of the gravitational energy between transitions between almost degenerate bound states are some fraction of the gravitational binding energy. Also the gravitational interaction energy associated with the classical em fields could contribute significantly to the density of the gravitational energy in TGD framework and tend to increase the overall energy scale. The reason is that the gravitational constant associated with classical fields is roughly 10^8 times larger than the ordinary gravitational constant [K14]. Thus, if the energy of classical fields is more than $10^{-8}m_p \sim 10$ eV per proton the classical field energy of, say, flux tubes becomes significant factor. Since hydrogen ground state binding energy is about 13 eV, this kind of energy density per atomic volume looks quite reasonable in case of water.

TGD universe is quantum critical system in the sense that space-time sheets representing magnetic and electric fields with arbitrary large sizes are present and correspond to two phases in equilibrium (compare with ice and water at melting point). Electric-magnetic duality is second fundamental symmetry of quantum TGD. Magnetic flux tubes carrying constant magnetic field (in lowest order approximation) have as their duals space-time regions carrying electric fields (constant in lowest order approximation). In biosystems various electrets and magnetic flux tube structures are the concrete realization of these two phases. Classical gravitational effects generate vacuum 4-currents near the boundaries of these structures serving as sources of magnetic resp. electric fields. The boundaries of these structures are singularities of the classical gravitational fields and these gravitational fields are good candidates for generating gravitional MEs responsible for long term memories.

Spin glass degeneracy corresponds in the formulation of hierarchy of Planck constants in terms of hierarchy of quantum criticalities [K44, K31, K32, K33, K34] to the existence of space-time surfaces, which can be regarded as many-sheeted singular coverings of space-time surface such that the sheets coincide at the ends of the space-time surface at boundaries of CD. The number of sheets corresponds to the value of $h_{eff}/h = n$. There are deep connections with p-adic length scale hypothesis and its generalization, with the notion of negentropic entanglement, with strong form of holography, and the vision about hierarchy of algebraic extensions of rationals as correlate for evolution [K137].

Long term memory and gravitational MEs

Interestingly, MEs (topological light rays) with fundamental frequencies with time scale measured using year as a unit are needed in the mirror model of long term memories (to remember event at a distance of T in past is to look in mirror at a distance $L = cT/2$). The gravitational transitions between huge number of almost degenerate spin glass states could be coded to the fundamental frequencies of MEs. In particular, structures with sizes slightly above cell membrane thickness, such as microtubules, could generate these MEs as the topological correlates of graviton emission with frequency equal to the increment of the gravitational binding energy in quantum jump involved. Thus there would be a direct correlation with long term memories and microtubules: microtubule conformations could code for long term memories.

The mirror mechanism of long term memory has beautiful interpretation in terms of topological correlates for virtual graviton exchange with vacuum.

1. The light reflected in mirror corresponds to topological light rays assignable to gravitons and is reflected from the curved vacuum. Topological counterpart of virtual graviton is emitted by (say) tubulin, absorbed by vacuumandemitted again by vacuum, and finally absorbed by tubulin. Curved vacuum acts as a mirror for gravitons and you see yourself in this mirror.

2. Why gravitons are the only possibility in time scale of years is simply that they interact so weakly that they can propagate light years before absorbed by curved vacuum. Time scales come out correctly and microtubules are known to be crucial for long term memories (Altzheimer's disease involves changes at microtubular level).

3. There are also genuine vacuum extremals interpretable as topological graviton rays. These graviton rays could reduce to vacuum MEs except in the turning point. This would mean "self-reflection" without scattering from background and interpretable as an absorption and emission of a virtual graviton. In case of non-vacuum extremals, classical momentum conservation however requires that the topological graviton exchanges momentum with the background space-time surface and thus is mirrored from it.

4. One could interpret the low energy topological graviton rays responsible for long term memory as a particular kind of $1/f$ noise accompanying all critical systems, in particular TGD Universe, which can be regarded as a quantum critical quantum spin glass. Gravitonic $1/f$ noise would be emitted in the transitions between almost degenerate spin glass states and would be kind of analog for gravitational brehmstrahlung.

If this view is correct, the time scales of long term memory at DNA level would correspond to very long time scales characterizing consciousness at the level of species. As a matter fact, the gravitational binding energy associated with $L(139) \sim .1$ nm (atomic physics) corresponds to the age of the universe: perhaps this explains why Schröedinger equation applies to the description of atom. $1/R$ dependence of the gravitational interaction energy would explain why very short length scales code biological information about very long time scales rather than vice versa.

While writing the above piece of text I did not known about the hierarchy of Planck constants. A photon with given energy can have arbitrary long wave length so that the minimum scale for macroscopic quantum coherence given by the wavelength is scaled up dramatically. For instance, the scaling by a factor 10^{12} can quite well be considered, and in the case of visible photon means scale of thousand kilometers- the scale of Earth.

14.3.3 Is The Right Brain Hemisphere The Quantum Entangler?

There are some reasons to suspect that the quantum communications with the geometric past occur more dominantly in the right brain hemisphere whereas classical communications would occur in the left hemisphere. This would explain among other things the holistic aspects of right brain consciousness. Left brain hemisphere is specialized more to symbolic processing of information and would indeed be more suitable to classical communication of this information.

Clearly, right brain would be passive receiver whereas left brain would be active expresser. DNA strands would be an example of this dichotomy at molecular level. This dichotomy would be realized also at the level of gene expression using MEs as the model of bio-photons involving in essential manner negative and positive energy MEs suggests. Of course, this statement must be take only in the spirit of fractality and would hold true only in certain range of p-adic time scales.

The following arguments lend some support for the proposed division of labour between right and left brain hemispheres.

Synesthesia as a key to the mechanism of episodal memory

What forces brain region to send negative energy MEs and thus to remember? "Hunger!" is the possible answer! During synesthesia the metabolism in the left cortex is reduced by by 18 per cent due to the abnormally high metabolism in memory circuit (for the model of synesthesia see [K105]). Perhaps the generation of the negative energy MEs is forced by the starvation of the neurons of the left cortex induced by the over-activity of the neurons of the memory coordination circuit. The starving cortical neurons of the left hemisphere would send massive amounts of negative energy

MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. Thus the miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction.

There are good reasons to expect that same mechanism might be at work also in the normal situation but involve a less dramatic artificial starvation of the neurons of the right brain hemisphere. Clearly, the role of hippocampus is dramatically different from what is usually believed and also forces to question the naïve belief that neuronal activity is a measure of the contribution of brain area to the conscious experience. While building long term memory representations as classical signals hippocampus and memory circuit would steal energy from certain areas of cortex, and the resulting metabolic starvation would force them to send negative energy MEs to gain energy in this manner. This in turn would lead to the generation of long term episodal or non-episodal memories as a side product. Quite generally it is known that limbic brain and cortex tend to work in complementary modes: when the cortex is in a high state of arousal, limbic brain is in a state of low arousal and vice versa. Perhaps the passive brain region is involved with memory recall and the active one with the construction of sensory or memory representations.

Left-handedness and episodal memory

It is known that persons with many left-handed family members have better ability for episodal memory recall and that this probably relates closely to the communication between left and right hemispheres. We begin to have verbal memories only after the age of four: at this time also the connection between right and left hemispheres has matured. The proposed mechanism of non-episodal memories requires that the right brain hemisphere shares the mental image representing the desire to remember and the left brain hemisphere communicates the memory classically. Als the communication between right and left hemisphere is necessary for this process to occur. Children before the age of four could live in a kind of a dream time experiencing mostly sensory episodal memories and presumably not being able distinguish memories from genuine experiences. This would also explain why we do not have declarative memories dating to the time before the age of four.

How could one understand the tendency of persons with many left-handed family members to have better episodal memory recall? The ability to have sensory memories can appear also when a damage occurs to the regions of the left hemisphere. It could be that classical communications between the hemispheres are worser than usually when episodal memory recall is favoured, and are replaced by quantum communications. The mental images in the left brain hemisphere would entangle with those in the right hemisphere entangling in turn with the geometric future and give rise to episodal memories. Thus the quantum communications between hemispheres might be better than usually. This kind of persons would be more "holistic" than ordinary persons.

NDEs and long term memories

That negative energy MEs could be responsible for episodal long term memories is supported by near death experiences. Persons having near death experiences are clinically dead: in particular, EEG is absent. If these persons indeed have conscious experiences and if they are able to remember them as it seems, and since EEG signals are out of question, only MEs generated during NDE remains as a viable alternative in TGD framework. Brain or possibly body should be involved with the receival of geometric memories if spin glass degeneracy is essential for the time-like entanglement by MEs.

Life review is one important aspect of the NDE experiences: entire 4-dimensonal body is experienced simultaneously. The starvation of neurons forcing them to generate negative energy MEs could explain the episodal memory feats of synesthetes and the eidetic memory, and would naturally be at work also during NDE experience. This is not the only possibility. This experience might also be partially due to the absence of the volitional actions. This life review memory could be interpreted as geometric memories not masked by the normal contributions to the contents of consciousness. An interesting possibility is that this contribution is generated by theta and delta bands of EEG during lifetime and is present also normally but, being strongly masked, is not recognized.

Dejavu experiences and memory feats

Dejavu experiences provide a challenge for any realistic model of memory. In Dejavu the sensory experience is accompanied by the feeling "I have experienced this already earlier".

A natural working hypothesis is that purely sensory memories, sensory re-experiences, do not contain information about the value of the geometric time associated with the sensation. This means that sensory memories cannot be distinguished from real experiences. On the other hand, cognitive and symbolic memories differ so radically from the sensory experiences that there is no difficulty of distinguishing them from genuine experiences. Therefore one knows that the experience represented by this kind of memory occurred in geometric past or represents an expectation of future. Symbolic (real) and cognitive (p-adic) representations are very probably continually transformed to each other. If this view is correct, then the simultaneous occurrence of the sensory and cognitive memories implies dejavu experience. The event giving rise to the sensory and cognitive memories might have occurred only few seconds earlier.

This view has some nontrivial implications concerning the character of conscious experience of children. Cognitive abilities are thought to appear only after the age of four or five years. If also symbolic memories are absent, small children might live in a kind of dream time, as also members of primitive cultures, such as aboriginals, are believed to live in. Also dream consciousness could involve in an essential manner sensory memories as suggested by temporal acontinuity of dream consciousness. One could also see dreams as transformations of cognitive representations to sensory ones and such reverse to what occurs in wake-up consciousness so that surreal dream logic could basically result from p-adic non-determinism. The back projection to the sensory organs would be an essential element of the mechanism.

The absence of a temporally organized consciousness would explain why we do not possess memories from the age before four. Perhaps also the bicameral consciousness, which according to Jaynes preceded modern consciousness, was kind of dream time consciousness in which memories were direct sensory experiences, like voices experienced as voices of gods and visual hallucinations. According to Jaynes, also schizophrenics are modern bicamerals.

Some time ago I saw a TV document about some autistic persons, who have very serious cognitive defects like inability count the number of objects if it exceeds two, are capable of miraculous memory feats. One of these fascinating individuals was an artist who could draw in full detail a picture about an area of London containing thousands of buildings after having seen the area once from a helicopter. Another autistic artist, virtuoso pianist, could reproduce every piece he had heard with highly personal style. Perhaps also great musical wunderkinds like Mozart have had similar direct sensory memory for music. Also a brain damage spoiling cognitive abilities can lead to the blossoming of exceptional artistic gifts. If the neuronal metabolic starvation forces the generation of negative energy MEs in turn giving rise to long term episodal memories then one could indeed understand how brain damage could have this kind of positive consequences.

The explanation suggesting itself is that the loss of cognitive memory is compensated by sensory memory in this kind of situations. A plausible reason for why average human being has dominantly cognitive memories is simple. Sensory memory contains huge amounts of un-necessary data: symbolic and cognitive memories have much higher survival value since only the relevant data are stored. Sensory genii have very hard time in the modern society unless they work as artists!

In light of foregoing, the poor cognitive abilities of animals suggest that also animals remember predominantly sensorily and live in dream time (note however that rats have hippocampal theta). For instance, dogs might have sensory memory dominated by odours. The challenge is to invent tests for this hypothesis. One could also try to device a non-destructive method leading to a temporary loss of cognitive consciousness and making possible to spend a day as a dog.

14.3.4 Going To The Neuronal Level

The following attempt to develop the model of long term memory at the neuronal level is made involves many uncertainties and must be taken as an exercise in order to get accustomed with the ideas involved.

Which parts of the brain are the quantum entanglers?

It is known that the electrical stimulation of amygdala, hippocampus, and temporal lobes can generate lively sensory memories. The simplest explanation is that quantum entanglement with the sensory representations of the geometric past is in question. The role of the electric stimulation would be only the generation of time like entanglement, not providing any information characterizing the memory. This would mean that large portions of brain can participate to the generation of episodal memories.

The fact that the part of body must be able to generate negative energy MEs with a proper ULF time scale, poses constraints on the system involved. Cellular sub-systems and microtubules are good candidates in this respect since the transition frequencies for the transitions involving change of classical gravitational are in the required range. Since resonance mechanism is probably involved, there are good reasons to believe that similar system is is involved with both the receival and sending of the message. Microtubular structures are good candidates adn accompany both neurons and glial cells.

Energetics poses also constraints. The receivers of negative energy MEs should have an easy access to the metabolic energy resources compensating the negative energy. In fact, the receiver must be in an excited state, which decays when negative energy ME is received (dropping ions to a larger space-time sheet could be also involved). Glial cells serve as metabolic resources of the brain and interact with neurons via Ca^{++} waves and are the first guess for the system entangling with negative energy MEs. Other parts of brain and body, even sensory organs, can get metabolic energy by entangling with astrocytes via negative energy MEs so that the desired sharing of mental images would indeed result.

The notion of memory field [J150] was derived from the study of short term memory and applies to the neurons of the frontal lobes at least. The span T of the memory field is essentially the time span of the long term memory. T correlates strongly with the fundamental frequency associated with the negative energy ME if quantum entanglement is involved, and the length of magnetic loop and curvilinear negative energy ME satisfies $L \sim cT = c/f$, where f is a frequency related to a transition in which gravitational energy of the system is question changes.

When f is expressed in terms of the size of the water blob generating gravitational negative energy ME in spin glass transition this gives $T \propto L^{-5}$, where L is the size of the water blob serving as a gravitational quantum antenna. MEs with T varying in the range 8.5 hours- 32 years in the length scale range 80 nm-10 nm are generated. One day (24 hours) would correspond to a length scale 33 nanometers: 3.3 times the thickness of the cell membrane. In case of neurons only the intracellular structures having much larger sizes and much higher gravitational binding energies might serve as entanglers (larger space-time sheets would be in question) and give rise to short term memory. The time scale of 1 minute corresponds to about .3 micrometers, millisecond corresponds to $L(167) \simeq 2.3$ micrometers, whereas $L(163)$ corresponds to a time scale of 1 second. This would suggests that sub-neuronal water blocks larger than the size of cell nucleus could generate short term memories which need not be conscious-to-us. Perhaps the flux loops of the magnetic body of the cell nucleus are involved.

For linear structures like microtubules one has $T \propto 1/L$. Even in this case a rather strong dependence on the time span of the long term memory on the system generating negative energy MEs results. The fact that microtubules are ideal for representing conscious information symbolically, suggests that neuronal/astrocytic microtubules serve as the entanglers at sending/receiving end of the quantum communication line responsible for long term memories. This picture also suggests that the magnetic flux loop of a given astrophysical length scale is associated with a microtubule of a given length.

Where the classical signals are generated and received?

There are several bits of information helping to guess how long term memories might be realized.

1. The damage of the hippocampus leads only to a loss of the ability to generate new declarative memories but does not lead to a loss of long term memories from the period when hippocampus was intact. Thus it seems that hippocampus plays essential role in the communication of our non-episodal declarative memories to the geometric past and that at least a dominant part of the receivers are somewhere else than in hippocampus. Since the stimulation of both

amygdala, hippocampus and temporal lobes induces long term episodal memories, it would seem that all these structures can serve as quantum entanglers.

2. New neurons and glial cells are regenerated in hippocampus and the regeneration is especially intense during ischemia which can destroy a lot of neurons [J128]. This would suggest that both glial cells and neurons are essential for the realization of long term memories.

These pieces of data give some guide lines in the attempt to build a more detailed model of long term memories.

1. The generation of classical signals requires metabolic energy and this suggests that the generation occurs as near as possible to energy resources. Glial cells are known to be the providers of the metabolic energy. Synchronously firing neuron groups are accompanied by astrocytes forming gap junction connected structures. For a long time it was believed that astrocytes play only the role of passive energy storages but it has become clear that there is signalling between astrocytes and neuronal groups based on Ca_{++} waves. Astrocytes couple also strongly to sounds: for instance, it is known that very mild blow in head inducing sound waves can lead to a loss of consciousness. Perhaps the astrocyte structures associated with hippocampal neurons generate positive energy MEs responsible for the classical communications making our non-episodal memories possible.

2. The receival of the classical signal does not require metabolic energy. If astrocytes are involved with the sending of the classical signal, then neurons would be naturally the receivers of the signal and the energy received with the signal would partially explain why synchronous firing of neuronal groups seems to require less metabolic energy than expected. Of course, quantum entanglement by negative energy MEs wither energy sources could also explain this.

Is memetic code used to code declarative long term memories?

Memetic code is a good candidate for the coding of declarative long term memories. The duration of single memetic codeword would be about .1 seconds and the duration of a single bit would be about 1 millisecond. This hypothesis fits nicely with the facts that many cyclotron frequencies are around 10 Hz and the frequency of neuronal synchronal firing is about kHz.

Quite recently it became clear that TGD predicts counterpart of Tesla's scalar waves as two sheeted structure defined by pairs of massless extremals having different directions of light-like four-momenta [K39, K89, K88]. These waves represent a pulse of electric field propagating with a velocity of light and an electric field in the direction of propagation. These waves corresponds in TGD to space-time sheet of finite length and duration ($L = cT$) carrying constant electric field and propagating with velocity of light to the direction of the field. This solution type is extremely general and dual to the magnetic flux tubes. Electrets are one manifestation of these structures in living matter (membrane potential is one example of this kind of structure).

One could consider the hierarchy of MEs representing geometrically a hierarchical structure of commands and that memetic code corresponds to the lowest level with bit represented by a electric pulses whose polarity determines whether "1" or "0" is in question: very much like in case of computers. Electret sequences would ultimately give atomic nuclei kicks in a direction depending on the value of the bit.

What about other synchronous EEG frequencies?

Genuine theta (hippocampal theta which spans both theta and alpha bands) and delta bands could correspond to more abstract levels of consciousness not directly experienced by us usually. During slow wave sleep theta and delta bands dominate and the interpretation in terms of the binding of the mental images to memory representations is highly suggestive. Hence these bands would contribute to our consciousness in the geometric future rather than in the geometric now.

1. Theta band might relate to long term memory consolidation by a construction of temporal replicas of ordinary long term memory representations generated already during the wake-up period. Sleep state is certainly ideal in this respect.

2. naïve extrapolation suggests that delta band memories correspond to a rather long temporal distance T (that is very low frequency $f = 1/T$ for gravitonic MEs). Delta band memories would be therefore generated by structures with sizes below the thickness of cell membrane. One could understand why delta band is strongest in childhood and weakens towards old age. If delta band memories correspond to very long temporal distances T, it is useless to generate these memories at the old age since there would be no brain receiving these memories. The long time span of the delta band memories would explain why childhood memories are stable and why some persons "return" to their childhood at the old age. The return to the sensory world of childhood at old age suggests that delta band memories must be sensory memories. Delta band representations might even give rise to transpersonal memories experienced during the later lives. The absence of ordinary sensory input masking delta band memories would explain why earlier life cycles can be recalled in meditative states.

3. The contribution of theta and delta band memories to our consciousness could also relate to the third person aspect of consciousness. Theta and delta waves could be associated with the magnetospheric sensory representations giving rise to multi-brained selves. The entanglement between sleeping brains inducing a loss of personal consciousness would induce a kind of collective stereo consciousness in which a large number of individual views about world fuse together would be in question. The search for correlations between the EEGs of sleepers having a close personal relationship might be rewarding. For instance, DNA could quantum entangle and give rise to conscious memories in very long time scale at the level of species.

Note that the presence of synchronous or asynchronous EEG correlate of memory generation is present also during memory recall does not seem to be necessary since the memory is indeed in the geometric past.

Questions

One important question is whether positive energy EEG MEs are involved with long term memories or only with sensory representations (assuming that sensory representations are realized at the magnetic body). The idea that MEs take care of memories and EEG MEs of sensory representations is attractive idea at least.

Fascinating questions relate to cognitive representations since these involve p-adic physics. Frontal lobes are known to be the seat of planning, volition and cognition. Therefore p-adic cognitive representations, p-adic entanglement and the p-adic selves characterized by positive entanglement negentropy should be realized in the neural circuits involving frontal lobes. These circuits have been even proposed to be "conscious circuits" but this probably reflects the erratics identification of consciousness as cognitive consciousness only. Cognitive representations could be realized at magnetic cognitive canvas using beta frequencies as resonant frequencies and beta MEs would entangle with the points of the cognitive magnetic canvas p-adic mental images representing intentions and plans. The transformation of these p-adic mental images to real ones would somehow generate generalized motor actions, in particular ordinary motor actions. That frontal lobes contain motor areas conforms with this view.

14.3.5 Hippocampus And Long Term Memories

The findings about hippocampal system provide a good test for the general ideas about long term memory. For a review about the role of hippocampus in long term memory see [J127].

Anatomy of hippocampal system

The anatomy of hippocampus is discussed in [J14]: here only very rough summary is given: possible inaccuracies are due to my amateurish knowledge of brain science.

Hippocampus is located with the inferior medial wall of the temporal lobe posterior to the amygdala. Hippocampus decomposes into anterior and posterior regions. Hippocampus consists of a number of subcomponents, and adjoining structures, such as the parahippocampal gyrys, perirhinal and peritorhinal cortex and uncus. The main body of the hippocampus consists of the

dentate gyrus (here brain cells are regenerated), the subiculum and the sectors referred to as CA1, CA2, CA3 and CA4. The uncus is a bulbar allocortical protrusion located in the anterior-inferior medial part of the temporal lobe.

There are three major neural pathways leading to and from the hippocampus. These include the fornix-fimbrial fiber system, and a supracallosal pathway which passes through the cingulate, and via the entorhinal area: this is the mesocortical gateway to the hippocampus. Through the fornix-fimbrial pathways hippocampus makes major interconnections with the thalamus, septal nuclei, medial hypothalamus, and exerts either inhibitory or excitatory influences on these nuclei.

The entorhinal cortex acts to relay information to and from the hippocampus. The hippocampus maintains via the entorhinal cortex interconnections with the neocortical multi-modal associations areas of the temporal, frontal, and parietal lobes, including surrounding structures, e.g., the parahippocampal gyrus, and allocortical tissues, the perirhinal cortex, septal nuclei and amygdala. The parahippocampal gyrus, entorhinal and perirhinal cortex, being directly interconnected with the hippocampus and the neocortex, act to relay input from the neocortical association areas to this structure.

The entorhinal cortex consists of 7 to 8 layers rather than only 6 layers. The entorhinal cortex maintains massive interconnections with all multi-modal neocortical association areas (as well as with the amygdala, hippocampus, septal nuclei, olfactory bulb, etc.) but none of the primary sensory areas which presumably relates to the fact that hippocampus is responsible for declarative rather than sensory memories.

Memory deficits and hippocampus

Memory deficits provide important information about the role of hippocampus with respect to the memory. In anterograde amnesia the ability to generate new long term declarative memories is lost and it is known that a damage to the hippocampus can cause this defect. Thus it seems that hippocampus is crucially involved with the construction of long term memories. Also the damage to the medial temporal lobes and subcortical structures such as medial thalamus and mammillary bodies can destroy the ability to generate long term memories. This supports the view that hippocampus is kind of a central entangler binding together mental images from various parts of brain: most naturally entanglement occurs along the three neuronal pathways going through hippocampus and presumably associated with torus-like magnetic flux tubes.

In retrograde amnesia memories about some period of time in past are lost. It seems that this deficit does not correlate with the damage of hippocampus. Thus the cautious conclusion is that long term memory recall occurs also elsewhere in brain. The selectivity of the retrograde amnesia suggests that the notion of the memory field applying in the case of short term memory [J150] generalizes. The brain structures responsible for the receival of long term memories are specialized in the sense that they entangle with the mental images of the geometric past located only in an interval around certain temporal distance T. If the memories involve only few reflections along a closed magnetic flux loop, the corresponding MEs have fundamental frequency $f = 1/T$ and correspond to spin glass transition for microtubules or for 3-dimensional sub-neuronal structures at a length scale between cell size and cell membrane thickness if the simplest estimate makes sense. This kind of resonant selectivity might be possible to achieve if the receiving system is driven to the bottom of the spin glass landscape with a depth which corresponds to the gravitonic energy $E = 2\pi f$ If memories involves large number of reflections, it is difficult to imagine, how this kind of selectivity could be achieved.

Hippocampus and declarative memory

It is known that there are several memory types and hippocampus is responsible for the construction of only declarative memories, which are verbal and highly symbolic representations of the geometrical aspects external world. Hippocampus is not essential for the recognition of familiar objects nor for procedural/motor memories which are implicit memories. The natural identification of declarative memories is as memories communicated classically using some coding but one cannot exclude sharing of mental images. Memetic code or its scaled up/scaled down is a good candidate in this respect. The modulation of hippocampal theta might provide the coding.

Sensory memories can be induced by the electric stimulation of both hippocampus, amygdala and temporal lobes. This suggests that lower levels of self hierarchy which we do not experience directly can have sensory memories. The entanglement by negative energy ME with the geometric past giving rise to an episodal memory is the most natural interpretation for the effect. Neural loops are the geometric correlates for entanglement at the level of CNS, and time-like quantum entanglement of parts of the electrically stimulated structures with primary sensory areas with the mediation of these loops should be involved. If the stimulation is too strong, hallucinations result. In this case the sensory representations in the brain geometrically now are presumably activated and back projection to the sensory organs would occur. An interesting possibility is that the strength of stimulation correlates with the temporal distance of the sensory representation in the geometric past activated in the stimulation.

Hippocampus provides spatial and temporal context

The right hippocampus of the taxi drivers in London is enlargened. This supports the view that hippocampus provides kind of a symbolic map of the spatial layout of the environment. Studies in animals suggest that hippocampus adds a spatial context to the mental images from cortex entangled with mental images in subhippocampal structures entangled with the mental images in hippocampus. The spatial map is based on various spatial cues serving as landmarks. Left hippocampus is in turn involved with the verbal memories and this suggests that it is responsible for providing a temporal context and time ordering of events. This suggests that hippocampus is responsible for the temporal and spatial organization of conscious experience besides generating memory representations. Perhaps a high level sensory representations at the magnetic body is in question.

Hippocampus is known to contain place cells providing cognitive representations for the objects of perceptive field. These place cells are pyramidal cells containing magnetic crystals which suggests that they act as projectors to the magnetic memory canvas. All kinds of features could be associated with these landmarks, and more generally, with the symbolic objects of the memory field.

Long term potentiation (LTP) does not occur in hippocampus but hippocampus is highly dynamical with synaptic contacts being generated all the time and even the size of hippocampus continually changing. It would seem that hippocampus provides by its own dynamical structure a context for various data coming from cortex, kind of a geometro-symbolic model for the external world. The mental image associated with this model of external world quantum entangles with the mental images in cortex, amygdala, hypothalamus, etc...

Not only spatial but also temporal context is important and hippocampus should provide also this. Purely sensory memories do not carry any information about whether memory is in question or not. For symbolic representations the situation is different. Symbolic representations would be realized as association sequences, perhaps in the time scale of hippocampal theta such that each 3-surface of association sequence contains lower level association sequences contains.... Memetic code words of duration .1 seconds would be at the lowest level and perhaps correspond to mesoscopic features of Freeman [E2].

The intronic portion of DNA could provide the fundamental hardwave representation of memes in terms of sequences of 21 DNA triplets: spoken language would be only a tip of an iceberg if this picture is correct [K52]. Positive energy em and MEs could realize these memes in the shape of vacuum current, which at given moment of time is non-deterministic and therefore optimal in this respect. Memetic code realized in terms of magnetization direction for quark sub-CDs is a further candidate for realizing the symbolic representations. This highest level representation adding context to the other data located in the geometric past would entangle via MEs with the brain of the geometric now in case of episodal memories. The fact that hippocampus is thought to be involved with the transfer of items in short term memory to long term memory in cortex conforms with the mirror mechanism.

Entorhinal cortex serves as some kind of a relay station between hippocampus and neocortex. Entorhinal cortex has very special structure being 7-to-8 layered rather than 6-layered. Entorhinal cortex maintains rich connections to various multimodal regions in temporal, parietal and frontal cortices but not to the primary sensory areas. This is consistent with the idea about three-leveled hierarchy *multimodal areas*$\rightarrow$ *entorhinal* $\rightarrow$ *cortex-hippocampus*, with the fact that the mental

images associated with hippocampal memory representations are symbolic rather than sensory, and with the assumption that multimodal areas, entorhinal cortex, and hippocampus entangle.

Hippocampal theta corresponds to EEG frequency range varying from about 4 Hz to 12-14 Hz and thus spans both theta and alpha bands. Hippocampal theta can be seen as a correlate for the binding of various cortical and subcortical mental images to a single mental image representing both that aspect of consciousness which makes possible organized view about space and time and declarative memory. MEs at hippocampal theta frequencies could project to the magnetic memory canvas providing an abstract representation about world analogous to sensory representation but without sensory qualia. It must be emphasized that the memory representation should provide an essential part of our everyday consciousness making possible space and time categories of everyday conscious experience. Novel and painful stimuli indeed induce hippocampal theta as well as orienting reactions, learning, selection and discrimination.

Remote emotions and associations?

Amygdala seems to be responsible for the formation of emotional aspects of the memories in accordance with entanglement paradigm. Amygdala is known to be sensitive to emotional contextual cues which can trigger perceptive experiences similar to previous ones. Associative memories seem to be in question.

Whether the associative memory is in the geometric now or past is not obvious and time-like quantum entanglement might perhaps allow to induce remote associations in the geometric past. If the cue is entangled with the cue in the geometric past, the activation of this cue by quantum entanglement could activate neural process generating the memory in the geometric past. This kind of mechanism would provide a general mechanism of active memory retrieval. The active scanning of memory neurons with memory fields characterized by different values of T would be a second mechanism of this kind. In fact, there need not be any sharp difference between ordinary associations and associations in past.

Memory consolidation and long term potentiation

The notions of memory consolidation and long term potentiation relate to the more standard views about long term memory and it is interesting to try to interpret them in TGD framework. Memory consolidation means the strengthening of memories by "replaying" them. Certainly a repettiion of mental image provides a manner to learn and establishing a long term memory also in TGD. The mere generation of gravitational MEs associated with a given mental image means consolidation: no modification of the existing neural connectivity is needed. Of course, standardized mental images are probably generated but this is not construction of memories in the strict sense of the word.

Memory consolidation involves hippocampal theta. In TGD framework hippocampal theta is a correlate for that part of consciousness which gives rise to an organized view about space and time: not necessarily in the geometric now however. Mirror mechanism implies that this process defines automatically memory representations about the state of brain so that memory consolidation is an automatic side effect.

It has been proposed that during REM sleep hippocampus is "replaying" the memories unconsciously [J174]. The fact that there is no sensory input at night time would suggest that sleeping brain is like an empty magnetic tape freely usable for the memory construction. Theta and delta bands could relate to the memory representations replayed during sleep period but could be also responsible for the construction of higher level sensory representations important for non-episodal memories.

There are however objection against the idea that REM sleep is specialized with the replaying. First, hippocampal theta, believed to be crucial for the formation of long term declarative memories, is not synchronous during REM sleep. Secondly, during dreams only the posterior portion of the hippocampus is active whereas during learning the active part is the anterior portion of the hippocampus.

TGD based vision suggests a first principle explanation for the activity of hippocampus during sleep and dreams. Both classical communications to the geometric future and the receival of negative energy MEs from the geometric future require metabolic energy feed. Since the

metabolism related to the motor activity and sensory preception is absent during sleep, the optimal realization of the long term memories is based on the entanglement with the sleeping brain of the geometric past. This would also explain why we do not have conscious experiences about memory recalls from the geometric future. Sleeping brain can also help the situation by performing memory recalls itself. REM sleep would not be in any special role except that it could make possible episodal sensory memories.

The memories about dream experience fade out rapidly after wake-up. This suggests that the lengths of the magnetic flux tubes along which classical communications occur during dreams, are short and therefore also the time span of the resulting declarative memories is brief. This as it should be since otherwise dreams would make possible pseudo memories. We could be conscious during dreams but would not remember it since long term memories would not be generated during this period. Alternatively, dream memory representations could be generated by the larger self to which we are fused during sleep. The above mentioned findings about the hippocampal activity during dreams could mean that magnetic flux loops of declarative memory get longer in posterior-anterior direction: this would mean a concrete identification for the neurophysiological correlates of the declarative memory fields. Also the dominating frequency of EEG/ZEG would become lower in this direction.

The basic question relates to the interpretation of the hippocampal theta. There are two options.

1. Hippocampal theta is associated with the MEs responsible for the classical communications to the geometric future making possible long term memories.

2. MEs take care of the classical communications to the geometric future (memetic code) whereas hippocampal theta contributes to the conscious experience of the geometric now by generating high level sensory representations at the personal magnetic body.

For the latter option hippocampal theta could be also involved with the generation of entanglement between various parts of brain crucial for the construction of long term memories making possible an organized view about space and time. This assumption conforms with the idea that EEG rhythms are responsible for the synchrony and entanglement. This would not happen during REM sleep since hippocampal theta is asynchronous during dreaming and during cortical synchrony (not much sensory input). Visual dream consciousness is indeed sensory consciousness without an organized view about space and time categories. This applies also to the non-REM verbal dreams. Furthermore, the de-synchronization of both hippocampal and cortical EEGs implies a confused state of mind. This would suggest that hippocampus indeed contributes also to our consciousness in the geometric now, and makes possible the organized view about space and time by constructing higher level sensory representations.

Long term potentiation (LTP) has been suggested as a mechanism by which hippocampus generates long term memories by strengthening the synaptic communications between neurons. In TGD framework this interpretation does not make sense: rather LTP can be seen as a special case of associative learning which is just gradual modification of the brain structure as a response to the conscious experience. Of course, LTP modifies gradually memory representations but these memory representations do not contain information about past.

As noticed, LTP does not occur in hippocampus itself. Instead, hippocampus grows rapidly in neuron number and synaptic connections during long term memory generation. This conforms with the view that hippocampus is more or less a real time dynamical representation for what might be called changing context. In particular, new neurons generated in hippocampus could be essential in representing the context and could generate gravitonic MEs crucial for the entanglement.

Relationship between cortical and hippocampal EEGs

Cortical de-synchronization accompanies hippocampal synchronization and vice versa. The simultaneous de-synchronization of cortical and hippocampal EEGs involves distractability and hyperresponsiveness so that person becomes owerwhelmed, confused, and may orient to and approach several stimuli.

These findings can be understood in TGD framework.

1. During cortical asynchrony there are good reasons to build long term memories so that hippocampus should be in synchronized state and bind various mental images to long term memories.

2. During cortical synchrony there is nothing to represent as long term memories and hippocampus can do something else. Perhaps participate in imagination and day dreaming as suggested by the fact that also during REM sleep hippocampal theta is asynchronous.

3. When both cortical and hippocampal theta are de-synchorized, not only the long term memory representations fail to be generated but also the construction of spatial and temporal context and this leads to confusion and difficulties with orientation to various stimuli.

14.3.6 Microtubuli And Long Term Memory

When I began consciousness theorizing whole-daily around about 1994, I became deeply fascinated about microtubuli (as probably most others in the field of quantum consciousness). I launched off by developing a rudimentary model about how microtubuli could act as quantum antennae in the TGD universe: massless extremals were the key element of the model. Needless to say, too much of the general theory of consciousness and of biosystems as macroscopic quantum systems needed for a deeper understanding was unconscious-to-me at that time.

After the rapid self-organization of the theory during this year and still continuing (I am living last days of August 2002 while writing this), it occurred to me that it might be a good idea to take a fresh look on the role of the microtubuli. While re-reading the wonderfully inspiring article of Nanopoulos dating back to 1995 [J69], I realized that the TGD based view about macrotemporal quantum coherence, the mirror mechanism of long term memory, and the quite recent discovery of cognitive codes and their physical realization, provide the tools for developing a view about the role of microtubuli in long term memory.

What made me somewhat skeptic about the importance of the microtubuli for *our* consciousness was the naïve view that the size L of the system system generating the memory increases when the geometrotemporal distance T of the long term memory increases. Microtubuli would be conscious but from our point of view this would represent something analogous to bit level in computers.

The understanding of how the macrotemporal quantum coherence is generated however challenged this view. TGD Universe is quantum spin glass and spin glass degeneracy is broken only by the classical gravitational binding energy. Quantum transitions between almost degenerate quantum spin glass states correspond to frequencies defined by the differences of the classical gravitational binding energy and generate gravitational MEs responsible for the quantum mirror mechanism. Gravitational binding energy increases with the system's size and this means an effective inversion of the length scale hierarchy, so that systems like microtubuli can contribute to our conscious experience much more significantly than some subsub....sub-self level at the bottom of the self hierarchy might be expected to do.

Basic findings about the correlation between long term memory and microtubuli

A basic difference between ordinary cell and neuron is that the microtubuli associated with the T shaped centriole in case of the ordinary cell, are in neuron replaced by long microtubule bundles starting in a region near nucleus and connecting it to dendrites and axonal ends. The natural guess is that at least these microtubuli are closely involved with the brain consciousness.

What happens in microtubuli is indeed very intimately related to what happens in synapses. The minimal modification of the standard neuroscience belief system is that microtubuli control how synapses, still assumed to be responsible for the memory representations, are modified during learning identified as generation of long term memories. In [J69] a lot of basic facts about microtubuli plus the evidence for the correlation between microtubuli and long term memory is discussed and references can be found in this article. Here I just summarize the basic points of the discussion of [J69].

1. The production of tubulin and MT activities correlate with peak learning, memory and experience in baby chick brains. Experiments with baby rats show that when they first open they eyes, neurons in their visual cortex begin producing vast quantities of tubulin.

2. The experiments with trained goldfishes show that the drug colchicine produces retrograde amnesia. The interference with MTs responsible for the structural modification of certain synapses is believed to affect memory fixation. In TGD framework one must carefully distinguish between learning and memory: microtubuli could provide both the long term memory representations and also control learning by controlling synaptic strengths.

3. The selective dysfunction of animal brain MTs by the drug colchicine causes defects in learning and memory which mimic the symptons of Alzheimer's disease (AD). It has been reported that in rats a continuous MT disruption induced by a chronic colchicine administration results in a dose-dependent learning deficit, and memory retention is also impaired. It has also been stressed that these colchicine-induced cognitive defects resemble those of AD, e.g., amnesia of the recent learning and loss of formerly established memories. These findings encourage to think that microtubuli are involved both with the generation of the memory representations and long term memory recall by mirror mechanism in accordance with the idea that microtubuli act as both receiving and sending quantum antennae in the sense that they generate MEs making possible time-like quantum entanglement. MEs generate coherent photons or gravitons according to the original definition of quantum antenna [K85]. Certainly, the antenna which sends is also optimal for receiving.

4. It has been suggested and also supported by detailed experimental studies that the impairment of MTs, leading to tangled and dysfunctional neural cytoskeleton, may be one explanation for the pathogenesis of AD.

5. In specific hippocampal regions of the brain of schizophrenic patients, distorted neuronal architecture has been found due to a lack of 2 MAPs. This suggests that the splitting of consciousness characterizing schizophrenia has a geometric correlate already at the microtubular level: macroscopic bound state entanglement responsible for the binding to long-lived holistic microtubular mental images and the generation of memory representations would not occur as they should.

How microtubuli could relate to declarative long term memories?

For several reasons microtubuli are tailor-made for the realization of long term declarative memories in TGD Universe (the structure of microtubuli is discussed in some detail in [K81], where the realization of cognitive codes is discussed). Microtubuli are however not the only candidates: also 2-D membrane like structures and genuinely 3-D structures could be involved and correspond to different types of long term memories.

1. Microtubuli can entangle with each other and with the surrounding world in conformational degrees of freedom to yield macrotemporal quantum coherence. Microtubule associated proteins (MAPs) can mediate naturally bound state entanglement between conformational patterns of different microtubuli. This makes possible macrotemporal quantum coherence and processes resembling quantum computation when bound states are formed. MAPs can act as switches initiating quantum computation and halting it. The simplest possibility is that MAP protein becomes just disconnected at some levels of the hierarchy of space-time sheets.

2. Tubulin dimers allow two different conformations and the patterns of tubulin conformations are ideal for binary representations of data natural for the representation of long term declarative memories. In [K81] a cognitive code explaining the numbers associated with microtubular geometry is discussed and a model for how the conformational patterns are coded into conscious experience in the phase transition in which spontaneous electric polarization occurs and forces all tubulin dimers to the ground state conformation. That microtubuli allow the realization of the symbolic counterparts of cognitive representations realized using cognitive neutrinos and possibly also by p-adic MEs, conforms with the fact that colchicine which affects MTs, induces cognitive defects characteristic of Alzheimer's disease. The linearity of microtubuli would be obviously essential and at least parts of the sensory pathways could be responsible for the representations of these memories.

3. In the standard view about long term memories one cannot identify microtubuli as seats of long term memory representations. The reason is simply that microtubule conformations are quite too short-lived for this purpose. This leaves only the identification of the synaptic strengths as a representation of long term memories. In TGD the situation is just the reverse and flexibility requires fast enough dynamics. The time scale defining sensory resolution is obviously a bottle neck time scale. The time scale for the phase transition leading to ground state of tubulin dimer in an external electric field and the time scale related to the control of the external electric field at the microtubular space-time sheet are the most obvious guesses. The first time scale should be of order of the time scale of conformational dynamics, about nanosecond. The latter time scale would be basically the duration of nerve pulse if nerve pulses are responsible for the phase transition in question. In TGD framework the modification of synaptic strengths can be more naturally seen as representing generation of new "habit routines" rather than memory representations which are much more involved and information rich.

4. Microtubuli are ideal for quantum mirror mechanism of long term memories. As already found, in case of spherical structures the dependence of gravitational binding energy on size of the structure is $E_{gr} \propto L^5$, whereas the gravitational binding energy depends on the length L of a linear structure as $E_{gr} \propto L$. For membrane like structures $E_{gr} \propto L^3$. Since microtubule lengths vary in the range 10 nm- 1 mm, this means that the temporal distance $T \propto 1/L$ of long term memory varies between 32 years 2.8 hours (very roughly; increase of the overall time scale due to the fact that increment of the gravitational binding energy in the transition is smaller than the gravitational binding energy itself). Inside axons microtubuli can bind to longer structures by MAPs and even meter sized structures associated with sensory pathways are possible. This lowers the lower bound for the time span to 10 seconds. The longest microtubuli are responsible for the representation of the shortest term memories realizable in this manner. Of course, memory circuits should regenerate again and again microtubular memory representation and in this sense synaptic strengths become an essential part of the memory representation.

5. Colchicine affects both memory recall and memory generation. This inspires the working hypothesis that microtubuli of a given length $L \propto 1/T$ in the geometric past entangle with a microtubule of same length in the geometric now during memory recall. For instance, the receiver in the geometric now could correspond to a postsynaptic microtubule whereas the sender in the geometric past corresponds to a presynaptic tubule. This is not the only alternative, receiving cells could be even glial cells.

6. That the memories of childhood are the most stable ones could be interpreted as reflecting the fact the microtubuli act both as receiving and sending quantum antennae, and that the long microtubuli responsible for generating the short term memory representations and for receiving them deteriorate towards the old age with much higher probability than the shorter ones. It could be possible to induce selective amnesia restricted to memories with a temporal distance $\sim T$ by a treatment which affects microtubuli of given length $\sim L \propto 1/T$.

7. Microtubuli could be also ideal for the communication of non-episodal memories involving classical communication by ultra slow MEs perhaps accompanied by Ca^{++} waves known to have an extremely wide velocity spectrum. Ca^{++} ions are associated with the outer surface of the microtubuli and dynamically comparable to a crop field in a wind. Ultra-slow orientational waves for these Ca^{++} ions representing sensory inputs and propagating along axons could make possible a classical communication of data from the geometric past as declarative memories. For sensory pathways the sequences of microtubuli could have a total length of order one meter. For the average length $L_0 = 10\ \mu m$ of the microtubule in brain, the time span $T_0 = 10$ seconds would give $v_0 \sim 1\mu m/s$, a typical velocity of in cellular level. In this case 10 nm length of microtubule would correspond to 10^{-2} seconds of time. This would mean that roughly 13 parallel sequences of 13 bits of information about 10 millisecond period. The bit rate of one bit per millisecond corresponds to the information storage capacity of the memetic code. For longer time intervals T and microtubule lengths L the bit rate would scale like $(L/L_0) \times (T_0/T) = v/v_0$. For $T = 1$ year and $L = L_0$ one

would have roughly one bit per hour. It seems that this mechanism can be at work only for short term memories whereas long term memories would involve closed magnetic loops.

Relation to the general model of long term memories

It is interesting to relate the proposed model with the general model of long term memories.

1. Long term memory is lost when tubulins return to ground state unless there is some mechanism regenerating the conformational state. In brain the function of neuronal loops generating the nerve pulse patterns repeatedly would take care of regenerating the memory representation. If this view is correct, then also memories of childhood involve this kind of continual regeneration. Sensory pathways do give rise to long term memories unless the feedback from brain to primary sensory organs (oto-acoustic sounds and the movement of eyes during REM sleep) regenerates these memory representations. During dream long term memories correspond to small value of T: does this allow to conclude that the feedback to the primary sensory organs during dreams results in long term memories with T about few minutes? The maximization of the lengths of the sensory pathways (left side of the body is connected to right brain hemisphere and vice versa) would relate to the maximization of the representational capacity if this mechanism is at work. The most natural assumption is that sensory representations are regenerated for time interval of order T so that the maximal values of T and stablest memories correspond to relatively short microtubuli in the interior of neuron.

2. Hippocampus is believed to be crucial for the generation of long term declarative memories and responsible for spatio-temporal organization of perceptive field. Hippocampus could act as a kind of entanglement center entangling with "features" at various brain areas and project them to the sensory magnetic canvas (the episodal component representing spatial relationships might accompany also non-episodal memories!). Feature sub-selves would have microtubular selves as sub-selves: this would mean entanglement between hippocampal and other microtubular memory representations. The microtubuli acting as central entanglers in hippocampus should be relatively short, with lengths not much longer than the length determined by the lower bound for temporal distance T for long term memories. The maximal length L of hippocampal axons should correspond to this T and $L \sim 10^{-2}$ meters from the size of the hippocampus might be a reasonable guess giving a time scale of about 15 minutes (these estimates are just orders of magnitude).

3. The recall of long term memories could basically correspond to a transition of a neuronal microtubule to a higher energy state by an emission of negative energy ME. The process would be preceded by the emission of a p-adic ME representing the intention to remember and transformed to a real negative energy MEs in the jump to a higher energy state. The neuronal/astrocytic microtubules of the right brain hemisphere could be specialized to send/receive negative energy MEs, whereas the astrocytic/neuronal microtubules of the left hemisphere would be specialized to send/receive positive energy MEs. Of course, this is just a naïve guess inspired by the right/left–holistic/reductionistic dichotomy. What is however clear that microtubuli with abnormally small metabolic energy feed would be responsible for generating long term memory recalls and those with abnormally large energy feed responsible for generating long term memories.

4. Tubulin dimers correspond to the Mersenne prime $p = M_k = 2^k - 1$, $k = 13$, and the n-ary 13-adic time scale nearest to p-adic prime nearest to .1 second time scale of the memetic code word is $T(20, 13) \simeq .8$ seconds whereas single bit lasts for $T(20, 13)/13 \simeq 61$ milliseconds. .8 seconds is rather natural time scale from the point of view of human consciousness. Corresponding frequencies are 1.25 Hz in delta band, and 16.25 Hz in the lower end of the beta band which conforms with the fact that cognition correlates with the beta band activity of EEG. That delta frequency alone does not give rise to conscious experience would be due to the fact that no phase transition giving rise to a conscious experience occurs if all tubulins possess same ground state conformation. The facts that delta band weakens during aging and also memory generation mechanisms deteriorate towards the old age, conform with the

idea that this band is responsible for the generation of memory codewords. If this view is correct, hippocampal theta should be responsible for the binding of mental images rather than coding of our long term memories. Of course, also a lower level representations in time scale of hippocampal theta could be in question.

5. At this stage it is not possible to answer the question whether microtubuli correspond to sub-selves or subsub....selves. If the entangled microtubuli correspond to our sub-selves, the microtubuli belonging to different neurons should be able to entangle with each other. This requires the presence of flux tube contacts between pre- and postsynaptic microtubuli. MEs with lengths of neuron length scale could serve as this kind of contacts and generate time like entanglement between the microtubuli of neurons along the neural pathway.

What about effectively 2-D and 3-D memory representations?

Microtubuli need not be solely responsible for our long term memory representations. The fact that microtubuli seem to correlate with cognition and declarative memories which involve typically representations linear with respect to time suggests that the effective dimension D of the structure involved determines the character of the long term memory and also that of sensory experience. Moreover, it is quite possible that a large number of entangled neurons results in a kind of "stereo consciousness" fusing a large number of slightly different views about the same sensory input. This would mean large number of entangling Grandmother neurons.

1. Cell membranes consist of a large number of parallel rather than serially ordered units. Hence cell membranes could be responsible for the storage of sensory memories, which are 2-dimensional at the basic level, say visual images. The neuron size of 10^{-4} meters corresponds to the lower bound of about millisecond for $T \propto L^3$.

2. Three-dimensional blobs of biomatter in length scale range 1 micron-10 nanometers span the range 1 millisecond-32 years for temporal distance T. This allows to consider the possibility that 3-D structures could be also responsible for long term memory representations. If one takes seriously the dimensional rule, 3-D structures should give to genuinely three-dimensional sensory memories and make 3-D spatial imagination and sensory experience possible. It is not obvious whether neurons contain any 3-D lattice like structures besides liquid crystal blobs of ordered water. Effectively 3-D structures could also result as composites of 2-D structures.

14.4 Hyper-Finite Factors Of Type II_1, Dark Matter Hierarchy, And Long Term Memories

This section is devoted to the progress that has occurred during since 2004 and represents new material which has not yet been fully integrated with the older material. The realization that the von Neumann algebra known as a hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition. One of the most important outcomes is a prediction of a hierarchy of quantum phases with arbitrarily large values of quantized Planck constant identified as dark matter and assumed to be the quintessence of living matter.

14.4.1 Hierarchies Of Algebraic Extensions Of Rationals, Quantum Criticalities, Planck Constants, Dark Matter, And Of Hyperfinite Factors

Quite recently (2004-2005) the hierarchy of Planck constants labelling hierarchy of dark matters was understood as labelling a hierarchy of quantum criticalities giving a precise content for the vision that TGD Universe is quantum critical and direct connection with super-symplectic symmetries of TGD emerges.

This hierarchy accompanies an even deeper hierarchy of algebraic extensions of rational numbers allowing to realized number theoretical universality by fusing reals and various p-adic number fields to anadelic structure inducing adelic counterparts at the level of space-time, embedding space, and WCW. This approach allows to identify preferred p-adic primes as ramified primes of algebraic extension.

In strong form of holography p-adic continuations of 2-surfaces to preferred extremals identifiable as imaginations would be easy due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K81]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes. Whether these primes correspond to p-adic lengths scale hypothesis or its generalization to small primes, is an open question.

The hierarchy of algebraic extensions realized abstractly at the level of WCW in terms of parameters characterizing space-time surfaces so that one avoids problems with symmetries. In the adelic approach cognition having p-adic space-time surfaces as its correlates is a basic aspect of existence in all length scales in this vision. Strong holography allows to reduced the intersection of realities and p-adicities to string world sheets and partonic 2-surfaces.

The fractal hierarchy of sub-algebras of super-symplectic algebra isomorphic to algebra itself realizes the quantum critical hierarchy. These algebras have conformal structure and for sub-algebra the conformal weights are n-ples of those for the entire algebra.

The Clifford algebra spanned by gamma matrices of WCW defines standard example about a von Neumann algebra known as hyper-finite factor of type II_1. Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of the WCW ("world of classical worlds"). The hierarchies of inclusion sequences for sub-algebras of super-symplectic algebra labelled by $n_i = m_i \times n_{i-1}$ define excellent candidates for hierarchies of inclusions of hyper-finite factors. The measurement resolution increases along this sequence since at each phase transition $n_i \to n_{i+1}$ gauge degrees of freedom are transformed to physical ones. This hierarchy also relates naturally to evolutionary hierarchy. According to the arguments of [K137] the value of n relates closely to the dimension of algebraic extension of rationals and ramified primes are factors of n: this however only by physical argument. Number theoretically the dimension of extension and ramified primes are independent.

14.4.2 Dark Matter Hierarchy

The identification of dark matter as phases having large value of Planck constant [K112, K138, K36] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [K138]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of [J70] [K37]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K65, K37]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K37].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations.

1. The argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of h_{eff} at all.

2. The failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy.

3. The phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

4. The recent view about quantum criticality allows to identify the space-time counterpart for $h_{eff} = n \times h$ as space-time surface, which is singular n-sheeted covering with the branches of the covering fusing to single 3-surface at the boundaries of CD. The very essence of quantum criticality is that n distinct space-time sheets collapse to single space-time sheet at the ends of CD. This identification replaces the earlier proposal that singular n-sheeted coverings of embedding space are in question. This view serves however still as a convenient auxiliary tool. The non-determinism associated with n-sheeted covering corresponds to the four-dimensional spin glass degeneracy.

Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1. The characteristic property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [K44].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [K138]. In particular, the notions space-time as a hyper-quaternionic four-surface of embedding space emerges.

2. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. In particular, experimentally favored values of h_{eff} in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2, C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. I have proposed that the most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2, C) \times SU(2)$.

3. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimic these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

Dark matter hierarchy and the notion of self

The introduction of dark matter matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed. The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [K36, K37].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. The hierarchy comes as $h_{eff} = n \times h$, n integer. There are indications for important sub-hierarchies such as hierarchies, for which n is power of prime. In particular, for the hierarch for which one has $n = m^r$, $m = 2^k$. The first guess about Planck constants was $m = 2^{11}$, which corresponds roughly to the ratio of proton and electron masses. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto 2^{kn}$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels.

The averaging of mental images over quantum jumps would occur only for the mental images sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n,p)$ for a given value $h_{eff} = m \times h$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m,n,p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

14.4.3 The Time Span Of Long Term Memories As Signature For The Level Of Dark Matter Hierarchy

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n,p)$ for a given value$h_{eff} = m \times h$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m,n,p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in

single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution [K37]. EEG frequencies correspond at this level dark Josephson photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question. The level in the would determine also the time span of long term memories as discussed in [K37].

The emergence of these levels must have meant evolutionary leaps since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K65, K37]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

14.4.4 Remote Metabolism, Long Term Memory, And Zero Energy Ontology

The notion of negative energy signals and time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) emerged before zero energy ontology. Since the mechanisms of remote metabolism, of memory, and of intentional action rely on time mirror mechanism, one should check that this mechanism is indeed consistent with zero energy ontology. Zero energy ontology could also yield new insights to these mechanisms.

Zero energy ontology

Zero energy ontology states that physical states have vanishing net conserved quantum numbers and states decompose to positive and negative energy state and that the latter one can be said to be located in the geometric future with of the positive energy state at the time-like boundary of the space-time sheet representing the system. It is possible to speak about energy of the system if one identifies it as the average positive energy for the positive energy part of the system.

The matrix ("M-matrix") representing time-like entanglement coefficients between positive and negative energy states unifies the notions of S-matrix and density matrix since it can be regarded as a complex square root of density matrix expressible as a product of real squared of density matrix and unitary S-matrix. The system can be also in thermal equilibrium so that thermodynamics becomes a genuine part of quantum theory and thermodynamical ensembles cease to be practical fictions of the theorist. In this case M-matrix represents a superposition of zero energy states for which positive energy state has thermal density matrix. As a matter fact, M-matrices for an orthonormal basis and it is now possible to construct unitary U-matrix relating various M-matrices in terms of S-matrix and the basis of hermitian square roots of density matrices [K78].

1. If the positive energy parts of zero energy states appearing in the superposition have only single value of energy, the notion of remote metabolism is certainly well-defined. Even in the case that the system is thermalized, remote metabolism makes sense since average energy can be increased by remote metabolism. One can even imagine a statistical variant of the process in which the temperature increases.

2. The critical question is whether crossing symmetry prevails in the sense that the positive energy signal propagating to the geometric future is equivalent to a negative energy signal propagating to geometric past.

The recent view about quantum measurement theory in ZEO allows to formulate the notion of negative energy signal propagating to geometric past in rigorous manner. State function reductions at both boundaries of CD are possible and the sequence of repeated reductions at fixed boundary gives rise to self as a conscious entity (Zeno effect). The first reduction to the opposite boundary means the death of self and re-incarnation at opposite boundary as time reversal of the original for which geometric time is opposite to that in original situation.

Time mirror mechanism and metabolism

Energy conservation and geometric arrow of time poses strong conditions on the mechanism. If positive energy part of state sends negative energy signal, then negative energy part of state must send a compensating positive energy signal. Furthermore, positive (negative) energy signals propagate towards geometric future (past).

1. If only single space-time sheet is involved, either negative energy signal S_-: $X^4_- \to Y^4_-$ or positive energy signal S_+: $X^4_+ \to Y^4_-$ is possible. The energy of both states is reduced in magnitude. For instance, this process tends to reduce destroy long term memories represented as bit sequences with bit represented by population inverted laser system.

2. Second possibility is that X^4 are Y^4 are disjoint and X^4 is in the geometric future of Y^4.

   The first possibility is S_+: $X^4_+ \to Y^4_-$ and negative energy signal S_-: $X^4_- \to Y^4_-$: the energy of both X^4 and Y^4 is reduced in this case.

   Second possibility is S_-: $X^4_+ \to Y^4_+$ and S_+: $Y^4_- \to X^4_-$. X^4 would suck energy from Y^4 in the geometric past. This option could correspond to both remote metabolism, memory recall, and intentional action. The presence of topological light ray connecting two systems would be also a correlate for time-like quantum entanglement making possible sharing and fusion of mental images and creating a sensation about flow of time just like it creates sensation of depth in stereo vision by fusion of right and left visual fields. Depending on the sign of the energy of the signal one would have memory or precognition. Precognition would require use of metabolic energy and this might be one reason for why it is rather rare.

3. Suppose next that the zero energy space-time sheet, call it X^4, is inside larger space-time sheet, call it Y^4: $X^4 \subset Y^4$. In this case one can have S_-: $X^4_+ \to Y^4_+$ accompanied by S_+: $X^4_- \to Y^4_-$. $X^4 \subset Y^4$ would suck energy from a larger system Y^4. It is of course possible to replace signals with signals of opposite energy in opposite time direction.

   A possible interpretation is as a metabolic charging of smaller space-time sheets by sucking energy from longer scales or by active pumping of energy to shorter scales. The transformation of long wavelength photons with large Planck constant to short wavelength photons with smaller Planck constant is an analogous process and might realize metabolic charging in biology. For instance, Sun-Earth system could correspond to Y^4 and biosphere to X^4.

To sum up, zero energy ontology completes the picture in the sense that it also provides a process making possible metabolic charging.

Thermodynamical considerations

It is not at all obvious whether the proposed picture is consistent with the standard thermodynamics. The transfer of energy from long to shorter length scales making possible to gain metabolic energy and realize the mechanism of long term memory indeed seems a genuinely new element. This process resembles dissipation in the sense that energy is transferred from long to short length scales. In an approach to thermal equilibrium temperature gradients are however reduced whereas remote metabolism favors the active generation of "hot spots".

These considerations relate closely to the notions of entropy and syntropy by Italian mathematician Luigi Fantappie [J121] assigned with the two arrows of time. I learned from the work of Fantappie in SSE conference held in Röros from Antonella Vannini [J37] and Ulisse Di [J171] [J171].The discovery of Fantappie was that in living systems entropic processes seem to be accompanied by syntropic processes which seem to be finalistic. He assigned these processes to the advanced solutions of wave equations.

It would seem that entropy and syntropy do not relate directly to the notion of remote metabolism.

1. Syntropy growth would indeed be the mirror image of entropy growth associated with negative energy mirror image of positive energy dynamics. This dynamics could be seen as sequences of downwards scalings leading from long time scale to short time scale. This sequence would define time sequences proceeding in opposite directions of time for positive and negative energy parts of states. Thus entropy growth would be accompanied by syntropy growth.

2. Syntropy growth could be also seen as a consequence of generalized second law applying with respect to subjective time and growth of syntropy would be growth of entropy but manifesting itself at space-time level in reversed direction of geometric time. For instance, the spontaneous assembly of bio-molecules from their parts could be seen as a decay process in the reverse direction of geometric time controlled by phase conjugate control signals.

3. Remote metabolism as generation of "hot spots" does not seem to reduce to these notions and might represent a genuine breaking of standard thermodynamical view about the world.

One must also distinguish the notions of entropy and syntropy from the notion of number theoretic entanglement negentropy N assignable with quantum entanglement with algebraic entanglement probabilities.

1. N is defined as the maximum of the p-adic entanglement negentropy $N(p)$ as a function of the p-adic prime p and thus assigns to an entangled system a unique prime p_{max}. $N(p)$ is obtained by replacing in the definition of the Shannon entropy the argument of logarithm with its p-adic norm. N is in general positive and thus defines a genuine measure of information.

2. The non-negative negentropy defined in this manner characterizes entanglement as a carrier of information rather than the state of either of systems and has nothing to do with the ordinary (non-positive) entropy characterizing the lack of knowledge about the state of either subsystem. Negentropy Maximization Principle [K73] favors the increase of the number theoretic negentropy and thus formation of entanglement quantum systems and generation of quantum coherence. Depending on the character of entanglement negentropic entanglement might be interpreted as a correlate for some conscious experience with positive content: say experience of understanding (time-like entanglement implying causal structure), of love (space-like entanglement), etc...

It is not obvious to me whether the remote metabolism as a way to build hot spots and diversity could be reduced to NMP or whether it should be regarded as something completely independent.

14.4.5 Applying Computer Analogy To The Model For Long Term Memories

The general model for long term memories does not say anything detailed about how memory recall can take place effectively. Taking seriously the idea that we made computers as our images, one can try to see whether the basic facts about memory storage and recall in the case of computers could help to guess how the memory recall is realized in TGD Universe.

The basic metaphor is 4-D brain as a kind of magnetic tape in time direction carrying memories as a text consisting of letters with fixed width (temporal duration) and decomposing into paragraphs, sections, etc... just like written text. Rhythms of generalized EEG would realize the decomposition to letters, and larger sub-units.

Computer analogy suggests also the analog of directory system allowing an easy and rapid access to a particular record in a particular file. Fractality would automatically make possible fractally scaled down variants of the system with life span scaled down to a second but details absent or not visible in the cognitive resolution available.

Web suggests a link system in temporal direction realizing temporal associations automatically and topological light rays which would be vacuum extremals in passive state could realize the link system.

The two kinds of memories seem to be closely related

There are two kinds of memories. The proposal is that the sharing of mental images of the geometric past gives rise to episodal memories, re-experiences. These memories would correspond to mental images identified as quantum jumps containing quantum jumps containing... for zero energy states. This hierarchy would correspond to dark matter hierarchy and hierarchy of Planck constant.

One can criticize this idea.

1. Does the quantum entangled zero energy state of the magnetic body and brain of the geometric past really give rise to the episodal memory as sharing of mental images? The sharing aspect would certainly give rise to experience of time as analog for the depth experience in stereo vision assumed to result from the sharing of left and right visual mental images. But why not interpret this kind of state as a representation for a "law of nature" telling that state pairs in the superposition of states are causally related? Isn't state function reduction reducing entanglement necessary to experience sharp sensory qualia? The answer to these questions is that it is entangled system whose qualia are in question, not either of the individual systems. In quantum context this would mean that the sum of observables giving rise to the qualia of separate systems are measured in quantum jump.

2. What it really means to have an episodal memory? For sharing of mental images by space-like entanglement of sub-selves the space-time correlate is the flux tubes connecting the space-time sheets condensed at larger disjoint space-time sheets. In the case of episodal memories it would seem that the experiencer-now and and experiencer-then must correspond to disjoint space-time sheets and containing smaller space-time sheets connected by a topological light ray. Hence also classical communications would be an essential part of the mechanism of memory and the distinction between episodal and declarative memories does not seem so sharp as thought originally.

3. The mere re-experiencing of events of the geometric past by quantum entangling with a subsystem representing sensory mental image is not very effective mechanism. A more effective manner to remember is to represent memories symbolically as bit sequences with bits represented as population inverted state and ground state of laser (say many-sheeted laser). In this case metabolism is required to keep the representations intact.

Memory recall as communications between magnetic body and brain of geometric past

Memory recall would be communications between magnetic body and brain of the geometric past. Magnetic body can be visualized as a kind of onion with several layers: the larger the radius of layer the longer temporal distance T to the geometric past it corresponds. In memory recall the size of the active layer would correspond naturally to the temporal distance to the brain of the geometric past where the memory is stored. The frequencies of large Planck constant photons involved with communications would correspond to this distance ($f \sim 1/T$) and a de-coherence to photons with much shorter wavelength would take place in the process.

Neuroscience suggests that theta waves, which still have wavelength of order Earth size scale, are involved. They could result in de-coherence of waves with wavelength of order $\lambda = cT$ reducing the value of Planck constant.

The most primitive memory recall would rely on the scanning of brain of geometric past by using negative energy signal with a slowly varying carrier frequency. One can however consider MEs which are present permanently as vacuum extremals and activated to non-vacuum extremals during memory recall: this would mean a realization of a link system.

How could one realize links in time-like direction?

Links are certainly one of the most powerful functions of the web. Links are always present and activated when used. The obvious counterpart for the web link would be a topological light ray connecting two subsystems with a time-like separation. Topological light rays can also reduce to vacuum extremals and the activation of the link could correspond to a feeding of energy to a

topological light ray deforming it to a non-vacuum extremal. This kind of links would be naturally associated with long term memories and would make it un-necessary to scan the entire geometric past in the search of a particular episodal or declarative memory.

Dreams and building up of copies of memories

Important memories should be stored in several copies since would increase the probability that the scanning of the geometric past allows to build ME bridge to the subsystem representing the memory mental image. Memories represented as bit sequences can be also lost in a repetitive recall since they might fail to receive metabolic energy feed.

Dreams might be a way to build this kind of copies. The copies built up in this manner can involve a considerable processing and it could even happen that for painful memories large number of less painful variants are constructed. Also the original memory could be transformed to less painful during the period of time-like entanglement. When it is important that memory remains unchanged, PS might in fact be not favorable and it is known that PS deprivation can help of keeping memory intact [J80].

There is a lot of evidence that memory processing indeed occurs during sleep (memory consolidation): in particular during paradoxical sleep (PS, REM periods with dreams) and during periods of deep slow wave sleep (SWS) preceding them. The sequential model for memories [J80] assumes that both periods are necessary. The first guess is that dreams and preceding SWS periods could build copies of both episodal and declarative memories.

The sensory experience associated with a dream possibly resulting partially by sharing of sensory mental image of geometric past (say previous day) could give rise to a symbolic representation realized as a kind of record. If also a copy of sensory mental image is created, the dream would involve virtual visual input generated by sending signals from brain to retina and other sensory organs involved (in TGD sensory organs carry fundamental sensory qualia). This back projection is present also during wake-up state and essential part of building sensory representation from the raw sensory data. The fact that dreams are by no means direct copies of the sensory inputs of the geometric past suggests that an active buildup of sensory mental images indeed takes place. One could however stretch the limits of imagination and argue that the dreams could be composed of sequences of shared mental images from different times: this would conform with the short time range of "dream logic".

If the brain can be regarded as a kind of magnetic tape in the temporal direction, SWS period might be interpreted as a kind of empty interval in the tape telling that a memory record comes next (kind of silence before concert). Second function of SWS pattern would be to divide the time axis to frames analogous to letters appearing as units in computer memory. The SWS interval might also contain a temporal pattern defining among other things what might be regarded as a name of the record in question. The temporal pattern of the negative energy signal used in memory recall should have such a pattern that it would "resonate" with this pattern. Note that vacuum extremal MEs could define "static" links to memory mental images activated during memory recall to non-vacuum extremals and one can imagine also sequences of these extremals building a sequence of links.

Directory system, holograms, and p-adic fractality

Directory system is necessary in order to handle computer memory effectively. Basically the directory would be a scaled down fractal variant of the geometric past with a reduction of details leaving only titles of sections and subsections, so to say. These directories would make possible an effective scanning of the brain of the geometric past by going directly to the correct directory coded roughly by the temporal distance. The fact that we can construct mentally fractally scaled down memory representations about what happened during day and even during lifetime without effort suggests that this kind of fractal representation indeed is there.

The obvious idea is that the items of directories serve as links to subdirectories so that it is possible to active link in each directory item leading to a subdirectory associated with that item.

The fact that p-adically small is large in the real sense would automatically realize small time scale representations of long temporal intervals. This would suggest that the memory storage mechanism is hologram like so that copies of memories in various time scales are present. Effective

p-adic topology would indeed suggest the presence of this kind of representation with various copies appearing as p-adically scaled variants of basic pattern for given p. For this option declarative memory recall would not require a precisely targeted signal to a particular moment of geometric past whereas sensory memories would require it (note however the possibility that dreams build more or less faithful copies of sensory memories).

One could imagine a fractal coding of names of directories and subdirectories by temporal distances in various p-adic length scales. Here effective p-adic topology giving rise to a hierarchy of p-adic length scales might play key role in the coding. Also dark matter hierarchy and hierarchy of Planck constants would be involved in an essential manner and code for various scales of long term memory. The fact that favored value of Planck constants and p-adic length scales come in octaves suggests a close interaction between the two hierarchies.

The p-adic view about cognition suggests that p-adic numbers give a representation for the addresses of records and that effective p-adic topology for real space-time sheets is essential. Their space-time counterparts would be discrete intersections field bodies and p-adic space-time sheets having literally infinite size. The density of points of intersection would reduce as one moves away from biological body both in temporal and spatial direction and the fact that p-adic numbers correspond always to non-negative real numbers would conform with the fact that memories are about geometric past and the memories of nearest past are the most precise and for time scales which are fractions of second become sensory experiences which are actually very short term memories as findings of Libet demonstrate.

What is the role of generalized EEG rhythms from the point of view of memory?

TGD predicts entire hierarchy of EEG rhythms which are predicted to correlate with various biorhythms. One challenge is to understand the precise role of EEG rhythms, in particular theta band known to be involved with memory consolidation. Functional magnetic resonance imaging led to the discovery of so called so called spontaneous fluctuations in BOLD (blood oxygen level dependent) signal having 1/f spectrum in average sense [J98] (I am grateful for Vesa Kiviniemi (who is also working in this field [J85]) for sending me this review article). The frequency spectrum of these fluctuations is in the range range $.1 - .001$ Hz.

This activity is regarded as spontaneous in the sense that it is not induced by stimulus, motor output, or task but is something independent and thus conflicts with the paradigm that EEG corresponds directly to the brain state dictated by the input to brain and motor output and by cognitive tasks. For this reason spontaneous BOLD fluctuations were originally interpreted as noise but it has become clear that the fluctuation patterns possess both spatial and temporal coherence and that it is possible to assign regions of spatial coherence with brain functions in various brain areas.

The variation of spontaneous BOLD fluctuations explains also the variation of responses in experimental situations involving fixed stimulus or tasks. Spontaneous BOLD fluctuations seem to superpose linearly with the effect due to stimulus or task. BOLD fluctuations seem correlate with the slow fluctuations in EEG known to modulate the power spectrum in various EEG bands. Interestingly, there are also ~ 1 Hz slow fluctuations of membrane potential, which could be related to the cyclotron frequencies of DNA nucleotides (carrying constant negative charge density).

These findings conform with the fact that TGD predicts a fractal hierarchy of EEGs corresponding to the hierarchy of values of Planck constant. A further prediction would be that scaled variants of alpha band and its harmonic should appear in BOLD fluctuations as also the counterparts of beta and theta bands whose positions cannot however predicted without further assumptions.

EEG and its generalization would allow to interpret EEG rhythms as dividing the magnetic tape in time direction to a linear lattice of separate frames which each could represent a record in turn containing further records. This would be much like a fractal variant for the decomposition of a written text to letters with an approximately constant width. SWS would define kind of empty lines between paragraphs in this text and during wake-up state similar empty lines might be present.

Of course, the strict linear lattice is an idealization. It could be perturbed by insertions just like written text by pictures. These insertions could represent sensory mental images due to sensory input. Another analogy for sensory input would be as external force inducing kicks to the

harmonic oscillator changing the amplitude of oscillation and inducing phase increments.

14.5 A Proposal For Memory Code

In an article in the March 8 issue of the journal PLoS Computational Biology, physicists Travis Craddock and Jack Tuszynski of the University of Alberta, and anesthesiologist Stuart Hameroff of the University of Arizona propose a mechanism for encoding synaptic memory in microtubules, major components of the structural cytoskeleton within neurons. The self-explanatory title of the article is "*Cytoskeletal Signaling: Is Memory Encoded in Microtubule Lattices by CaMKII Phosphorylation?*" [J101] (see `http://tinyurl.com/7dcgjwf`).

14.5.1 Basic Ideas Of The Model Of Memory Code

The hexagonal cylindrical lattice of microtubule suggests the possibility of lattice consisting of bits and probably very many proposals have been made. One such idea is that bit is represented in terms of the two basic conformations of tubulin molecules called α and β. The recent proposal is that bit corresponds to the phosphorylation state of tubulin. Also a proposal that the bits form 6-bit bytes is considered: 64 different bytes are possible which would suggest a connection with the genetic code.

The motivation for the identification of byte is that CaMKII enzyme has in the active state insect like structure: 6 + 6 legs and the legs are either phosphorylated or not. This geometry is indeed very suggestive of connexion with 6 inputs and 6 outputs representing genetic codons representable as sequences of 6 bits. The geometry and electrostatics of CaMKII is complementary to the microtubular hexagonal lattice so that CaMKII could take care of the phosphorylation of microtubulins: 6 tubulins at most would be phosphorylated at one side. The presence of Ca^{+2} or calmodulin flux flowing to the neuron interior during nerve pulse is responsible for self-phosphorylation of CaMKII: one can say that CaMKII takes itself care that it remains permanently phosphorylated. I am not sure whether this stable phosphorylation means complete phosphorylation.

It is however difficult to imagine how Ca^{+2} and calmodulin flux could contain the information about the bit sequence and how this information could be coded in standard manner to phosphorylation pattern of legs. The only possibility which looks natural is that phosphorylation is a random process and only the fraction of phosphorylated legs depends on Ca^{+2} and calmodulin fluxes. Another possibility would be that the subsequent process of phosphorylation MT by completely phosphorylated CaMKII manages to do it selectively but it is very difficult to imagine how the information about codon could be transferred to the phosphorylation state of MT.

For these reasons my cautious conclusion is that phosphorylation/its absence cannot represent bit. What has been however found is a mechanism of phosphorylation of MTs, and the question is what could be the function of this phosphorylation. Could this phosphorylation be related to memory but in different manner? The 6+6 structure of CaMKII certainly suggests that the analog of genetic code based on 6 bits might be present but realized in some other manner.

What does one mean with memory?

Before proceeding one must make clear what one means with memory in the recent context. The articles of New Scientists with - almost as a rule - sensationalistic titles, do not pay too much attention for the fact this kind of proposals are always based on some philosophical assumptions which might be wrong.

1. What one means with "memory" in the recent context? The memory in question is behavioral memory. Conditioning producing reflect like reaction is a typical example of behavioral memory and need not have anything to do with conscious memory such as episodal memory in which one literally re-lives an event of past. Electric stimulation of some regions of temporal lobes can indeed induce this kind of memories. The idea about coding would suggest the identification of this memory with a highly symbolic computer memory based on "carving in stone".

2. The proposal is inspired by the idea of brain or cell as computer and can be criticized. There is no pressing need for coding since behavioral memory can be reduced to the formation of associations and associative learning by computers is standard example of this kind of behavioral memory. One can of course consider the coding for declarative and verbal memories and genetic code provides an attractive candidate for a universal code. This kind of code might be behind the natural languages as a kind of molecular language.

3. Behavioral memories can be defined as changes of behavior resulting from a continued stimulus. The understanding of behavioral memory relies on the notions of synaptic strength, synaptic plasticity, and long term potentiation. Synaptic strength tells how strongly the postsynaptic neuron responds to the nerve pulse pattern arriving along pre-synaptic axon and mediated by neurotransmitter over the synaptic gap. For instance, glutamate acts as excitatory neurotransmitter and binding to receptor. At neuronal levels long term potentiation means increase of the synaptic strength so that post-synaptic neuron becomes "more attentive" to the firing of pre-synaptic neuron.

   Hebb's rules [J13] (see `http://tinyurl.com/y7q2gueo`) - not established laws of Nature and plagued by exceptions - state that the effectiveness of synaptic receptors increases, when the two neurons fire simultaneously: it is important to notice that these firings need not have any causal connection with each other. The simultaneous firing activates NMDA receptors in the post-synaptic neuron and generates Ca^{+2} flux which correlates with the increase of the synaptic strength. NMDA obeys same chemical formula $C_5H_9NO_4$ as glutamate: in fact, glutamate and asparagin the two acidic amino-acids. It is also known that the presence of CaKMII is necessary for the increase of the synaptic strengths.

4. There is however an almost-paradox involved with this view about memory if assumed to explain all kinds of memories - in particular episodal memories. Long term conscious memories can be lifelong. Synaptic structures are however highly unstable since the synapses and proteins involved are cycled. To my view this argument is somewhat naïve. There could be a flow equilibrium. The flow pattern of fluid flow in flow equilibrium can be stable although the fluid is replaced with new one all the time. The proposal of authors is that memories are stored to some more stable structures and that microtubules are these more stable structures making possible short term memories. Post-synaptic microtubules, which differ from presynaptic microtubules in several ways are indeed stabilized by MAPs. Authors also propose the thin filaments associated with the cytoskeleton are responsible for long term memories.

   Authors believe on computationalism and they apply standard view about time so that their conclusion is that long term memories are stored elsewhere and remain able to regulate synaptic plasticity. In this framework the notion of memory code is very natural.

LTP and synaptic plasticity

From Wikipedia one can read that synaptic plasticity [J28] (see `http://tinyurl.com/cn7724o`) means possibility for changes in function, location and/or number of post-synaptic receptors and ion channels. Synapses are indeed very dynamical and synaptic receptors and channel proteins are transient, which does not seem to conform with the standard view about long term memory and indeed suggest that the stable structures are elsewhere.

Long term potentiation [J19] (see `http://tinyurl.com/djmhrp`), briefly LTP, involves gene expression, protein synthesis and recruitment of new receptors or even synapses. The mechanism of LTP is believed to be following. The glutamate from pre-synaptic neuron binds to post-synaptic receptors, which leads to the opening of Ca^{+2} channels and influx of Ca^{+2} ions to dendritic spines, shafts and neuronal cell body. The inflow of Ca^{+2} induces activation of multiple enzyme including protein kinase A and C and CaMKII. These enzymes phosphorylate intra-neuronal molecules.

It is known that the presence of CaMKII is necessary for long term potentiation. This supports the proposal of authors that microtubules are involved in an essential manner in memory storage and processing and regulation of synaptic plasticity. The observation about the correspondence between the geometries of CaMKII and microtubular surface is rather impressive support for the role of MTs. To my opinion, the hypothesis about memory code is however un-necessary.

Microtubules

Quite generally, microtubules (MTs) are basic structural elements of cytoskeleton. They are rope like polymers and grow as long as 25 micrometers long. They are highly dynamical. The standard view identifies their basic function as maintaining of cell structures, providing platforms for intracellular transport, forming the spindle during mitosis, etc..

Microtubules [J20] (see `http://tinyurl.com/ya6rm9r`) are extremely rich in eukaryotic biology and brain neurons. They are believed to connect membrane and cytoskeletal levels of information processing together. MTs are the basic structural elements of axons and MTs in axons and dendrites/neuronal cell bodies are different. Dendrites contain antiparallel arrays MTs interrupted and stabilized by microtubule associated proteins (MAPs) including MAP_2. This difference between dendritic and axonal microtubules could be relevant for the understanding of the neuronal information processing. Microtubules are associated also with long neural pathways from sensory receptors, which seem to maximize their length.

For these reasons it would not be surprising if MTs would play a key role in the information processing at neuronal level. Indeed, the more modern view tends to see microtubules as the nervous system of the cell, and the hexagonal lattice like structure of microtubules trongly suggests information processing as a basic function of microtubules. Many information processing related functions have been proposed for microtubules. Microtubules have been suggested role as cellular automatons and also quantum coherence in microtubular scale has been proposed.

The proposal of the article is that short term memory is realized in terms of a memory code at the level of MTs and that intermediate filaments which are much more stable could be responsible for long term memory.

CaMKII enzyme

According to the proposal the key enzyme of memory would be Calcium/calmodulin-dependent protein kinase II: briefly CaMKII [J9] (see `http://tinyurl.com/6x4toa3`). Its presence is known to be necessary for long term potentiation.

In passive state CaMKII has snowflake shape. The activated kinase looks like double sided insect with six legged kinase domains on both sides of a central domain. Activation means phosphorylation of the 6+6 legs of this "nano-insect". In the presence of Ca^{+2} or calmodulin flux CaKMII self-actives meaning self-phosphorylation so that it remains permanently active.

There are however grave objections against phosphate=1–no-phosphate=0 coding.

1. Only the fluxes of Ca^{+2} and/or calmodulin matter so that it is very difficult to imagine any coding. One would expect that the fraction of phosphorylated legs depends on these fluxes in equilibrium but it is very difficult to image how these fluxes could carry information about a specific pattern of phosphorylation for legs. If all legs are phosphorylated the coding to microtubular phosphorylation would require that 6 bits of information is fed at this stage by telling which leg actually gives its phosphate to tubulin. This does not look two plausible but one must be very cautious in making too strong conclusions.

2. Since metabolic energy is necessary for any information processing, the more plausible interpretation would be that phosphorylation makes bit active. Bit itself would be represented in some other manner. The 6+6 leg structure of CaMKII is very suggestive of a connexion with 6 incoming bits and 6 outgoing bits - possible same or conjugated. The interpretation in terms of DNA codon and its conjugate is what comes first in mind.

One should not however throw away child with the wash water. The highly interesting discovery discussed in the article [J101] (see `http://tinyurl.com/7dcgjwf`) is that the spatial dimensions, geometric shape, and electrostatic binding of the insect-like CamKII and hexagonal lattices of tubulin proteins in microtubules fit nicely together. The authors show how CaMKII kinase domains can collectively bind and phosphorylate MTs. This alone could be an extremely important piece of information. There is no need to identify bit with phosphorylation state.

14.5.2 TGD View About The Situation

TGD based view about memory could have been developed by starting from the paradox related to long term memories. Memories are long lasting but the structures supposed to be responsible for their storage are short-lived. TGD based solution of the paradox would be based on new view about the relationship between geometric time and experienced time.

1. According to this view brain is 4-dimensional and primary memories are in the time-place, where the neural event took place for the first time. In principle there would be no need to store memories by "carving them in stone". To remember would be to see in time direction: this view is indeed possible in zero energy ontology. Time-like entanglement and signalling to the geometric past using negative energy signals would be the basic mechanisms of memory.

2. Stable memories require copies also for another reason. The negative energy signal to geometric past is not expected to allow a precise targeting to a one particular moment of time in past. To circumvent the problem one must make the target large enough in time direction. The strengthening of memory would mean building up large number of copies of memory. These copies are produced in every conscious memory recall and learning would be based on this mechanism. The neuronal mechanism would produce large number of copies of the memory and one can ask whether CaMKII indeed generates phosphorylated sections of MT somehow essential for the representation of long term symbolic memories as names for experiences rather than experiences themselves.

3. Metabolism must relate also to conscious memory recall. Since negative energy signals are involved, there is great temptation to assume that de-phosphorylation liberating metabolic energy corresponding to the absorbed negative energy accompanies memory recall. Large $\hbar$ for the photons involved would allow very low frequencies -expected to characterize the time span of memory recall - and make communications over very long time intervals possible. This would mean that the original memory representation is destroyed in the memory recall. This would conform with the spirit of quantum no-cloning theorem [B3] (see `http://tinyurl.com/2dhl4oe`). Several copies of the memory representation would be needed and also feed of metabolic energy to generate new copies. In this framework conscious memory recall would be dynamical event rather than stable bit sequence in accordance with the vision about quantum jump as moment of consciousness.

Braiding as a universal model for memory

This leaves a lot of freedom to construct more detailed models of symbolic memories.

1. Braiding of magnetic flux tubes would make possible not only topological quantum computation [K3] (see `http://tinyurl.com/ybyscdpt` but also a universal mechanism of long term memory. In the model of DNA as topological quantum computer) the flux tubes connect DNA nucleotides and lipids of cell membrane. It turned out that the flux tubes carrying dark matter - identified as ordinary particles but with non-standard value of Planck constant [K44] - could connect all kinds of biomolecules and that braiding and reconnection could serve as basic quantum mechanisms in the functioning of biomolecules. Flux tubes could also connect the tubulins of microtubules and lipids of axonal or dendritic membrane.

2. Two kinds of braidings are present: the lipid flow defines braiding in time direction as the analog of dance and the fact that lipids are like dancers with threads from shoes the wall - now microtubule surface - so that the dance induce braiding of these threads storing the dynamics of the dance to memory. The presence of both space-like and time-like braiding and the fact that they are in well-defined sense dual has become central idea of quantum TGD itself. Originally it was however discovered in the model for DNA as topological quantum computer [K3].

3. Both active memory recall by sending negative energy dark photon to geometric past and spontaneous memory recall by receiving a positive energy photons from geometric past require metabolic energy. Therefore the presence of phosphate in braid strands is necessary. The

flux tubes defining braid strands can be therefore assumed to be active only if they have phosphate at the other end. A more appropriate TGD based interpretation is that this makes possible negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book), which is one of the basic predictions of the number theoretic vision about life. High energy phosphate bond would thus a signature of negentropic entanglement, which could serve as a correlate for the experience of understanding. One could relate ATP-ADP process as a basic process of life directly to cognition. The presence of phosphate would tell that there is magnetic flux tube - actually pair of them- beginning from the molecule.

TGD variant of the microtubular model for memory

The finding of the authors inspires a more detailed formulation for the vision for how memories could be realized at microtubular level.

1. The phosphorylation of tubulins would generate active braids strands and their presence would make possible memory recall. Note that memories as such could be stored to the braiding in any case if the microtubule-lipid flux tubes are present always. Every nerve pulse pattern would induce a flow of lipids at neuronal membrane if the membrane is in a phase corresponding to 2-D liquid crystal. This flow pattern would be stored to the braiding of the flux tubes.

2. In the model of DNA as topological quantum computer one assigns to braid strands connecting DNA nucleotides to lipids 4 different states representing the nucleotides A, T, C, G. In the original model the A, T, C, G were mapped to four states defined by quarks u, d and their antiquarks at the ends of braid strands. This proposal can be of course accused of being quite too science fictive. TGD however predicts the possibility of scaled up variants of QCD type physics even in the scale of living matter and there are some indications for this.

   A more down-to-earth realization of the genetic code proposed quite recently [K59] is that braid states correspond to pairs of magnetic flux tubes. To the ends of both flux tubes one assigns electron so that the electrons form spin triplet and spin singlet state defining 3+1 states representing A, T, C, G. This gives also a connection with electronic super-conductivity which is fundamental assumption in the model of nerve pulse based on Josephson currents: nerve pulse corresponds to a simple perturbation of the ground state in which all Josephson current along axon are oscillating in the same phase. Mathematically the phase difference behaves like gravitational pendulum [K97].

   The 6=2+2+2 legs could correspond to flux tube pairs and each flux tube pair would represent DNA nucleotide in terms of the spin state of electron pair. Phosphorylation would activate the braid strand by making possible negentropic entanglement and information storage and recall. This conforms with the fact of life is that metabolic energy is needed for all kinds of information processing including also information storage.

   If all 6 tubulins to which bits are assigned are indeed phosphorylated in the active state and if the memory recall involves use of metabolic energy as proposed, then the reading of the memory would mean complete de-phosphorylation of 6-tubulin sequences. The prediction would be the presence of phosphorylated 6-tubulin sequences at microtubular surface and their disappearance in memory recall. I do not know whether there is any manner to test these predictions.

3. For this proposal LTP would involve a generation of active braid strands. The post-synaptic neuron would be in "wake-up" state and would pay attention to the nerve pulse patterns arriving from the pre-synaptic neuron. This activation would be induced by simultaneous firing of post-synaptic and pre-synaptic neurons. As a consequence, the lipid flow would generate braidings providing memory representations and defining in temporal domain quantum computation like processes.

4. This does not yet explain why CaMKII is necessary for LTP. There is a high temptation to regard the increase of the synaptic sensitivity as a property of synaptic connection. One can imagine several mechanisms.

(a) For instance, active flux tube connections between presynaptic lipids and postsynaptic microtubuli could be generated by phosphorylation, and the flux tubes might increase the flow of glutamate between pre- and post-synaptic neurons and in this manner increase synaptic strength. Flux tubes might make possible a continual flow of dark particles between pre- and post-synaptic neurons. They could also make possible negentropic entanglement between the two neutrons binding the neurons to single coherent quantum whole.

(b) The strength of this connection could be affected also by the presence of active braid strands making possible quantum memory and topological quantum computation. Also more complex processes assigned with LTP would become possible since microtubules might be seen as conscious intelligent structures able to modify their nearby environment.

14.6 How subjective memories are realized in TGD inspired theory of consciousness?

We remember our conscious experiences: also as re-experiences and not just as learned, often unconscious, behaviors that reduce to associations. In the following the notion of memory is discussed from the points of view of computer science and neuroscience, of quantum theories of consciousness, and of TGD inspired theory of consciousness.

14.6.1 Memory as challenge in computer science and neuroscience

The notion of conscious memories is highly problematic both in computer science and neuroscience.

1. Computers completely lack subjective memory if they are what they are believed to be, that is to obey the Turing paradigm. Computers are also believed to be deterministic, either in the sense of classical physics or of statistical quantum mechanics. Since non-determinism is the basic aspect of conscious entities, computers are expected to lack conscious experiences. One can of course challenge the Turing paradigm and this is done in [L176].

2. In neuroscience, memory is often interpreted as mere learned behaviors This view is a remnant of behaviorism. Associations provide a mechanism of memory and association is also the basic mechanism of the now fashionable large language models. This interpretation does not explain at all the episodic, experiential memories that we also have. Some of us have very intense sensory memories. All of us have dreams involving memories and the electric stimulation of the parietal brain regions can induce lively sensory memories of the past events.

   Memories must be stored in some sense. In neuroscience, the finiteness of the memory space becomes a basic problem. If memories are "carved in stone", a large number of stones are needed and their number is increasing all the time. It might be necessary to give up some memories, most naturally the oldest ones. Computationalist would say that new data is written over the older data. What happens is just the opposite: the last memories to disappear are the childhood memories. The strong emotional content of these memories is certainly one reason for this. They are also remembered many times and this produces many copies of them, which makes it easier to recall them. This might be used as a neuroscience explanation for their stability.

   The understanding of the reading of memories, that is having a conscious experience providing information about the memory, remains an unsolved challenge in the neuroscience context: this would require a genuine theory of conscious experience.

14.6.2 Memory as a key challenge for quantum theories of consciousness

Any theory of consciousness, including quantum theories of consciousness, should be able to explain the basic mechanism of conscious memory. A basic element of subjective memory is its temporality. Its content corresponds to the events of the past.

1. An attractive idea is that, by their non-determinism which is a basic behavioral feature of conscious entities, quantum jumps determine the development of consciousness. Subjective memory recall would therefore represent information about the previous quantum jumps. The quantum states should represent information about what was experienced in the past.

2. The information of the conscious experience, if determined by the quantum jump, must be about the initial and the final states of the quantum jump and the transition between them. It should be encoded into the final state of the quantum jump. In the standard ontology of quantum theory this is not possible. According to the standard quantum theory, quantum states 3-D time=constant snapshots and do not remember anything about the previous quantum jumps.

   Therefore, theories of consciousness based on standard quantum mechanics cannot explain subjective memory, which is from previous conscious experiences, i.e. quantum jumps. For some reason, this fact seems to have been overlooked.

The understanding of subjective memories is therefore a hard challenge for the theories of consciousness.

1. If one accepts only the statistical view of quantum theory, a natural question would be that in some sense the characterization of quantum statistical time evolution corresponds to some kind of Markov chains. Stronger condition would be quantum states are replaced by sequences of 3-D quantum states. This would require a failure of strict determinism but standard quantum theory does not allow this.

2. The failure of strict classical determinism is however a valuable guideline and would mean that quantum states are in some sense "slightly" 4-dimensional so that also the brain would be "slightly" 4-dimensional. The zero energy ontology (ZEO) of TGD indeed predicts this. Quantum states are superpositions of 4-D classical time evolutions obeying almost deterministic holography so that they are not quite 3-dimensional.

3. In TGD, the zero energy ontology (ZEO) combined with holography=holomorphy vision suggests a universal mechanism of this kind. In the sequal the general TGD based mechanism of memory storage is discussed. By its universality, the proposed mechanism applies also to matter which is usually regarded as "dead" (since it looks dead in the time scales of our perceptive abilities).

14.6.3 TGD view of subjective memory

We have memories about the conscious experiences of the past. How are these memories formed? Zero energy ontology (ZEO) [L108] [K143] suggests a rather concrete model for the representations of the memories in terms of the geometry of the space-time surface.

ZEO briefly

Consider first a brief summary of ZEO.

1. The basic notions of ZEO are causal diamond (CD), zero energy state, and state function reduction (SFR). Zero energy state be seen as a pair of ordinary 3-D quantum states at the light-like boundaries and as a superposition of space-time surfaces inside $CD = cd \times CP_2$ obeying holography [L180]. Here cd is the intersection of future and past-directed light-cones of M^4. There are two kinds of SFRs: "small" SFRs (SSFRs) and "big" SFRs (BSFRs).

2. A sequence of SSFRs is the TGD counterpart for a sequence of repeated measurements of the same observables: in wave mechanics they leave the state unaffected (Zeno effect). Already in quantum optics, one must loosen this assumption and one speaks of weak measurements. In ZEO, SSFRs do not affect the 3-D states at the "passive" boundary of CD but change the 3-D states at the active boundary, this gives to the flow of consciousness and defines a self as a conscious entity. In the TGD framework, SSFRs give rise to a flow of consciousness, which defines self as a conscious entity.

3. BSFR is the counterpart of the ordinary SFR. In the BSFR the arrow of the geometric time changes. BSFR means death of self and to a reincarnation with an opposite arrow of geometric time. Death and birth as reincarnation with an opposite arrow of time are universal notions in the TGD Universe. Falling asleep and biological death are examples of BSFR. Since TGD predicts quantum coherence in arbitrarily long scales, the arrow of time can change in even cosmological scales.

The classical representation of the information of subjective memories

Consider now the classical representation of the information of subjective memories.

1. Zero energy states can be regarded as pairs of 3-D many-fermion states at the opposite light-like boundaries of the CD. Second view of zero energy state is as a superposition of space-time surfaces obeying holography and therefore analogous to Bohr orbits. This picture is made more complex by the hierarchy of CDs.

2. It is essential that the holography is almost deterministic. holography=holomorphy principle allows the explicit construction of space-time surfaces as holomorphic minimal surfaces, and they are analogous to Bohr orbits when one interprets 3-surface as a generalization of a point-like particle. Already 2-D minimal surfaces fail to be completely deterministic (a given frame can span several minimal surfaces). This non-determinism forces ZEO: otherwise one would have ordinary ontology with 3-D objects as basic geometric entities.

   The failure of complete determinism makes 4-dimensional Bohr orbits dynamical objects by giving them additional discrete degrees of freedom. They are absolutely essential for the understanding of memory and one can speak of a 4-dimensional brain.

3. The 3-D many-fermion states and the restriction of the wave function in WCW to a wave function to the space-of 3-surfaces as the ends of Bohr orbits at the passive boundary of CD are unaffected by the sequence of SSFRs. This is the counterpart for the Zeno effect.

   This requires that a given SSFR corresponds to a measurement of observables commuting with the eigen observables at the passive boundary. The simplest option is that these observables are associated with the discrete degrees of freedom due to the classical non-determinism.

4. The 3-D states at the opposite, active, boundary of CD are however affected in SSFRs and this gives rise to self and flow of consciousness. Also the size of CD increases in a statistical sense. The sequence of SSFRs gives rise to subjective time correlating with the increase of geometric time identifiable as the temporal distance between the tips of the CD. The arrow of time depends on which boundary of CD is passive and the time increases in the direction of the active boundary.

5. In TGD, ordinary SFRs correspond in TGD to BSFRs. Both BSFRs and SSFRs are possible in arbitrarily long scales since the h_{eff} hierarchy makes possible quantum coherence in arbitrary long scales.

   The new element is that the arrow of geometric time changes in BSFR since the roles of the active and passive boundaries of CD change. BSFR occurs when the set of observables measured at the active boundary no longer commutes with the set of observables associated with the passive boundary.

   The density matrix of the 3-D system characterizing the interaction of the 3-surface at the active boundary with its complement is a fundamental observable and if it ceases to commute with the eigen observables at the passive boundary, BSFR must take place.

   The degrees of freedom characterizing the classical non-determinism are crucial for memory. Since they commute with the eigen observables at the passive boundary, they naturally belong to the degrees of freedom measured in SSFRs.

14.6.4 Memory recall and memory storage in ZEO

Consider now what memory recall could mean in this framework. There are two views of memory recall: classical and quantal.

1. The classical view is that active memory recall requires what might be regarded as communications with the geometric past. This requires sending a signal to the geometric past propagating in the non-standard time direction and absorbed by a system representing the memory locus (part of the brain or of its magnetic/field body). The signal should be generated in a BSFR of some subsystem. In ZEO this is possible since BSFRs change the arrow of the geometric time.

   The signal must be received by a system of the geometric past representing the memory. The signal would be received at a quantum critical memory location by a resonance mechanism, and a second BSFR would occur, resulting in a response that would propagate to the future brain. This pair of BSFRs corresponds to the TGD counterpart of quantum tunnelling.

2. The second way to see the memory recall relies on time-like quantum entanglement between memory locus and the system which remembers. Memory recall would be state function reduction reducing the entanglement and essentially a quantum measurement.

   How are the memories coded geometrically?

1. This can be understood by asking what happens in SSFR. What happens is that from a set of 3-D final states at the active boundary some state is selected. This means a localization in the "world of classical worlds" (WCW) as the space of Bohr orbits. The 3-D surfaces at the active boundary of the CD represent the outcome of quantum measurement. The final state as a zero energy state represents classically the quantum transition to the final state! This is not possible in the standard ontology.

2. The findings of Minev et al [L99] [L99] that in quantum optics quantum jumps correspond to smooth classical time evolutions leading from the initial state to the final state. This provides direct support for the ZEO view. The interpretation works for SSFRs and also for the transitions of atoms as pairs of BSFRs having interpretation as quantum tunnelling events.

Is consious experience associated with SSFRs assignable to the classical non-determinism?

ZEO therefore gives a geometric representation of a subjective experience associated with the SSFR. One obtains conscious information of this representation either by passive or active memory recall by waking up the locus of non-determinism assignable to the original conscious event. The slight failure of determinism for BSFRS is necessary for this. The sequence of SSFRs is coded to a sequence of geometric representations of memories about conscious events.

This is how the Universe gradually could develop representations of its earlier quantum jumps to its own state. Since the algebraic complexity of the Universe can only increase in a statistical sense the quantum hopping of the Universe in the quantum Platonia defined by the spinor fields of WCW implies evolution.

It is tempting to think that cognitive and sense-awareness, or at least memory, correspond to regions of the space-time surface (minimal surface), where quantum jumps between the different classical alternatives are possible. These "hot spots" would be analogous to the frames spanning the soap film and as quantum critical systems serve as seats of memories.

1. At least for SSFRs associated with remembering, classical non-determinism and quantum non-determinism would correspond to each. Could this be the case also for sensory and cognitive SSFRs, in fact all SSFRs? Could the classical-quantum correspondence fail only for BSFRs as counterparts of the "ordinary" SFRs.

2. The "memory locations" at the space-time surface, especially in the 4-dimensional brain, correspond to the loci of non-determinism (and of quantum criticality).

3. Memory recall would require a signal to the geometric past propagating in the non-standard direction of geometric time. The signal would be generated in a BSFR of some subsystem. The signal would be received by the quantum critical memory location by a resonance mechanism, and a second BSFR would occur, resulting in a response that would propagate to the future brain.

Memory and TGD inspired quantum biology

Can one say anything more concrete?

1. TGD predicts that any system can have a self as a sequence of SSFRs. Therefore there is an entire hierarchy of systems, which can be conscious and the question is what level in the hierarchy biological consciousness corresponds to. In the case of the brain, the quantum critical slightly non-deterministic hotspots of the 4-D space-time surface representing the brain could be associated with DNA, microbuli, neurons, axons, and larger structures constructed from them.

2. Perhaps the most natural identification for the seat of our conscious experience is associated with the field bodies (magnetic and electric) of these systems. The reason is that they contain dark variants of the ordinary particles characterized by a very large value of effective Planck constant h_{eff}, which serves as a measure for algebraic complexity, representative capacity, and intelligence.

3. Gravitational Planck constant $\hbar_{gr}$ and electric Planck constant characterize the gravitational [L166, L168] electric bodies [L175, L185]. Both DNA, microtubuli, and DNA have large electric charges and the gravitational magnetic bodies of the Earth and Sun are excellent candidates for the field bodies involved.

   Water is an essential part of the living matter and expected to be crucial for our conscious experience. The proposal is that the monopole flux tubes accompanying the ordinary basic biomolecules carry sequences of dark protons providing a fundamental representation of the genetic code, which is universal and possible in all scales.

4. The notion of dark DNA leads to a proposal that the genetic code, realized in terms of a completely unique icosa tetrahedral tessellation of the hyperbolic 3-space H^3 [L173], would be crucial in the communications based on multi-resonance mechanism as selector of the receiver and frequency modulation as the way to represent information.

   This mechanism, associated with the EEG and its possible fractally scaled copies at longer and shorter time scales, would be essential also for the memory recall. Dark photons obtained from ordinary photons have period and wavelength scaled up by h_{eff}/h. Large values of h_{eff} long time scales. The larger the value of h_{eff} the longer the time span of the memory.

Chapter 15

Life and Death and Consciousness

15.1 Introduction

Life and death have remained the deepest mysteries of science. The development of quantum theories of consciousness has however encouraged scientist to make also questions about the essence of life and death. In this article TGD based view about consciousness, about about life and death is discussed.

To begin with, it is good to represent the basic ideas of TGD inspired theory of consciousness.

1. Living system bring in mind elementary particle like coherent unit. This suggests that macroscopic quantum coherence is an essential aspect of life and consciousness. Non-predictability, which does not mean randomness, is second essential aspect of living systems and we experience it as free will. The description of this aspect however leads to problems in the materialistic approach originally inspired by physicalism and the idea that physicist can predict everything given the initial values.

   State function reduction seems to be however a genuine non-deterministic physical phenomenon and leads to severe problems in quantum measurement theory: it is very difficult to combine the non-determinism of state function reduction with determinism of unitary time evolution (causality problem): this has led to a multitude of interpretations trying to avoid the paradox. The obvious first guess is that it might hold key to the understanding of consciousness.

2. TGD inspired quantum theory of consciousness can be seen as a generalization of quantum measurement theory replacing the notion of observer as kind of black box with the notion of self as conscious entity. In TGD framework causality problem is solved by assuming that there are two times: subjective time defined by sequence of state function reductions following the analog of unitary time evolution lasting for finite time and geometric time of physicist. Corresponding causalities are independent and quantum jump replaces entire time evolution with a new one so that the conflict between the causalities is resolved.

   This picture leads to what I call Zero Energy Ontology (ZEO). In ZEO physical states are zero energy states, which are superpositions of pairs of positive and negative energy states serving as analogs of what might called classical event. They respect basic conservation laws and solution of field equations connects the members of state pair: this realizes holography. The members of pair are localized at boundaries of causal diamond (CD) obtained by taking the intersection of future and past directed light-cones of Minkowski space and replacing its points by CP_2.

   State function reduction occurs in cascade like matter proceeding to shorter scales and from system to the sub-system if system decomposes to a product of unentangled sub-systems in the reduction. The outcome at passive boundary of CD is a set of inherently negentropically entangled subsystems having no entanglement between themselves. These systems can be seen as sub-selves of self experiencing these subsystems as mental images.

For given CD state function reduction occurs repeatedly to what I call passive (light-like) boundary of CD and leaves members of state pairs at it invariant. Also the passive boundary itself remains unchanged. The members of state pairs at opposite, *active* boundary of CD experiences the analog of unitary time evolution followed by a reduction passive boundary: this occurs repeatedly as in Zeno effect. Active boundary also drifts further away from the passive boundary whereas nothing happens at the passive boundary.

3. The basic variational principle of consciousness theory identified as quantum measurement theory is Negentropy Maximization Principle (NMP), which demands that entanglement negentropy associated with entanglement is not reduced. In real number based theory entanglement negentropy would be non-positive and genuine information would not be possible. The requirement that the theory describes also cognition, however leads to the generalization of real number based physics to what I call adelic physics. p-Adic number fields allow only algebraic number valued entanglement and assign to it negentropy, which can be positive. One has negentropic entanglement (NE) NMP allows several variants but the mildest form requiring that NE is not reduced seems to be the realistic one.

4. Self as conscious entity can be regarded as generalized Zeno effect identified as a sequence of state function reductions to the same (passive) boundary of CD not changing the part of state at it. Eventually the first reduction to opposite boundary takes place and self dies and re-incarnates as time reversed self at the opposite boundary of CD - obviously a highly non-trivial prediction of ZEO. The flow of subjective time can be interpreted as the increase of temporal distance between the tips of CD.

To help the reader to build a context it helps to summarize what TGD inspired consciousness is and what it is not. In particular, I try to make explicit those key assumptions of TGD, which are in conflict with the existing belief system. The basic assumptions of TGD as a theory can be certainly be blamed of being speculative but the basic predictions of TGD follow from these assumes and are not speculations in the framework of TGD.

1. The approach is that of physicist but not of physicalist. TGD tries to extend physics as a theory of regularities of conscious experience to a theory of consciousness. TGD does not try to reduce consciousness to a property of some system as physicalist would do, and therefore also avoids the hard problem plaguing monistic and dualistic approaches. For physicist the idea that consciousness would be assignable only to brain, human brain, or even male brain is extremely non-feasible and bring in mind the view about Earth as the center of Universe.

   One could blame TGD for panpsychism. This kind of view is adopted also by Tononi and Koch in IIT approach [J143] (for TGD based criticism of IIT see [K123]). Self hierarchy is the key prediction challenging the standard neuroscience based view, and combined with the identification of sub-selves as mental images gives rise to a rather powerful and predictive approach. Hence in the following life and death are seen as universal notions expected to make sense in much wider framework than biological systems.

2. The experience from discussions is that the relationship between geometric and subjective times is difficult notion. In particular, understanding of how subjective time as a sequence of state function reductions (to the same boundary of causal diamond (CD)) corresponds to clock time has been one of the main challenges of TGD inspired theory of consciousness during the last two decades.

   Existence is often thought to be just single type of existence but now conscious existence is assigned with state function reductions, something between two quantum worlds (objective existences in the sense of physics), which represent mathematical existence and are zombies. For a non-mathematician this notion is not easy to grasp. It is however extremely economical ontologically since it allows to get rid of the assumption that there is something "behind" the quantum worlds as mathematical realities. Conscious existence means continual re-creation of the quantum universe and together with NMP it implies evolution.

3. In ZEO physical states are replaced with something analogous to events, pairs of positive and negative energy states with opposite total quantum numbers. This is also new and difficult to

comprehend. For people thinking in terms eastern philosophies ZEO might be easier notion but for a "westener" the idea that there are only observations of events and that physical world as something absolute and given is only a narrative, looks weird. ZEO is of course consistent with the laws of physics, in particular conservation laws, but implies their scale dependence accepted already in quantum field theories.

ZEO can be also defended by its extreme flexibility allowing to avoid the usual problems causing grey hairs for theoretician. In classical physics initial values fix the entire time evolution and only single solution of field equations is realized: in strict sense theories are untestable and obsolete. One can also wonder what metaphysical principle selects the initial values. Also in quantum physics conservation laws restrict strongly the set of allow time evolutions and the idea about theory for entire Universe becomes somewhat obsolete.

4. The assumption about fixed arrow of time is not usually questioned. ZEO forces to give up this belief, and predicts the notions of time-reversed self and re-incarnation. These can be argued to be very weird predictions, and they might be of course wrong. This can be tested. TGD inspired theory of consciousness is indeed a theory and good theories usually predict something not consistent with naive everyday intuitions. Libet's strange findings about active aspect of consciousness [J44] could be understood if the arrow of time changes in motor actions.

5. The notion of macroscopic quantum coherence is central and represents new physics relevant for quantum biology. The new quantum biology comes from several sources: the hierarchy of Planck constants $h_{eff} = n \times h$ making possible macroscopic quantum coherence for large enough values of n assignable to dark matter as phases of ordinary matter so that dark matter would become key player in the drama of living matter.

   Second new notion is what I call many-sheeted space-time. In field theory and general relativity limit of TGD the effects of many-sheeted space-time show as small anomalies [K117] but in biology this notion becomes central.

   The third new notion is that of magnetic body (MB) deriving from the new view about classical fields implied by the postulate that space-times are 4-D surfaces in $M^4 \times CP_2$. Systems have field identity, field body, in particular magnetic body serving as intentional agent receiving sensory data from biological body and controlling it by using analog of EEG realized in terms of dark photons. Also this notion raises strong emotional reactions. I can only defend TGD by telling that this is what TGD naturally predicts, and I have done quite impressive work in finding anomalies where magnetic body raises its head.

6. There are proposals that the lattice-like structures formed by neurons in some brain regions could be mapped to discrete sets of 2-D hyperbolic space H^2, possibly tesselations analogous to lattices of 2-D plane. The map is rather abstract: the points of tesselation would correlate with the statistical properties of neurons rather than representing their geometric positions as such.

   In TGD framework zero energy ontology (ZEO) suggests a generalization of replacing H^2 with 3-D hyperbolic space H^3. The magnetic body (MB) of any system carrying dark matter as $h_{eff} = nh_0$ provides a representation of any system (or perhaps vice versa). Could MB provide this kind of representation as a tesselation at 3-D hyperboloid of causal diamond (cd) defined as intersection of future and past directed light-cones of M^4? The points of tesselation labelled by a subgroup of $SL(2, Z)$ or it generalization replacing Z with algebraic integers for an extension of rationals would be determined by its statistical properties.

   The positions of the magnetic images of neurons at H^3 would define a tesselation of H^3. The tesselation could be mapped to the analog of Poincare disk - Poincare ball - represented as $t = T$ snapshot (t is the linear Minkowski time) of future light-cone. After $t = T$ the neuronal system would not change in size. Tesselation could define cognitive representation as a discrete set of space-time points with coordinates in some extension of rationals assignable to the space-time surface representing MB. One can argue that MB has more naturally cylindrical instead of spherical symmetry so that one can consider also a cylindrical representation at $E^1 \times H^2$ so that symmetry would be broken from $SO(1, 3)$ to $SO(1, 2)$.

$M^8 - H$ duality would allow to interpret the special value $t = T$ in terms of special 6-D brane like solution of algebraic equations in M^8 having interpretation as a "very special moment of consciousness" for self having CD as geometric correlate. Physically it could correspond to a (biological) quantum phase transition decreasing the value of length scale dependent cosmological constant Λ in which the size of the system increase by a factor, which is power of 2. This proposal is extremely general and would apply to cognitive representations at the MB of any system.

7. Adelic physics leads to a number theoretic variant of quantum measurement theory. Together with ZEO this leads to a number theoretic model of quantum measurement using the unique discretization of space-time surface provided by cognitive representations of space-time surfaces using points whose M^8 coordinates belong to the extension of rationals defining the adele. The discrete dynamics in the Galois group of the extension of rationals is part of the cognitive dynamics.

8. Adelic physics, $M^8 - H$ duality, and zero energy ontology lead (ZEO) to a proposal that the dynamics involved with "small" state function reductions (SSFRs) as counterparts of weak measurements could be basically number theoretical dynamics with SSFRs identified as reduction cascades leading to completely un-entangled state in the space of wave functions in Galois group of extension of rationals identifiable as wave functions in the space of cognitive representations. As a side product a prime factorization of the order of Galois group is obtained.

   The result looks even more fascinating if the cognitive dynamics is a representation for the dynamics in real degrees of freedom in finite resolution characterized by the extension of rationals. If cognitive representations represent reality approximately, this indeed looks very natural and would provide an analog for adele formula expressing the norm of a rational as the inverse of the product of is p-adic norms. The results can be applied to the TGD inspired model of genetic code.

One can compress the general vision to following mnenomics: ZEO, CD, NMP, NE, and Zeno effect. In the sequel I describe TGD more precisely. The article [L48] gives a more detailed view about TGD, TGD inspired theory of consciousness, and TGD inspired quantum biology. Appendix of this article contains a summary of TGD inspired quantum biology.

15.2 TGD

General theory of relativity (GRT) plagued by the problem that the notions of energy and momentum are not well-defined for curved space-time time. The proposal for overcoming the energy problem (made 1977, thesis came 1982) was that space-times are not abstract 4-D manifolds but representable as 4-D surfaces in certain 8-dimensional space-time $H = M^4 \times CP_2$, which is empty Minkowski space M^4 with points replaced with certain very small 4-D space CP_2 fixed uniquely from the condition that standard model symmetries and standard model fields can be geometrized. This choice of H is uniquely fixed both by twistorial considerations [K126, K48] or by the condition that theory is consistent with standard model symmetries.

It soon turned out that the modification can be seen also as a generalization of string model with strings in 10-D space-time replaced with 3-D surfaces in 8-D H, whose "orbits" are identifiable as space-time surfaces. Recently the connection with string model picture has become much deeper. By strong form of holography (SH) 2-D string world sheets and partonic 2-surfaces carry the data needed to construct quantum states and construct solutions of field equations (preferred extremals). 4-D space-time is however necessary for quantum-classical correspond necessary to describe measurements.

TGD Universe is predicted to be fractal: this replaces the naïve Planck length scale reductionism with fractality for which the simplest realization would be p-adic length scale hypothesis emerging from p-adic thermodynamics and dark matter hierarchy. Non-trivial predictions emerge in all scales from Planck length to cosmology and this makes it very difficult to communicate TGD for colleagues believing firmly on naïve length scales reductionism.

In what follows I will proceed from quantum TGD to classical TGD without starting from particle physics observations - it would be extremely boring to repeat same old arguments again and again and reader can find these arguments from [K141].

15.2.1 Quantum TGD

The basic idea is to generalize Einstein's program as geometrization of classical physics to geometrization of the entire quantum theory so all notions of quantum theory except state function reduction which is identified as basic building brick of conscious experience would reduce to geometry.

Reduction of quantum theory to Kähler geometry and spinor structure of WCW

The condition that the entire quantum theory is geometrized requires infinite-dimensional geometric structure instead of space-time and the "world of classical worlds" (WCW) identified roughly as the space of space-time surfaces is the natural identification [K30, K55].

1. The construction of quantum TGD leads to a generalization of the notion of super-space of Wheeler and to construction of infinite-dimensional geometry that I call "World of Classical Worlds" (WCW) having rough mathematical identification as space of 3-surfaces in H (ZEO dictates the identification in more detail). The mere mathematical existence of WCW geometry fixes it essentially uniquely - this is true already for the loop spaces of string model [A19] - and therefore physics. A huge generalization of the symmetries of super-string models emerges giving hopes of understanding the theory.

   The geometrization of hermitian conjugation of quantum theory requires that WCW allows complex structure its metric is Kähler metric [K55] and coded by Kähler function identified in terms of Kähler action for a preferred extremal: this gives direct connection with classical physics since induced Kähler form define classical U(1) field, for the U(1) factor of electroweak gauge group assignable with weak hyper-charge. twistor lift implies the presence of a volume term identifiable in terms of cosmological constant. It would bring also Planck length into the theory as the radius of twistor sphere [K126].

2. Quantum states are identified as classical WCW spinor fields so that there is no need to perform quantization and state function reduction is the only genuinely quantal aspect of TGD [K139, K104]. Spinor structure requires identification of gamma matrices anticommuting to WCW metric and if the metric is Kähler metric, the anti-commutation relations are completely analogous to those of fermionic oscillator operators and one can indeed express the gamma matrices as linear superpositions of fermionic oscillator operators at space-time surface. Second quantization at space-time level is a purely classical notion at WCW level and becomes geometrized in WCW context.

3. ZEO (Zero Energy Ontology) is an essential element of theory. Usually one assumes that in classical physics generalized positions and their time derivatives (generalized velocities) giving at given moment of time in 3-D snapshot of space-time dictated the time evolution. This has generalization to Schrödinger equation. One has initial value problem.

   This Newtonian view does not work in TGD: boundary value problem provides a more natural formulation. The generalized positions at two moments of time are more natural data and the dynamical evolution connecting the two 3-D snapshots defines by holography more or less equivalent view about the situation. These pairs are analogous to classical events and one can construct as their quantum superpositions what I call zero energy states and quantum jumps are quantum events occurring between these classical events.

   ZEO is much more flexible than ordinary ontology since any zero energy state can be created from vacuum whereas in standard classical ontology only one solution of field equations is realized and in principle it is not possible to test the theory without additional assumptions. ZEO is especially natural in biology and neuroscience: the notions like function, behavioral pattern, and habit are not easy to describe in terms of the state of organism as 3-D snapshot of time evolution.

The two time=constant snapshots are actually replaced with past and future boundaries of CD, which is the intersection of future and past directed light-cones of Minkowski space with each point replaced with CP_2. The ends of space-time surfaces are at the these boundaries. Zero energy states have opposite conserved quantum numbers at the opposite boundaries of CD: this guarantees that conservation laws are satisfied and the system is consistent with standard laws of physics. CDs form a fractal hierarchy. There are CDs within CDs and CDs can also overlap.

In order to avoid confusion it must be made clear that since WCW spinor fields and zero energy states are formally purely classical entities. Only the state function reduction replacing zero energy state (classical event) would be genuinely quantal element of the theory. The Wheelerism for this would be "Quantization without quantization".

4. The recent formulation for the notion of preferred extremal relies on strong form of General Coordinate Invariance (SGCI). SGCI states that two very different kinds of 3-surfaces can identified as fundamental objects. Either the light-light 3-D orbits of partonic 2-surfaces defining boundaries between Minkowskian and Euclidian space-time regions or the space-like 3-D ends of space-time surfaces at boundaries of CD (both ends!). If both choices are equally good, partonic 2-surfaces and their tangent space-data at the ends of space-time should be the most economic choice.

   This eventually led to the realization that partonic 2-surfaces and string world sheets should be enough for the formulation of WCW geometry and quantum TGD [K29]. Classical fields in the interior of space-time surface would be needed only in quantum measurement theory, which demands classical physics in order to interpret the experiments. The outcome is SH stating that quantum physics should be coded by string world sheets and partonic 2-surfaces inside given CD. SH is very much analogous to the AdS/CFT correspondence but is much simpler: the simplicity is made possible by much larger group of conformal symmetries. 2-dimensionality of space-time regions carrying fermion field can be deduce also from the condition that electromagnetic charge is well-defined for spinor modes: this requires that W boson fields vanish and this implies in the generic case 2-D string world sheets. Number theoretic vision suggests the interpretation of string world sheets and partonic 2-surfaces as commutative or co-commutative sub-manifolds of the space-time having quaternionic (associative) tangent space as a 4-surface in the embedding space with octonionic (non-associative) tangent space [K120, K137].

   If these 2-surfaces satisfy some consistency conditions one can continue them to 4-D space-time surface inside CD such that string world sheets are surfaces inside them satisfying the condition that charged (possibly all) weak gauge potentials identified as components of the induced spinor connection vanish at the string world sheets and also that energy momentum currents flow along these surfaces. String world sheets carry second quantized free induced spinor fields and fermionic oscillator operator basis is used to construct WCW gamma matrices.

5. The existence of WCW geometry requires maximal possible group of symmetries for the geometry of WCW. Essentially a union of infinite-dimensional symmetric spaces labelled by so called zero modes not contribution to the line element of WCW would be in question. The natural candidate for this infinite-dimensional isometry group is symplectric group acting in CP_2 and at 3-D light-cone. This group maps vacuum extremals to vacuum extremals but is not a symmetry of more general extremals: if this were the case WCW metric would be trivial.

Quantum Criticality and hierarchy of Planck constants as dark matter hierarchy

The Kähler coupling strength α_K appearing in Kähler action is analogous to temperature. In its original form [K55] QC stated that this coupling strength is analogous to critical temperature and therefore has discrete spectrum. This idea makes sense even if Kähler action is generalized to contain additional terms: all coupling constants would be analogous to critical thermodynamical parameters.

Indeed, the twistor lift of TGD [K126, K48] replacing space-time surfaces with their twistor spaces in 12-dimensional product of twistor spaces of M^4 and CP_2 indeed brings in cosmological constant Λ and Planck length as radius of the sphere S^2 serving as the fiber of twistor space. This lift makes sense only for $M^4 \times CP_2$ making this choice unique. If Planck length and cosmological constant emerge in this manner their spectrum would be fixed by QC condition. The negative pressure implying accelerated cosmic expansion can be also assigned to magnetic flux tubes with monopole flux so that the situation remains open.

The meaning of QC at the level of dynamics has become only gradually clearer. The development of several apparently independent ideas generated for about decade ago have led to the realization that QC [K31, K32, K33, K34] is behind all of them. Behind QC are in turn number theoretic vision and strong forms of general coordinate invariance (GCI) and holography (SGCI and SH).

1. The hierarchy of Planck constants labelling a hierarchy of dark phases of ordinary matter corresponds to a hierarchy of quantum criticalities assignable to a fractal hierarchy of sub-algebras of the super-symplectic algebra assignable to the boundary of CD with points replaced with CP_2. The conformal weights are n-ples of those for the entire algebra.These algebras are isomorphic to the full algebra and act as gauge conformal algebras so that a broken super-conformal invariance is in question. For $n > 1$ the hierarchy levels are interpreted in terms of dark matter. What is highly non-trivial that the conformal weights itself need not be integers or half integers as usually. The generators of algebra could have conformal weights which are proportional to zeros of zeta and poles of zeta so that the number of generating elements (finite for ordinary super-conformal algebras) would be infinite [K43]. Physical states would however have real conformal weights which would be half integers (conformal confinement).

   Could n correspond to the value of effective Planck constant $h_{eff}/h = n$? Why n should correspond to the number of sheet for the space-time surface as covering space? It has become clear that there is no obvious reason why for this. Number theoretic vision provides much more feasible answer. Adelic hierarchy corresponds to a hierarchy of extensions of rationals and the Galois groups of extensions act as symmetry groups permuting number theoretic discretizations of space-time surface and combining them to single n-fold covering space, where n divides the the order of Galois group of the extension. These groups also act as autormorphism groups of the dynamical Kac-Moody groups assignable to the hierarchy of sub-algebras of the super-symplectic algebra.

2. QC in turn reduces to the number theoretic vision about SH. String world sheets carrying fermions and partonic 2-surfaces are the basic objects as far as pure quantum description is considered. Also space-time picture is needed in order to test the theory since quantum measurements always involve also the classical physics, which in TGD is an exact part of quantum theory.

   SH says that space-time surfaces are continuations of collections of string world sheets and partonic 2-surfaces to preferred extremals of Kähler action for which Noether charges in the sub-algebra of super-symplectic algebra vanish. This condition is the counterpart for the reduction of the 2-D criticality to conformal invariance. This eliminates huge number of degrees of freedom and makes SH possible. TGD does not reduce physics to that of strings since the fact that strings are surfaces inside 4-D space-time surfaces is an essential part of physics and also the experimental testing requires 4-D space-time as also the notion of 8-D embedding space.

3. The hierarchy of algebraic extensions of rationals defines the values of the parameters characterizing the 2-surfaces, and one obtains a number theoretical realization of an evolutionary hierarchy. One can also algebraically continue the space-time surfaces to various number fields - reals and the algebraic extensions of p-adic number fields. Physics becomes adelic [K137].

   p-Adic sectors serve as correlates for cognition and imagination. One can indeed have string world sheets and partonic 2-surfaces, which can be algebraically continued to preferred extremals in p-adic sectors by utilizing p-adic pseudo constants providing huge flexibility. If this is not possible in the real sector, a fragment of imagination is in question! It can also happen

that only part of real space-time surface can be generated: this might relate to the fact that imaginations can be seen as partially realized motor actions and sensory perceptions.

4. The assignment of the hierarchy of Planck constant to a hierarchies of inclusions of hyperfinite factors of type II_1 is natural. Also the interpretation in terms of finite measurement resolution makes sense. As n increases the sub-algebra acting as conformal gauge symmetries is reduced so that some gauge degrees of freedom are transformed to physical ones. The transitions increasing n occur spontaneously since criticality is reduced. A good metaphor for TGD Universe is as a hill at the top of a hill at the top.... In biology this interpretation is especially interesting since living systems can be seen as systems doing their best to stay at criticality using metabolic energy feed as a tool to achieve this. Ironically, the increase of $\hbar$ would mean increase of measurement resolution and evolution!

5. If twistor lift is not performed, the only coupling constant of the theory is Kähler coupling constant $\alpha_K = g_K^2/4\pi\hbar$, which appears in the definition of the Kähler function K characterizing the geometry of WCW. In the most general case α_K has a spectrum of critical values and this conjecture seems at this moment the most reasonable one. It has indeed turned out that the discrete spectrum could have interpretation in terms of discretized coupling constant evolution for U(1) coupling constant of standard model. The identification of the spectrum in terms of zeros of so called fermionic zeta function expressible in terms of Riemann zeta is attractive [K43]. The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed values of $\alpha_K = g_K^2/4\pi\hbar_{eff}$ should be analogous to critical temperatures and determined by QC requirement.

15.2.2 Classical TGD

In TGD framework classical physics is an exact part of quantum physics rather than being only an approximate limit of quantum theory emerging from the stationary phase approximation to path integral, which would in TGD allow all space-time surfaces. Now one does not have path integral but functional integral over the pairs of 3-surfaces at bounaries of CD. Only preferred extremals of Kähler are allowed in the functional integral so they satisfy classical field equations and even more: effective 2-dimensionality holds by SH. Stationary phase approximation can be made also now but selects "preferred preferred extremals". The reason is that for real value of α_K the Minkowskian space-time regions give imaginary exponent to the action exponential whereas Euclidian space-time regions give real exponent identifiable as exponent of Kähler function. In fact, the value of α_K can be also complex but this does not affect this picture.

Space-time surfaces as preferred extremals of Kähler action

Preferred extremal of Kähler action have remained for a long time one of the basic poorly defined notions of TGD. There are pressing motivations for understanding what "preferred" really means. For instance, the conformal invariance of string models naturally generalizes to 4-D invariance defined by quantum Yangian of quantum affine algebra (Kac-Moody type algebra) characterized by two complex coordinates and therefore explaining naturally the effective 2-dimensionality [K126].

In ZEO preferred extremals are space-time surfaces connecting two space-like 3-surfaces at the ends of space-time surfaces at boundaries of CD. A natural looking condition is that the symplectic Noether charges associated with a sub-algebra of symplectic algebra with conformal weights n-multiples of the weights of the entire algebra vanish for preferred extremals. These conditions would be classical counterparts the condition that super-symplectic sub-algebra annihilates the physical states.

What is needed is the association of a unique space-time surface to a given 3-surface defined as union of 3-surfaces at opposite boundaries of CD. One can imagine many ways to achieve this. "Unique" is probably too much to demand: for the proposal unique space-time surface is replaced with finite number of conformal gauge equivalence classes of space-time surfaces. This would bring in finite number of discrete degrees of freedom. In any case, it is better to talk just about preferred extremals of Kähler action and accept as the fact that there are several proposals for what the precise meaning of this notion.

Many-sheeted space-time and topological field quantization

At classical level the basic is the notion of many-sheeted space-time which can be visualized in 2-D situation as a structure consisting of space-time sheets extremely near to each other and connected by wormhole contacts. General Relativity becomes approximate description obtained by replacing the sheets with single slightly curved region of Minkowski space. The sheets correspond to material objects that one can say that we directly see them. The experimental tests distinguishing TGD from GRT relate to many-sheetedness.

Preferred extremal property implies extremely powerful quantization conditions as is clear from the fact that the 2-D data should fix the preferred extremal by SH.

The quantum field theory limit of TGD - GRT plus standard model - is obtained when the sheets are compressed to single region of slightly curved piece of M^4 by identifying gauge potentials as sums of induced gauge potentials for the spinor connection of CP_2 and gravitational field as sum for the deviations of the induced metrics from Minkowski metric. This corresponds to the vision that the force experienced by a test particle - small 4-surface - is sum of those induced as it touches various space-time sheets. One gets rid of topological complexity but the extreme simplicity of space-time dynamics is lost in this replacement.

The compactness (finite size) CP_2 implies topological field quantization: the classical electric fields, magnetic fields, and radiation fields decompose to topological field quanta, space-time sheets, and one can say that physical systems have field identity, field body. This is not true in Maxwell's theory.

The notion of magnetic body carrying dark matter identified as macroscopically quantum coherent $h_{eff} = n \times h$ phases has become central in TGD inspired quantum biology [K93, K92]. Magnetic body becomes intentional agent using biological body as a sensory receptor and motor instrument. Communication and control would be based EEG and its fractally scaled variants consisting of dark photons. The size of magnetic body is rather large, at EEG frequency range the size scale is defined by the wave length of photons involved and is of the order of the size scale of Earth. The proposal is that bio-photons are created in a phase transition transforming dark photons to ordinary photons [K15]: since bio-photons have energies are in the range of visible and UV photons, this requires that the value of h_{eff}/h is roughly the ratio of the frequency of EEG photon with the frequency of visible photon and rather large.

I have called radiation quanta "massless extremals" (MEs) or topological light rays. For MEs the signals propagate at maximal signal velocity (for general space-time sheet light velocity is reduced since the paths along curved space-time sheet is general longer) and thanks to the tubular structure of ME they represent precisely target communications. A further property is that the shape of signal is preserved since positive frequency can propagate in one direction only.

New ontology

TGD leads to a new ontology at both space-time level and quantum level.

1. At space-time level many-sheeted space-time represents new piece of ontology. Single space-time sheet is extremely simple objects and the information needed to construct it is by SH 2-dimensional. Complexity emerges at quantum field theory limit when the sheets o f the many-sheeted space-time are replaced with single slightly curved region of M^4.

2. The hierarchy of Planck constants identified in terms of dark matter as phases of ordinary matter represents second new ontological element. Dark matter is assumed to reside at magnetic body which also represents a new ontological element.

3. A further modification of ontology is the replacement of the usual positive energy ontology (PEO) with what I call ZEO already described. In ZEO quantum states are superpositions of quantum evolutions connecting the positive and negative energy parts of the states. Zero energy states are essentially 4-D and only the positive and negative energy parts are 3-D. Quantum jumps/state function reductions re-create the zero energy states with new ones and this allows to solve the basic paradox of ordinary quantum measurement theory due to the fact that non-determinism of state function reduction is in conflict with the determinism of unitary time evolution. One also ends up with identification of "self" as conscious entity:

self corresponds to generalized Zeno effect: to a sequence of state function reduction to say positive (positive) energy part of zero energy state [K10] [L51]. Self dies when the first reduction to negative (positive) part occurs. Also the origin for the flow of experienced time can be understood.

Hierarchies

TGD Universe is characterized by various hierarchies. At space-time level there is a hierarchy of space-time sheets labelled by a hierarchy of p-adic length scales coming as primes near powers of two and probably generalizing to primes near powers of prime [K79, K137]. In ZEO and at embedding space level there is a hierarchy of CDs labelled by their size scales coming as integer multiples of CP_2 scales. The fractal hierarchy of symplectic sub-algebras leads to a generalization of quantum theory based on a hierarchy of Planck constants characterizing hierarchy of dark matters [K44, K31, K32, K33, K34], hierarchies of inclusions of hyper-finite factors [K138], hierarchies of breakings of super-symplectic gauge symmetry [K139, K104] associated with a hierarchy of quantum criticalities [K31, K32, K33, K34]. There is also a number theoretic hierarchy of algebraic extensions of rationals accompanied by those of p-adic number fields [K137] allowing to see evolution as a gradual increase of the complexity for extensions of rationals assignable to the parameters characterizing string world sheets and partonic 2-surfaces. In TGD inspired theory of consciousness [K68] self hierarchy emerges.

At the basic level the fundamental hierarchy seems to be the heirarchy of breakings of super-symplectic symmetry as gauge symmetry. Super-symplectic algebra and its Yangian generalization have the structure of conformal algebra and is naturally associated with critical systems which are now 4-dimensional. There are also other conformal algebras involved.

By SH implied by the SGCI the core of the mathematical description of quantum TGD reduces to that for 2-D systems associated with partonic 2-surfaces and string world sheets. Although space-time is 4-D, all that can be said mathematically about quantum physics can be reduced to these 2-D "space-time genes". 4-D space-time surfaces are however necessary for the classical description of TGD necessary to interpret quantum measurements in terms of frequencies and wavelengths classical space-time picture about particles. This reduction implies that the representations of charges of super-symplectic Yangian [K126, K48] are in terms of fermionic strings connecting partonic 2-surfaces, which means enormous simplification of the theory. This representation also involves a generalization of AdS/CFT duality to TGD framework as manifestation of SGCI basically [K29].

15.2.3 Number theoretical physics

Number theoretical physics involves several threads [K137].

1. p-Adic physics as correlate for cognition, imagination, and intentionality [K119] p-Adic physics was originally inspired by the challenge of understanding the mass scales of elementary particles but it soon turned that the interpretation in terms of mathematical correlates of cognition and imagination is very natural. This in turn forced the conclusion that cognition is probably present in all length scales, rather than only at the level of brain. The eventual outcome was a fusion of real and p-adic physics in terms of adelic physics.

2. Classical number fields emerge very naturally in TGD framework [K120]. For instance, the conjecture is that space-time surfaces as preferred extremals of Kähler action are quaternionic sub-manifolds of embedding space endowed with octonionic structure. Also quaternion analyticity [A47, A37] as a generalization of complex analyticity central in string models is very attractive conjecture [K126] in accordance with the original vision that 2-D analyticity in some sense generalizes to its 4-D variant.

3. Infinite primes [K118] are constructed by a repeated second quantization of arithmetic quantum field theory and could be essential for understand of quantum TGD.

In the sequel I discuss only the p-adic physics and the fusion of real physics and various p-adic physics to adelic physics as proposal for the physics of matter and mind or correlates of sensory and cognitive consciousness.

p-Adic physics as physics of cognition, imagination and intentionality

1. The attempt to understand elementary particle mass spectrum led to the hypothesis that p-adic number fields - one for each prime $p = 2, 3, 5, ...$, which are completions of rationals like real numbers, allow to construct what I called p-adic thermodynamics allowing to understand particle masses as kind of thermal masses resulting when massless particles suffer slight thermal mixing with particles with mass scale given by CP_2 mass of order 10^{-4} Planck masses.

2. The failure of well-orderedness property for p-adic numbers brings in the corresponding failure due to a finite measurement resolution and leads to the vision that p-adic numbers are ideal for describing the effects of finite measurement resolution and cognitive resolution.

3. The failure of strict determinism for the partial differential equations suggest strongly that it serves as a correlate for cognition, imagination, and maybe also intention is closely related.

4. The fusion of real physics and various p-adic physics (identified as correlates for cognition, imagination, and intentionality) to single coherent whole leads to adelic physics [K137]. Adeles associated with given extension of rationals are Cartesian product of real number field with all p-adic number fields extended by the extension of rationals. Besides algebraic extensions also the extension by any root of e is possible since it induces finite-dimensional p-adic extension. One obtains hierarchy of adeles and of corresponding adelic physics interpreted as an evolutionary hierarchy.

   An important restriction is that p-adic Hilbert spaces exist only if one restricts the p-adic numbers to an algebraic extension of rationals having interpretation as numbers in any number field. This is due to the fact that sum of the p-adic valued probabilities can vanish for general p-adic numbers so that the norm of state can vanish. One can say that the Hilbert space of states is universal and is in the algebraic intersection of reality and various p-adicities.

5. One can define the p-adic counterparts of Shannon entropy for all finite-dimensional extensions of p-adic numbers, and the amazing fact is that these entropies can be negative and thus serve as measures for information rather than for lack of it. The formula is simple:

$$S = -\sum_k P_k log(P_k) \to \sum_k P_k log(N_p(P_k)) \quad . \tag{15.2.1}$$

   Here $N_p(x)$ is the p-adic norm, which for n-D extension is defined as n:th root of the determinant of the matrix of the linear map defined by multiplication with x. The change of sign is dictated by the fact that converging Boltzmann weights $e^{-E/kT}$ must in be TGD proportional to positive powers p^k with increasing k by the properties of p-Adic norm.

   p-Adic entropy can have both signs bit NMP suggests that the sign tends to become negative so that interpretation as a measure for conscious information is possible. Furthermore, all non-vanishing p-adic negentropies are positive and the number of primes contributing to negentropy is finite since any algebraic number can be expressed using a generalization of prime number decomposition of rational number. These p-adic primes characterize given systen, say elementary particle.

   The possibility of NE together with NMP [K73] implies that the reduction does not always lead to an unentangled state but can generate NE. Living systems would be systems generating NE and biological evolution could be seen as a gradual generation of negentropic resources - I have called them Akashic Records. For rational probabilities entanglement negentropy equals to real entropy [L47]. This might relate to the Jeremy Englands vision that high entropy is relevant for living matter.

   What is important that entanglement negentropy and thermodynamical entropy are *not* negatives of each other. Hence NMP is not in conflict with the second law but predicts it for the ordinary matter as a consequence of non-determinism of state function reduction. It is

however true that large entropic recources realized as a large number of states with the same energy makes possible both large thermodynamical entropy and NE with large negentropy.

The extension of real physics to adelic physics

In TGD framework cognition is described in terms of p-adic number fields and has led to a fusion of real and various p-adic physics to what I call adelic physics [K137]. Real physics corresponds to sensory experience and p-adic physics to cognition and imagination. Originally I talked about p-adic physics as physics of cognition and intentionality but I have have become ambivalent about intentionality: this issue remains unsettled.

Real-p-adic correspondence has been a longstanding problem. Continuous correspondence at space-time level does not respect symmetries. Algebraic correspondence respects symmetries but not continuity. Also GCI has been a problem. In the proposed framework real-p-adic correspondence can be realized in elegant manner without conflict with fundamental symmetries and achieving continuity only for discretization.

1. The naïve idea is that rationals belong to the intersection of reals and p-adics. More generally, points in algebraic extension of rationals would be common to realities and p-adicities which correspond to "thought bubbles" or imaginations. This hierarchy defines a hierarchy of adeles having interpretation in terms of evolution leading to increasingly complex algebraic extensions of rationals.

2. The first guess was that this means at space-time level that embedding space points with rational valued coordinates (or values in the extension of rationals) correspond to common points of real and p-adic space-time surfaces. This picture however leads to problems with both GCI and key symmetries of TGD. What are the preferred coordinates of space-time surface which would be in algebraic extension of rationals in the intersection? Should one restrict symmetry groups to their discrete subgroups?

3. A partial resolution of the problem came from the realization that the intersection of realities and p-adicities corresponds to space-time surfaces, whose representation is such that they make sense both in real and p-adic sense [K137]. This requires that the WCW coordinates of these surfaces are invariant under various symmetries and general coordinate transformations of space-time belong to the extension of rationals in question. At the level of WCW the coordinates are highly unique on basis of symmetries and by GCI at space-time level. This also means discretization of the infinite-dimensional WCW and together with huge isometry group of WCW gives hopes about computatibility of TGD.

4. As often happens, also the original idea about points of given algebraic extension of rationals as common to real and p-adic space-time surfaces makes sense: one can say that these discrete points define cognitive representations in the real world. The point is that space-time surfaces can be identified as 4-surfaces in H and discretization is induced by that of H. At the first step, the pieces of hyperboloids inside CD and CP_2 can be replaced with their discrete variants making sense both in real and p-adic sense [L50].

   The discretization of space-time surface is *induced* by the discretization at the level of $CD \times CP_2$ in terms of algebraic points of space-time surface and one avoids problem with p-adic version of general coordinate invariance and various space-time symmetries because for coset spaces the coordinate choice is unique apart from isometries: angles or hyperbolic angles serve as coordinates. Angles do not exist in p-adic context. The phases $exp(i\phi)$ - and therefore the values of trigonometric functions - exist in algebraic extensions of p-adic numbers as roots of unity associated with angles $\phi_{m,n} = m2\pi/n$. Also the roots $e^{m/n}$ define finite-D extension of p-adic numbers since e^p is ordinary p-adic number.

   The outcome is a precise mathematical formulation for the p-adic counterparts of space-time surfaces as preferred extremals of Kähler action. The p-adic variants of coset spaces can be seen as discretizations of real coset spaces with discrete points replaced by p-adic continua analogous to the monads of Leibniz [L50]. This would make possible discretization without loosing differentiability central for field equations. One can define p-adic field equations inside these monads and strong SH makes sense in both real and p-adic sector.

The same algebraic expressions would describe real and p-adic solutions of field equations locally when restricted to string world sheets and partonic 2-surfaces (maybe also their light-like orbits). Inside monads real-p-adic correspondence would respect algebraic structures and symmetries. In the intersections symmetry groups would be replaced with discrete subgroups and continuity would be respected in the approximation provided by discretization and would confirm with the idea about finite measurement resolution.

5. This procedure is unique for given choice of discrete subgroups G and H. One can however take any discrete subgroup with matrix elements in algebraic extension of rationals and its subgroup and form a discrete analog of coset space: there is infinite hierarchy of measurement/cognitive resolutions. For instance, in the case of $SU(2)$ these discrete approximations of $SU(2)$ containing finite set of points correspond to the discrete subgroups labelling inclusions of hyperfinite factors of type II_1 and include only Platonic solids as genuinely 3-D approximations of sphere. This is discrete structure in real world.

p-Adic physics as physics of imagination

A further step in the progress came from the discovery of SH [K29]. 2-dimensional surfaces (string world sheets and partonic 2-surfaces) are fundamental objects and 4-D physics is a kind of algebraic continuation from this intersection of reality and various p-adicities in both real and p-adic sectors of the adelic Universe. 4-D space-time surfaces are preferred extremals of Kähler action making them effectively 2-D in the sense that the 2-D surfaces serve as "space-time genes". Also the quantum states assignable to the 2-D surfaces can be algebraically continued to the entire 4-D space-time.

It is however quite possible that the continuation in the real sector to a preferred extremal of Kähler action fails. In p-adic sectors the possibility of p-adic pseudo constants, which are piecewise constant functions with vanishing derivative, makes the continuation much easier. This inspires the idea that imagination corresponds to these p-adic continuations. p-Adic continuation might be possible whereas real continuation could fail: one would have imagined world, which cannot be realized as often happens!

This argument becomes more precise as one realizes that SH is slightly broken: even information theoretically one has only effective 2-dimensionality [K137]. This means that 4-surfaces as preferred extremals are dictated by the data at string world sheets and possibly also partonic 2-surfaces and by data discrete set of points with preferred embedding space coordinates in the extension of rationals defining the adele structure by inducing the extensions of p-adic number fields. For p-adic number fields pseudo-constants make it easy to construct the algebraic continuation to a preferred extremal containing the discretization. For reals this is possible only in special cases. These discretizations correspond to realizable imaginations.

Note that Galois group acts as symmetries in the space of space-time discretizations and under certain conditions gives rise to a space-time surface, which is a covering space with n sheets, n a factor of the order of Galois group. The identification $h_{eff}/h = n$ is natural and reduces the hierarchy of Planck constants and dark matter to adelic physics. Ramified primes for the extension of rationals involved are preferred for extension and if the extension allows especially many realizable imaginations, it is surviver in the number theoretic fight for survival. Ramified primes for these extensions should be winners in the number theoretic evolution. Whether p-adic length scale hypothesis and its generalization follow from this conjecture, remains an open question.

Negentropic entanglement (NE)

In a given p-adic sector the entanglement entropy is defined by replacing the logarithms of probabilities in Shannon formula by the logarithms of their p-adic norms as already described. The resulting entropy satisfies the same axioms as ordinary entropy but makes sense only for probabilities, which are rational valued or in an algebraic extension of rationals. The algebraic extensions corresponds to the evolutionary level of system and the algebraic complexity of the extension serves as a measure for the evolutionary level. p-Adically also extensions determined by roots of e can be considered. What is so remarkable is that the number theoretic entropy can be negative.

A simple example allows to get an idea about what is involved. If the entanglement probabilities are rational numbers $P_i = M_i/N$, $\sum_i M_i = N$, then the primes appearing as factors of N

correspond to a negative contribution to the number theoretic entanglement entropy and thus to information. The factors of M_i correspond to negative contributions. For maximal entanglement with $P_i = 1/N$ in this case the entanglement entropy is negative. The interpretation is that the entangled state represents quantally concept or a rule as superposition of its instances defined by the state pairs in the superposition. Identity matrix means that one can choose the state basis in arbitrary manner and the interpretation could be in terms of "enlightened" state of consciousness characterized by "absence of distinctions". In general case the basis is unique.

Metabolism is a central concept in biology and neuroscience. Usually metabolism is understood as transfer of ordered energy and various chemical metabolites to the system. In TGD metabolism could be basically just a transfer of NE from nutrients to the organism. Living systems would be fighting for NE to stay alive (NMP is merciless!) and stealing of NE would be the fundamental crime.

TGD has been plagued by a longstanding interpretational problem: can one apply the notion of number theoretic entropy in the real context or not. If this is possible at all, under what conditions this is the case? How does one know that the entanglement probabilities are not transcendental as they would be in generic case? There is also a second problem: p-adic Hilbert space is not a well-defined notion since the sum of p-adic probabilities defined as moduli squared for the coefficients of the superposition of orthonormal states can vanish and one obtains zero norm states.

These problems disappear if the reduction occurs in the intersection of reality and p-adicities since here Hilbert spaces have some algebraic number field as coefficient field. By SH the 2-D states states provide all information needed to construct quantum physics. In particular, quantum measurement theory.

1. The Hilbert spaces defining state spaces has as their coefficient field always some algebraic extension of rationals so that number theoretic entropies make sense for all primes. p-Adic numbers as coefficients cannot be used and reals are not allowed. Since the same Hilbert space is shared by real and p-adic sectors, a given state function reduction in the intersection has real and p-adic space-time shadows.

2. State function reductions at these 2- surfaces at the ends of CD take place in the intersection of realities and p-adicities if the parameters characterizing these surfaces are in the algebraic extension considered. It is however not absolutely necessary to assume that the coordinates of WCW belong to the algebraic extension although this looks very natural.

3. Does NMP apply to the sum of real and p-adic entropies (Option 1) or only to the sum of p-adic entanglement entropies (which can be negative) (Option 2). The situation is not settled yet.

   (a) For Option 1 the total entropy vanishes identically for *rational* probabilities and NMP would say nothing about the situation [L47]. NMP would not prevent or favor state function reduction. It is not clear whether this situation corresponds to that in the physics of ordinary matter as opposite to that of living matter. For algebraic probabilities there would be a competition between real and p-adic sectors and p-adic sectors would win for algebraic extensions in the sense that p-adic entropy would be larger than real entropy.

   (b) For Option 2 NMP would stabilize NE also for rational probabilities. One can wonder whether one obtains the ordinary state function reduction at all for this option. In ZEO state function reductions to the opposite boundary of CD would be however forced to occur and second law would be the outcome also in this case.

   For both options it could quite well happen that NMP for the sum of real and p-adic entanglement entropies does not allow the ordinary state function reduction to take place since p-adic negative entropies for some primes would become zero and net negentropy would be lost.

   In both cases mind would have causal power: it can stabilize quantum states against state function reduction and tame the randomness of quantum physics in absence of cognition!

Can one interpret this causal power of cognition in terms of intentionality? If so, p-adic physics would be also physics of intentionality as originally assumed.

A fascinating question is whether the p-adic view about cognition could allow to understand the mysterious looking ability of idiot savants (not only of them but also of some greatest mathematicians) to decompose large integers to prime factors. One possible mechanism is that the integer N represented concretely is mapped to a maximally entangled state with entanglement probabilities $P_i = 1/N$, which means NE for the prime factors of P_i or N. The factorization would be experienced directly.

One can also ask, whether the other mathematical feats performed by idiot savants could be understood in terms of their ability to directly experience - "see" - the prime composition (adelic decomposition) of integer or even rational. This could for instance allow to "see" if integer is - say 3rd - power of some smaller integer: all prime exponents in it would be multiples of 3. If the person is able to generate an NE for which probabilities $P_i = M_i/N$ are apart from normalization equal to given integers M_i, $\sum M_i = N$, then they could be able to "see" the prime compositions for M_i and N. For instance, they could "see" whether both M_i and N are 3rd powers of some integer and just by going through trials find the integers satisfying this condition.

15.3 ZEO and generalization of quantum measurement theory to a theory of consciousness

TGD inspired theory of consciousness is based on certain basic assumptions such as the identification of state function reduction as a measurement of universal observable identified density matrix characterizing entanglement and Negentropy Maximization Principle (NMP) as fundamental principle. Both the adelic approach and the notion of "World of Classical Worlds" (WCW) force to challenge these assumptions.

15.3.1 Questions

Do all state function reductions correspond to measurements of density matrix?

The earlier approach has assumed that state function reduction always corresponds to a measurement of density matrix serving as a universal observable. Measurement of density matrix allows to measure simultaneously arbitrary number of commuting observables by assuming to be a function of product of measured commuting observables represented as matrices. This makes sense at space-time level but at the level of WCW one encounters difficulties. For instance, the choice of quantization axis corresponds to a higher level choice localization to a sector of WCW with moduli characterizing this choice. Also the measurement of $h_{eff}/h = n$ measuring the dimension of Galois group would make sense and force a localization to an extension with Galois group with this dimension. Single entanglement between different points of WCW is not possible (WCW spinor field is analogous to classical spinor describing single particle state and no second quantization is assumed at the level of WCW and one has complete locality), this selection cannot correspond to a measurement of density matrix.

But is the measurement of density matrix really the only possible quantum measurement and does it correspond to act of goal directed intentional free will? Density matrix characterizes entanglement with environment. Is the measurement of density matrix only a reaction: a choice amongst given alternatives. Eastern philosophers make a sharp distinction between real intentional action and mere reaction. For instance, Krishnamurti talks a lot about this and sees that basically all problems of human kind is that we have not been able to transcend to the level at which our actions would be more than reactions.

Genuine intentional actions would very naturally correspond to self measurements realized as WCW localitions such as fixing the quantization axis, or selecting the extension of rationals defining particular evolutionary level of adele hierarchy, or choosing the boundary of CD at which state function reductions occur (arrow of geometric time) are possible.

Is NMP a fundamental principle or does it follow from adelic physics?

NMP has been regarded as a fundamental principle of TGD inspired theory of consciousness. Adelic approach however strongly suggests the reduction of NMP to number theoretic physics somewhat like second law reduces to probability theory: there would be no need to postulate NMP as a separate principle and NMP would hold true only in statistical sense so that we would not live in the best possible world as strongest form of NMP would imply. The dimension of the extension rationals characterizing the hierarchy level of physics and defined an observable measured in state function reductions is positive and can only increase in statistical sense. Therefore the maximal value of entanglement negentropy increases as new entangling number theoretic degrees of freedom emerge. $h_{eff}/h = n$ identifiable as factor of Galois group of extension characterizes the number of these degrees of freedom for given space-time surfaces as number of its sheets.

This forces to re-think what happens in the state function reduction in which the passive boundary of state function reduction becomes opposite boundary meaning death of self and its re-incarnation as time-reversed self: this reduction has been seen as strongest support for NMP as fundamental principle rather than consequence of adelic physics. The new view relies of the observation that the states at passive boundary are eigenstates of some observables, call them passive observables. The reductions at active boundary must correspond to measurements of observables commuting with the passive observables. Self as a generalized Zeno effect can live only as long as it is able to measure observables commuting with the passive ones. The increase the dimension of extension of rationals in unitary time evolutions between reductions - number theoretic evolution - could generate new observables commuting with the passive observables. Self lives as long as it evolves.

In the sequel I describe briefly the basic of TGD inspired theory of consciousness as generalization of quantum measurement theory to ZEO (ZEO), describe the definition of self, consider the question whether NMP is needed as a separate principle or whether it is implied is in statistical sense by the unavoidable statistical increase of $n = h_{eff}/h$ if identified as a factor of the dimension of Galois group extension of rationals defining the adeles, and finally summarize the vision about how p-adic physics serves as a correlate of cognition and imagination.

In the sequel I will use some shorthand notations for key principles and notions. General Coordinate Invariance (GCI); World of Classical Worlds (WCW); Strong Form of GCI (SGCI); Strong Form of Holography (SH); Preferred Extremal (PE); Zero Energy Ontology (ZEO); Negentropy Maximization Principle (NMP); Negentropic entanglement (NE) are the most often occurring acronyms.

15.3.2 ZEO

One must generalize ontology in order to solve the contradiction between deterministic time evolution and the evolution by state function reductions. This requires understanding the notion of subjective time and its relationship to the geometric time. The new ontology must allow to see selves as something unchanged in some aspects and continually changing in some other aspects. Also the experience about the flow of subjective time must be explained.

1. In TGD framework the answer is ZEO [K73]. The concept of quantum state is generalized. States are now analogs for physical events characterized by initial and final quantum state that is pairs of positive and negative energy states. The conserved quantum numbers of the members are opposite so that zero energy states can be created from vacuum. This is a radical generalization of the physicalist world of view but entirely consistent with conservation laws: there is no need to give laws of physics in order to have free will. Positive and negative energy parts of the zero energy states can be assigned to opposite light-like boundaries of CDs, which are intersections of future and past directed light-cones multiplied by CP_2. CDs form a fractal scale hierarchy. They can be seen as embedding space correlates for the 4-D perceptive fields of selves.

2. CD is a central notion in ZEO and serves as embedding space correlate for self. State function reduction can occur to either boundary of CD ("upper" or "lower"). Self can be seen as a generalized Zeno effect - a sequence of state function reductions to either boundary of CD.

These two kinds of selves can be said to be time reversals of each other. The period of non-boiling pot corresponds to the passive boundary of CD not changing in the reductions: also the parts of zero energy states at this boundary remain unaffected. The opposite - active - boundary is shifted towards future reduction by reduction and states at it are changed. The shifting the geometric future gives rise to the experienced time flow. This is the analog of unitary time evolution.

15.3.3 From quantum measurement theory to a theory of consciousness

The notion of self can be seen as a generalization of the poorly defined definition of the notion of observer in quantum physics. In the following I take the role of skeptic trying to be as critical as possible.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. The density matrix was assumed to define the universal observable. Note that a density matrix, which is power series of a product of matrices representing commuting observables has in the generic case eigenstates, which are simultaneous eigenstates of all observables. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

Self as generalized Zeno effect

The precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO (ZEO) only rather recently (2014).

1. Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant - "small" state function reductions. The parts of zero energy states at second boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontolo1gy these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.

2. The first quantum jump to the opposite boundary corresponds to the act of "free will" or birth of re-incarnated self. Hence the act of "free will" changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means "death" of self and "re-incarnation" of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.

3. This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

State function reductions at the level of WCW

One can identify several rather abstract state function reductions selecting a sector of WCW.

1. There are quantum measurements inducing localization in the moduli space of CDs with passive boundary and states at it fixed. In particular, a localization in the moduli characterizing the Lorentz transform of the upper tip of CD would be measured. The measured moduli characterize also the analog of symplectic form in M^4 strongly suggested by twistor lift of TGD - that is the rest system (time axis) and spin quantization axes. Of course, also other kinds of reductions are possible.

2. Also a localization to an extension of rationals defining the adeles should occur. Could the value of $n = h_{eff}/h$ be observable? The value of n for given space-time surface at the active boundary of CD could be identified as the order of the smallest Galois group containing all Galois groups assignable to 3-surfaces at the boundary. The superposition of space-time surface would not be eigenstate of n at active boundary unless localization occurs. It is not obvious whether this is consistent with a fixe value of n at passive boundary.

   The measured value of n could be larger or smaller than the value of n at the passive boundary of CD but in statistical sense n would increase by the analogy with diffusion on half line defined by non-negative integers. The distance from the origin unavoidably increases in statistical sense. This would imply evolution as increase of maximal value of negentropy and generation of quantum coherence in increasingly longer scales.

3. A further abstract choice corresponds to the replacement of the roles of active and passive boundary of CD changing the arrow of clock time and correspond to a death of self and re-incarnation as time-reversed self.

Can the reductions at the level of WCW reduce to measurements of density matrix?

Can one assume that these measurements reduce to measurements of a density matrix of either entangled system as assumed in the earlier formulation of NMP, or should one allow both options. This question actually applies to all quantum measurements and leads to a fundamental philosophical questions unavoidable in all consciousness theories.

1. Do all measurements involve entanglement between the moduli or extensions of two CDs reduced in the measurement of the density matrix? Non-diagonal entanglement would allow final states states, which are not eigenstates of moduli or of n: this looks strange. This could also lead to an infinite regress since it seems that one must assume endless hierarchy of entangled CDs so that the reduction sequence would proceed from top to bottom. It looks natural to regard single CD as a sub-Universe.

   For instance, if a selection of quantization axis of color hypercharge and isospin (localization in the twistor space of CP_2) is involved, one would have an outcome corresponding to a quantum superposition of measurements with different color quantization axis!

   Going philosophical, one can also argue, that the measurement of density matrix is only a reaction to environment and does not allow intentional free will.

2. Can one assume that a mere localization in the moduli space or for the extension of rationals (producing an eigenstate of n) takes place for a fixed CD - a kind of self measurement possible for even unentangled system? If there is entanglement in these degrees of freedom between two systems (say CDs), it would be reduced in these self measurements but the outcome would not be an eigenstate of density matrix. An interpretation as a realization of intention would be approriate.

3. If one allows both options, the interpretation would be that state function reduction as a measurement of density matrix is only a reaction to environment and self-measurement represents a realization of intention.

4. Self measurements would occur at higher level say as a selection of quantization axis, localization in the moduli space of CD, or selection of extension of rationals. A possible general rule is that measurements at space-time level are reactions as measurements of density matrix whereas a selection of a sector of WCW would be an intentional action. This because formally the quantum states at the level of WCW are as modes of classical WCW spinor field single particle states.

5. If the selections of sectors of WCW at active boundary of CD commute with observables, whose eigenstates appear at passive boundary (briefly *passive observables*) meaning that time reversal commutes with them - they can occur repeatedly during the reduction sequence and self as a generalized Zeno effect makes sense.

   If the selections of WCW sectors at active boundary do not commute with passive observables then volition as a choice of sector of WCW must change the arrow of time. Libet's findings show that conscious choice induces neural activity for a fraction of second before the conscious choice. This would imply the correspondences *"big" measurement changing the arrow of time - self-measurement at the level of WCW - intentional action* and *"small" measurement - measurement at space-time level - reaction.*

   Self as a generalized Zeno effect makes sense only if there are active commuting with passive observables. If the passive observables form a maximal set, the new active observables commuting with them must emerge. The increase of the size of extension of rationals might generate them by expanding the state space so that self would survive only as long at it evolves.

   Otherwise there would be only single unitary time evolution followed by a reduction to opposite boundary. This makes sense only if the sequence of "big" reductions for sub-selves can give rise to the time flow experienced by self: the birth and death of mental images would give rise to flow of time of self.

A hierarchical process starting from given CD and proceeding downwards to shorter scales and stopping when the entanglement is stable is highly suggestive and favors self measurements. CDs would be a correlate for self hierarchy. One can say also something about the anatomy and correlates of self hierarchy.

1. Self experiences its sub-selves as mental images and even we would represent mental images of some higher level collective self. Everything is conscious but consciousness can be lost or at least it is not possible to have memory about it. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.

2. By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J148] could be understood as a sharing of mental images between brain hemispheres, which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.

3. At the level of 8-dimensional embedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. For instance .1 second time scale defining sensory chronon corresponds to the secondary p-adic time scale characterizing the size of electron's CD (Mersenne prime M_{127}), which suggests that Cooper pairs of electrons are essential for the sensory qualia.

The above argument states that the measurements at the level of WCW cannot be regarded as measurements of a density matrix since no second quantization at level of WCW is carried out. About a year after developing this argument I realized that the hierarchy of infinite primes suggests an infinite hierarchy of second quantizations. Could the counterpart for the hierarchy of infinite primes be realized at WCW level automatically? One can indeed interpret the measurements at WCW as either localizations or as reductions of entanglement between states associated with

different points of WCW. The point is that the disjoint union of 3-surfaces X^3 and Y^3 can be regarded either as a pair (X^3, Y^3) of 3-surfaces in $WCW \times WCW$ or as a 3-surface $Z^3 = X^3 \cup Y^3 \subset WCW$. The general identity behind this duality $WCW = WCW \times WCW = ... = WCW^n = ...$

One could think the situation in terms of $(X^3, Y^3) \in WCW \times WCW$ in which case one can speak of entanglement between WCW spinor modes associated with X^3 and Y^3 reduced by the measurement of density matrix. Second interpretation as a localization of wave function of $Z^3 = X^3 \cup Y^3 \in WCW$.

Experimental support for the relative arrow of time

It has been found that the arrow of time is relative [D8] (see `http://tinyurl.com/yatp6dum`). Expressing this in more cautious terms, heat can flow from from system with temperature T_1 to a system with temperature $T_2 > T_1$ if there is correlation between the two systems meaning that the density matrix for the two nuclear systems (samples consisting of hydrogen atoms and carbon atoms) is not mere tensor product of density matrices but contains an additional term describing correlation. It must be emphasized that this finding is not in conflict with the standard view about second law which only says that heat flows from system with higher temperature to that with lower temperature provided that there are no correlations between the systems.

The argument runs as follows. The mutual information for the uncorrelated systems vanishes, and since it can only increase this implies flow of heat in the standard direction. If the mutual information is non-vanishing in the initial situation (due to the correlation) it can also decrease and this can give a heat flow in non-standard direction. This has been observed.

Although one can model the finding using standard thermodynamics, one can ask whether something deeper might be involved. Should one be cautious and talk only about the changing direction of heat flow due to the breaking of the basic assumptions of thermodynamics, and avoid speaking about direction of thermodynamical time? Or could a genuine change of the arrow of time take place? Going even deeper, one must ask what thermodynamical time, the time of physicist (geometric time), and the arrow of time do really mean? What is the relationship between these two times? This leads to ponder questions about the basics of quantum measurement theory and here I can only consider TGD based vision [L72].

1. The basic prediction of zero energy ontology (ZEO) is that the arrow of geometric time can have both signs whereas the arrow of subjective time (relating closely to thermodynamic time) defined by experience created by sequence of state function reductions is always the same. The arrow of geometric time is indeed relative. The flow of geometric time corresponds to the increase of distance between tips of causal diamond (CD) and the increase in particular reduction is at either tip of CD and in this manner defines arrow of time. CD grows either "upwards" or "downwards". A geometric measure for experienced time is that distance between the tips of CD which always increases.

   Time reflection symmetry (T) with respect to the center of CD is broken in TGD: the classical time evolutions of space-time surfaces are not T mirror images of each other. This is true also for the quantal evolutions defined by zero energy states essentially as quantum superpositions of classical evolutions. States and their time reversals obey the initial conditions at opposite boundaries of CD. Arrow of time is forced by the place (either boundary of CD), where initial conditions are posed, not by the initial conditions themselves.

2. One must however remember that ZEO describes genuine quantum systems whereas thermodynamics decribes ensemble, which is a highly idealized notion. In ZEO arrow of geometric time would change in each "big" quantum jump and would remain the same during the sequence of "small" state function reductions defining the counterpart of Zeno effect or weak measurement.

3. Initial conditions breaking the basic assumptions of thermodynamics induce correlations and the heat flow in "wrong" direction in the model for the finding. The arrow of time is claimed to be changed in time interval of length of order 2 millisecond. Interestingly, millisecond happens to characterize the time scale of nerve pulse and ZEO predicts that in living matter the change of the arrow of time takes place routinely. In ZEO based description the growth of the temporal distance between the tips of CD would be of order 2 milliseconds.

It would be however the opposite boundary of CD in geometric past that would receide farther away. One can argue that it is not possible measure the position of the past boundary of CD directly. But is it possible to measure the distance between the tips of CD indirectly from the behavior of the ensemble? ZEO would suggest that the time appearing in the Hamiltonian modelling the system corresponds to the distance between tips of CD and never decreases. The change of the direction of heat flow would correspond to the reduction to the original boundary of CD in the experiment and the correlation would make ZEO visible.

If the two descriptions are equivalent, the initial correlations for the ensemble force should correspond to posing initial conditions at the non-standard boundary of CD leading to the reversal of the arrow of time. The very act of posing the correlations would correspond to a "big" state function reduction to opposite boundary of CD. In standard quantum measurement theory state preparation indeed corresponds to this state function reduction so that the two descriptions might be consistent.

15.3.4 Copenhagen interpretation dead: long live ZEO based quantum measurement theory!

I encountered a very interesting ScienceDaily article "*Physicists can predict the jumps of Schrödinger's cat (and finally save it)*" (see `http://tinyurl.com/y5lpe2eo`). The experimental findings described in the article are extremely interesting from the point of view provide by TGD inspired quantum measurement theory relying on Zero Energy Ontology (ZEO) and provides a test for it.

In standard quantum measurement theory (Copenhagen interpretation) of Bohr quantum jump is random in the sense that it occurs with predictable probabilities to an eigenstate of the measured observables. Their occurrence cannot be predicted and even less prevented - except by monitoring - Zeno effect.

The findings of Minev *et al* are described in the article "*To catch and reverse a quantum jump mid-flight*" [L99] (see `https://arxiv.org/abs/1803.00545`). The outcome of quantum jump is indeed unpredictable but the time of occurrence is to high degree predictable: there is a detectable warning signal, period of "flight" from the initial to the final state!

A curious feature is that the external signal responsible for the quantum jump can be stopped during the "flight" from the initial to final state. As if the quantum jump is analogous to a domino effect. It is also claimed that the jump can be reversed during flight period by a control signal: if jump has already occurred then one might argue that the control signal induces quantum jump in opposite direction when applied at time which is roughly the mid-time of "flight".

If the findings by Minev *et al* are replicable, one is forced to give up the basic assumption of the standard quantum measurement theory stating that state function reductions occur completely randomly and instantaneously. State function reduction (SR) looks like a continuous, deterministic process. Bohr's theory would be dead also officially and one must finally go back to the blackboard and start serious thinking about fundamentals. It took 92 years - almost a century! State function reduction (SR) is definitely more complex phenomenon than predicted by Bohr.

What is most intriguing that SR looks smooth, deterministic classical time evolution although the outcome is not predictable. People loving hidden variables might be happy but better to think about this more precisely before jumping to any conclusions. Authors apply so called quantum trajectory theory to describe the findings [B17] and report that the model is able to predict the parameters of the parameterization with one per cent accuracy.

Zero energy ontology (ZEO) based view about quantum measurement and the relationship between geometric and subjective time explains why state function reduction looks like a deterministic process. Unfortunately, what ZEO is, is not completely clear [L102]. This allows to consider two options.

1. Both options imply that one can apparently anticipate quantum jump. This could be however an illusion: the observed classical time evolution could occur *after* the quantum jump in opposite direction of time. The fact that the absence of the signal inducing quantum jump does not affect the occurrence of quantum jump suggests that the "flight" period indeed represents the classical evolution after the quantum jump in the reversed direction of time so that the absence of the external signal would not anymore affect the situation. Generalized Zeno effect is essential element ZEO based quantum measurement theory so that SR might

be prevented. Perhaps a more plausible interpretation is that the control signal induces the reversal of the quantum jump already occurred. A careful analysis to distinguish between subjective and geometric time and arrows of time for the observer and atom would be needed.

2. The more conventional option nearer to the interpretation of experimenters is that the observed time evolution occurs *before* the quantum jump in standard direction. The period before quantum jump consists of a sequence of "small" state function reductions - "weak" measurements. $M^8 - H$ duality suggests a concrete assignment of the moments of time to them [L102] and there would be also the last moment of this kind. After these things proceed to "big" state function reduction in analogy with domino effect. It is not however obvious why the classical time evolution should appear to converge to the final outcome deterministically.

First ZEO based based view about the findings

What about TGD and zero energy ontology (ZEO) based quantum measurement theory [K78]? Could it explain the revolutionary findings?

1. The new element is that quantum states are not time= constant snapshots for time evolution but superpositions of entire deterministic time evolutions at the level of space-time surfaces and at the level of induced spinor fields. SR replaces super position of classical time evolutions with a new one. This like selecting and starting new deterministic computer program. Non-determinism is in these choices [L72].

2. The notion of causal diamond (CD) identified as an intersection of future and past directed light-cones of M^4 with points replaced with CP_2 is crucial. The notion of CD is strongly suggested by the gigantic symmetries of CD essential for the construction of quantum TGD. CD could be seen as embedding space correlate for the perceptive field of a conscious entity - self. The upper boundary of CD - to be called active boundary A represents the boundary for space-time region from which self can receive classical signals and is therefore natural. The lower boundary, to be called passive boundary B, brings in mind cosmic expansion and follows as a prediction from $M^8 - H$ duality.

3. There are two kinds of state function reductions in ZEO.

   (a) In "small" SRs (SSRs) the states change at active boundary of causal diamond (CD) (call it A) but remain unchanged at passive boundary (call it P): generalized Zeno effect occurs at the passive boundary and "weak measurements" (see `http://tinyurl.com/zt36hpb`) at A. The observables measured commute with those determining the states at P as their eigenstates. In particular, the location of A is measured localizing it and corresponds to the measurement of time as distance between the tips of CD.

   "Big" SRs (BSRs) reverse the arrow of time of zero energy states and the roles of A and P. BSR is preceded by a sequence of SSRs - "weak" or almost classical measurements. In TGD inspired theory of consciousness [L72, L102] [K57] this sequence defines the life cycle of a conscious entity - self.

What is of crucial importance that BSR creates the illusion that it is an outcome of a continuous process: this realizes quantum classical correspondence (QCC). Standard observer assumes standard arrow of time and the space-time surfaces in the final time reversed state seem to lead to the 3-surface serving as a correlate for the final state! As if BSR would be outcome of a smooth deterministic process, which it is not! There is actually a superposition of these 3-surfaces at A after BSR but in the resolution used this is not detected. Putting it more precisely:

1. The time reversal of time evolution is in good approximation obtained by time reflection symmetry T but not quite since T is slightly broken. This is extremely small effect.

2. Before BSR one has a distribution of 3-surfaces X^3 defining the ends of space-time surfaces X^4 at A: 3-surfaces X^3 corresponds to different outcomes of BSR and can differ dramatically. Observer is not conscious of this. This is like a situation of Schrödinger cat before measurement: it is impossible to be conscious about the superposition of dead and alive cat.

After BSR one has quantum superposition of space-time surfaces directed to geometric past. Near the end of space-time at A they look like leading to a unique classical counterpart of final state of state function reduction. As if the state function reduction were a smooth, continuous, deterministic process. BSR guarantees this but BSR is not a smooth evolution.

The experimental findings could be understood by applying this general picture.

1. One can assign to the evolution from initial state G of atom at P to final state E at A a sequence of small reductions, weak measurements and also superposition of classical time evolutions approximated by single evolution in given measurement resolution. The state E is superposition of various measurement outcomes and each of them corresponds to a superposition of space-time surfaces identical in the measurement resolution used.

2. Then occurs the BSR: atom jumps from state E to state D. This selects from the superposition of space-time surfaces/time only the evolutions apparently leading to D. Or more precisely: the superposition of reversed time evolutions starting from D at A and very similar near A but deviating farther from it. The illusion about continuous, smooth, deterministic time evolution from G to D is created!

3. Also the possibility to anticipate the reduction would be an illusion due to the different arrows of time for observer and the observed system after BSR. The time reversed time evolution actually starts from the final state. The warning signal (absence of photon emission would be natural consequence of the reduction but in reversed arrow of time. The illusion would be due to the identification of arrows of time of observer and the atom that made state function reduction. This conforms with the observation that one can drop away the periodic signal inducing the quantum jumps during the "flight" period identified as the deterministic process representing the quantum jump.

   The lesson would be that one must always check whether the arrow of time for the target of attention is same as my own. Not a good idea to be on the wrong lane (means death also in ZEO based consciousness theory).

   It is also claimed that on can prevent the quantum jump using a signal during the "flight" period. Generalized Zeno effect is basic element of TGD but the signal forcing the state to remain in P would be present before the quantum jump. This would suggest that the control signal induced quantum jump in opposite direction. To really understand the situation a careful analysis of the relationships between subjective and geometric times of observer and between geometric time of observer and atomic system after and before the quantum jump would be needed.

Also Libet's findings about active aspects of consciousness [J44] can be interpreted in ZEO along the same lines. The observation that the neural activity begins before conscious decision can be understood by saying that the act of free will as a big state function reduction changed the arrow of time for an appropriate subsystem of the system studied. Tte time reversed classical evolutions from the outcome of the volitional action were interpreted erratically as a time evolution leading to the conscious decision. A less precise manner to say this is that conscious decision (big state function reduction) sent a classical signal to geometric past with opposite arrow of time initiating neural activity. Libet's finding led physicalistic neuroscientists to conclude that free will is an illusion. The actual illusions were physicalism and the belief that arrow of time is always the same.

To sum up, ZEO is fantastic magician. Maybe this magic is necessary for the mental health of observer: a world without this illusion would be like nightmare where one cannot trust anything.

Second ZEO based based view about the findings inspired by $M^8 - H$ duality

I have learned to take experimental findings very seriously and I am ready to aks whether the above described option the only possibility allowed by ZEO or can one think other alternatives? It would be nice to answer "No" but one can consider variants of ZEO [L102] inspired by so called $M^8 - H$ duality [L61, L112].

The sequence of "small" state function reductions (SSRs) should have the last one. Is the "big" state function reduction (BSR) forced by some condition? One idea is that the life cycle of self corresponds to a measurement of all observables assignable to the active boundary A of CD and commuting with those defining the unaffected states at passive boundary P are measured (time as a location of A belongs to these observables measured in each SSR).

I have discussed in [L102] possible modifications of ZEO inspired by so called M^8-H duality [L61, L112]. One motivation is that time flow as shifting M^4 time $t = constant$ hyper-plane can be argued to be more natural than that for light-cone boundary. Light-cone boundaries are however favored by its huge symmetries essential for the definition of the geometry of "world of classical worlds" (WCW). M^8-H duality forces passive light-cone boundary P and the identification of A as boundary of region where sensory signals can arrive to self is natural.

M^8-H duality allows to consider variants the original ZEO.

1. M^8-H duality

Let us first briefly summarize what M^8-H duality [L61] is.

1. M^8-H duality is one of the key ideas of TGD, and states that one can regard space-times as surfaces in either complexified octonionic M^8 or in $M^4 \times CP_2$. The dynamics M^8 is purely algebraic and requires that either tangent or normal space of space-time surface is associative (quaternionic).

2. The algebraic equations for space-time surfaces in M^8 state the vanishing of either the real or imaginary part (defined in quaternionic sense) for octonion valued polynomial $P(o)$ with real coefficients. Besides 4-D roots one obtains as universal exceptional roots 6-spheres at boundary of the light-cone of M^8 with radii given by the roots r_n of the polynomial in question. They correspond to the balls $t = r_n$ (t is octonionic real coordinate) inside Minkowski light-cone with each point have as fiber a 3-sphere S^3 with radius contracting to zero at the boundary of the light-cone of M^4. These 6-spheres are clearly analogous to branes connected by 4-D space-time surfaces.

3. The intersections of space-time surfaces with 6-spheres would be 2-D and I have interpreted them as partonic 2-surfaces identifiable as topological particle reaction vertices - partonic 2-surfaces - at which incoming and outgoing light-like 3-surfaces meet along their ends. These light-like 3-surfaces - partonic orbits - would represent the boundaries between space-time regions with Euclidian and Minkowskian signatures of the induced metric. Partonic 2-surfaces would be analogs of the vertices of Feynman diagrams. The boundaries of string world sheets predicted as singularities of minimal surfaces defining space-time surfaces would be along the partonic orbits and give rise to QFT type description using cognitive representations and analogs of twistor diagrams consisting of lines.

2. M^8-H duality and consciousness

One can ask whether M^8-H duality and this braney picture has implications for ZEO based theory of consciousness. Certain aspects of M^8-H duality indeed challenge the recent view about consciousness based on ZEO (zero energy ontology) and ZEO itself.

1. The moments $t = r_n$ defining the 6-branes correspond classically to special moments for which phase transition like phenomena occur. Could $t = r_n$ have a special role in consciousness theory?

   (a) For some SSRs the increase of the size of CD reveals new $t = r_n$ plane inside CD. One can argue that these SSRS define very special events in the life of self. This would not modify the original ZEO considerably but could give a classical signature for how many ver special moments of consciousness have occurred: the number of the roots of P would be a measure for the lifetime of self and there would be the largest root after which BSR would occur.

   (b) Second possibility is more radical. One could one think of replacing CD with single truncated future- or past-directed light-cone containing the 6-D universal roots of P

up to some r_n defining the upper boundary of the truncated cone? Could $t = r_n$ define a sequence of moments of consciousness? To me it looks more natural to assume that they are associated with very special moments of consciousness.

2. For both options SSRs increase the number of roots r_n inside CD/truncated light-one gradually and thus its size? When all roots of $P(o)$ would have been measured - meaning that the largest value r_{max} of r_n is reached -, BSR would be unavoidable.

   BSR could replace $P(o)$ with $P_1(r_1 - o)$: r_1 must be real and one should have $r_1 > r_{max}$. The new CD/truncated light-cone would be in opposite direction and time evolution would be reversed. Note that the new CD could have much smaller size size if it contains only the smallest root r_0. One important modification of ZEO becomes indeed possible. The size of CD after BSR could be much smaller than before it. This would mean that the re-incarnated self would have "childhood" rather than beginning its life at the age of previous self - kind of fresh start wiping the slate clean.

   One can consider also a less radical BSR preserving the arrow of time and replacing the polynomial with a new one, say a polynomial having higher degree (certainly in statistical sense so that algebraic complexity would increase).

3. Is a more conservative view possible?

Could this picture allow to build a more conservative picture more akin to that proposed by experimenters?

1. The interpretation of the detected time evolution as that *before* the quantum jump would conform with the interpretation of experimentalists that a kind of domino effect is involved and also with the observation that stopping the signal causing the quantum jumps does not anymore affect the situation.

2. It is however unclear how to understand why the evolution looks like leading to the outcome unless the sequence of r_n:s defines a sequence of steps gradually taking the system near the final state.

3. What about preventing the BSR by external signal and even reversing the quantum jump? This would require an external perturbation of the octonionic polynomial increasing the value of the largest root r_{max} or even the degree of the polynomial and bringing in additional significant moments of life. Is it possible to speak about external perturbations of the coefficients of polynomials assumed to be rational numbers? The perturbations would come from a higher level in the hierarchy of selves (experimentalist), and one can imagine them in the framework of many-sheeted space-time.

To sum up, to my opinion (which could change) the first option looks more plausible. The introduction of moments $t = r_n$ as special moments in the life of self looks highly attractive and also the possibility of wiping the slate clear.

15.4 Negentropy Maximization Principle

Negentropy Maximization Principle (NMP [K73]) stating that the reduction of entanglement entropy is maximal at a given step of state function reduction process following U-process is the basic variational principle for TGD inspired theory of consciousness and says that the information contents of conscious experience is maximal. Although this principle is diametrically opposite to the second law of thermodynamics it is structurally similar to the second law. NMP does not dictate the dynamics completely since in state function reduction any eigen state of the density matrix is allowed as final state. NMP need not be in contradiction with second law of thermodynamics which might relate as much to the aging of mental images as to physical reality.

15.4.1 Basic Form Of NMP

Negentropy Maximization Principle (NMP) in its original form codes for the basic rules of the standard state function reduction and implies that system ends up to an eigenstate of the density matrix identified as observable. In TGD framework must ask whether NMP should be restricted only to the entanglement between zero modes of WCW representing classical degrees of freedom and quantum fluctuating degrees of freedom or generalize it to apply to any pair of subsystems so that state function reduction sequence could be regarded as a sequence of self measurements. I have chosen the latter option as a working hypothesis.

NMP that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step of the process. State function process could proceed at the level of all CDs. It is not clear whether one can assign any geometric time duration to this process or whether there is any need for this. If the subsystem allows entangled pairs of free systems (no binding energy) there is more or less unique pair with the maximal entanglement entropy and NMP therefore implies a decomposition to a unique pair of unentangled systems. The process repeats itself for these systems and stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. Number theoretic entanglement entropies mean an important modification of this picture.

15.4.2 Weak Form Of NMP

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities p_n by the logarithms of their p-adic norms $|p_n|_p$. This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding or some positive emotion like love.

Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness.

NMP combined with number theoretic entropies leads to an important exception to the rule that the generation of bound state entanglement between system and its environment during U process leads to a loss of consciousness. When entanglement probabilities are rational (or even algebraic) numbers, the entanglement entropy defined as a number theoretic variant of Shannon entropy can be non-positive (actually is) so that entanglement carries information. NMP favors the generation of algebraic entanglement. The attractive interpretation is that the generation of algebraic entanglement leads to an expansion of consciousness ("fusion into the ocean of consciousness") instead of its loss.

State function reduction period of the quantum jumps involves much more than in wave mechanics. For instance, the choice of quantization axes realized at the level of geometric delicacies related to CDs is involved. U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction involves also a choice between generic and negentropic entanglement (between real world, a particular p-adic world, or their intersection) it might be possible to identify a candidate for the physical correlate for the choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The hedonistic option is risky since it can lead to non-algebraic bound state entanglement implying a loss of consciousness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices. Note that if the total entanglement negentropy defined as sum of contributions from various levels of CD hierarchy up to the highest matters in NMP then also sub-selves should develop negentropic entanglement. For instance, the generation of entropic entanglement at cell level can lead to a loss of consciousness

also at higher levels. Life would evolve from short to long scales.

The consistency with quantum measurement theory leads to an important constraint on the density matrix giving rise to negentropic entanglement. The density matrix of the final state must be a projector as in the ordinary quantum measurement theory. It's dimension can be however higher than one now. Therefore negentropic entanglement cannot be confused with real entanglement and there is no problem due to the fact that for real number based entanglement it is impossible to know in practice whether the entanglement coefficients are rational numbers. The entanglement giving rise to a density matrix, which is projector corresponds in the 2-particle case entanglement matrix proportional to unitary matrix typical for quantum computer type systems.

TGD inspired theory of consciousness forces to challenge the hypothesis that NMP always forces the state function reduction to the sub-space defined by the projector with maximal dimension appearing in the decomposition of the density matrix. NMP would not allow the self to make choices, which are bad deeds in the sense that they do not increase maximally the negentropic resources of the Universe. We would live in the best possible Universe becoming better all the time. This is obviously too good to be true.

A weaker form of NMP allows the choice leading to maximal negentropy gain but allows also those choices for which the reduction occurs to a sub-space of the space defined by projector. When this sub-space is 1-dimensional standard quantum measurement results and the self is isolated from the target of observations. Negentropic entanglement has interpretation as attention with positively colored contents of consciousness. Experience of love would be one attribute of this kind of state. Weak form of NMP would be like God allowing the sinner to chose between Good and Evil.

Do positively colored emotions allow a representation of Boolean logic?

Weak form of NMP allows the state function reduction to occur in $2^n - 1$ ways corresponding to subspaces of the sub-space defined by n-dimensional projector if the density matrix is n-dimensional projector (the outcome corresponding to 0-dimensional subspace and is excluded). If the probability for the outcome of state function reduction is same for all values of the dimension $1 \leq m \leq n$, the probability distribution for outcome is given by binomial distribution $B(n,p)$ for $p = 1/2$ (head and tail are equally probable) and given by $p(m) = b(n,m) \times 2^{-n} = (n!/m!(n-m)!) \times 2^{-n}$. This gives for the average dimesion $E(m) = n/2$ so that the negentropy would increase on the average. The world would become gradually better. Note that one assumes that there is some preferred basis for the states and these numbers apply when this basis is given.

One cannot avoid the idea that these different degrees of negentropic entanglement could actually give a realization of Boolean algebra in terms of conscious experiences.

1. There should be a mapping of k-dimensional subspaces of n-dimensional space to the fermionic representation of Boolean algebra

2. Could one speak about a hierarchies of codes of cognition based on the assignment of different degrees of "feeling good" to the Boolean statements? If one assumes that the n:th bit is always 1, all independent statements except one correspond at least two non-vanishing bits and corresponds to negentropic entanglement. Only of statement (only last bit equal to 1) would correspond 1 bit and to state function reduction reducing the entanglement completely (brings in mind the fruit in the tree of Good and Bad Knowlege!).

3. A given hierarchy of breakings of super-symplectic symmetry corresponds to a hierarchy of integers $n_{i+1} = \prod_{k \leq i} m_k$. The codons of the first code would consist of sequences of m_1 bits. The codons of the second code consists of m_2 codons of the first code and so on. One would have a hierarchy in which codons of previous level become the letters of the code words at the next level of the hierarchy.

In fact, I ended up with almost Boolean algebra for decades ago when considering the hierarchy of genetic codes suggested by the hierarchy of Mersenne primes $M(n+1) = M_{M(n)}$, $M_n = 2^n - 1$.

1. The hierarchy starting from $M_2 = 3$ contains the Mersenne primes $3, 7, 127, 2^{127} - 1$ and Hilbert conjectured that all these integers are primes. These numbers are almost dimensions

of Boolean algebras with $n = 2, 3, 7, 127$ bits. The maximal Boolean sub-algebras have $m = n - 1 = 1, 2, 6, 126$ bits.

2. The observation that $m = 6$ gives 64 elements led to the proposal that it corresponds to a Boolean algebraic assignable to genetic code and that the sub-algebra represents maximal number of independent statements defining analogs of axioms. The remaining elements would correspond to negations of these statements. I also proposed that the Boolean algebra with $m = 126 = 6 \times 21$ bits (21 pieces consisting of 6 bits) corresponds to what I called memetic code obviously realizable as sequences of 21 DNA codons with stop codons included. Emotions and information are closely related and peptides are regarded as both information molecules and molecules of emotion.

3. This hierarchy of codes would have the additional property that the Boolean algebra at $n + 1$:th level can be regarded as the set of statements about statements of the previous level. One would have a hierarchy representing thoughts about thoughts about.... It should be emphasized that there is no need to assume that the Hilbert's conjecture is true.

   One can obtain this kind of hierarchies as hierarchies with dimensions $m, 2^m, 2^{2^m}, ...$ that is $n(i+1) = 2^{n(i)}$. The conditions that $n(i)$ divides $n(i+1)$ is non-trivial only for at the lowest step and implies that m is power of 2 so that the hierarchies starting from $m = 2^k$. This is natural since Boolean algebras are involved. If n corresponds to the size scale of CD, it would come as a power of 2.

   p-Adic length scale hypothesis has also led to this conjecture. A related conjecture is that the sizes of CDs correspond to secondary p-adic length scales which indeed come as powers of two. In case of electron this predicts that the minimal size of CD associated with electron corresponds to time scale $T = .1$ seconds, the fundamental time scale in living matter (10 Hz is the fundamental biorhythm). It seems that the basic hypothesis of TGD inspired partly by the study of elementary particle mass spectrum and basic bio-scales (there are 4 p-adic length scales defined by Gaussian Mersenne primes in the range between cell membrane thickness 10 nmandsize 2.5 μm of cell nucleus!) follow from the proposed connection between emotions and Boolean cognition.

Hilbert's conjecture relates in interesting manner to space-time dimension. Suppose that Hilbert's conjecture fails and only the four lowest Mersenne integers in the hierarchy are Mersenne primes that is $3, 7, 127, 2^{127} - 1$. In TGD one has hierarchy of dimensions associated with space-time surface coming as 0, 1, 2, 4 plus embedding space dimension 8. The abstraction hierarchy associated with space-time dimensions would correspond discretization of partonic 2-surfaces as point set, discretization of 3-surfaces as a set of strings connecting partonic 2-surfaces characterized by discrete parameters, discretization of space-time surfaces as a collection of string world sheet with discretized parameters, and maybe - discretization of embedding space by a collection of space-time surfaces. Discretization means that the parameters in question are algebraic numbers in an extension of rationals associated with p-adic numbers.

In TGD framework it is clear why embedding space cannot be higher-dimensional and why the hierarchy does not continue. Could there be a deeper connection between these two hierarchies. For instance, could it be that higher dimensional manifolds of dimension $2 \times n$ can be represented physically only as unions of say n 2-D partonic 2-surfaces (just like $3 \times N$ dimensional space can be represented as configuration space of N point-like particles)? Also infinite primes define a hierarchy of abstractions. Could it be that one has also now similar restriction so that the hierarchy would have only finite number of levels, say four. Note that the notion of n-group and n-algebra involves an analogous abstraction hierarchy.

15.4.3 Can One Define Measures For The Information Contents Of Mental Image?

Despite the fact that one cannot write formula for the contents of conscious experience, one can define information measures for conscious experience as differences of the information measures for the initial and final quantum histories. Negentropy gain is the most natural information measure of this kind. For instance, the sum of the net entanglement negentropy gains over the steps of the

self measurement cascade could define a quantity characterizing net information gain for a single moment of consciousness at each step.

One could also information measure to selves as the entanglement negentropy after the state function reduction process has ended. This would assign to each subsystem stable under NMP a negentropy. For bound state entanglement this information would be negative but for negentropic entanglement it would be positive. One can ask whether the hypothesis that this information increases during quantum jump sequence is equivalent with NMP. In the case of entire Universe the application of this principle becomes problematic.

Entropy gradients with respect to subjective time could be used to characterize how the information gain of conscious experience of self changes. These gradients approach zero when self approaches thermal equilibrium. In TGD framework entropy gradients correlate with emotions, which means a somewhat counter intuitive connection between emotions and information gain or loss (consistent however with the fact that peptides are both informational molecules and molecules of emotion [J55]). Note that the binding of information molecules to receptors means the formation larger bound states accompanied by the experience of oneness at molecular level (are sex and spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that life and conscious intelligence reside in the intersection of the real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entanglement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP.

1. For the minimal option life would be also effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world sheets partonic two-surfaces appears in U-matrix so that only the data from rational and some algebraic points of the partonic 2-surface dictate U-matrix. This means discretization at parton level and something which might be called number theoretic quantum field theory should emerge as a description of intentional action.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K3]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K103].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden

Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

15.4.4 Hyper-Finite Factors Of Type II_1 And NMP

Hyper-finite factors of type II_1 bring in additional delicacies to NMP. The basic implication of finite measurement resolution characterized by Jones inclusion is that state function reduction can never reduce entanglement completely so that entire universe can be regarded as an infinite living organism. It would seem that entanglement coefficients become $\mathcal{N}$ valued and the same is true for eigen states of density matrix. For quantum spinors associated with $\mathcal{M}/\mathcal{N}$ entanglement probabilities must be defined as traces of the operators $\mathcal{N}$. An open question is whether entanglement probabilities defined in this manner are algebraic numbers always (as required by the notion of number theoretic entanglement entropy) or only in special cases.

15.4.5 $M^8 - H$ duality and consciousness

$M^8 - H$ duality is one of the key ideas of TGD and one can ask whether it has implications for TGD inspired theory of consciousness and it indeed forces to challenge the recent ZEO based view about consciousness [L72] .

Objections against ZEO based theory of consciousness

Consider first objections against ZEO based view about consciousness.

1. ZEO (zero energy ontology) based view about conscious entity can be regarded as a sequence of "small" state function reductions (SSRs) identifiable as analogs of so called weak measurements at the active boundary of causal diamond (CD) receding reduction by reduction farther away from the passive boundary, which is unchanged as also the members of state pairs at it. One can say that weak measurements commute with the observables, whose eigenstates the states at passive boundary are. This asymmetry assigns arrow of time to the self having CD as embedding space correlate. "Big" state function reductions (BSRs) would change the roles of boundaries of CD and the arrow of time. The interpretation is as death and re-incarnation of the conscious entity with opposite arrow of time.

   The question is whether quantum classical correspondence (QCC) could allow to say something about the time intervals between subsequent values of temporal distance between weak state function reductions.

2. The questionable aspect of this view is that $t_M = constant$ sections look intuitively more natural as seats of quantum states than light-cone boundaries forming part of CD boundaries. The boundaries of CD are however favoured by the huge symplectic symmetries assignable to the boundary of M^4 light-cone with points replaced with CP_2 at level of H. These symmetries are crucial or the existence of the geometry of WCW ("world of classical worlds").

3. Second objection is that the size of CD increases steadily: this nice from the point of view of cosmology but the idea that CD as correlate for a conscious entity increases from CP_2 size to cosmological scales looks rather weird. For instance, the average energy of the state assignable to either boundary of CD would increase. Since zero energy state is a superposition of states with different energies classical conservation law for energy does not prevent this [L110]: essentially quantal effect due to the fact that the zero energy states are not exact eigenstates of energy could be in question. In BSRs the energy would gradually increase. Admittedly this looks strange and one must be keen for finding more conventional options.

4. Third objection is that re-incarnated self would not have any "childhood" since CD would increase all the time.

One can ask whether $M^8 - H$ duality and this braney picture has implications for ZEO based theory of consciousness. Certain aspects of $M^8 - H$ duality indeed challenge the recent view about consciousness based on ZEO (zero energy ontology) and ZEO itself.

1. The moments $t = r_n$ defining the 6-branes correspond classically to special moments for which phase transition like phenomena occur. Could $t = r_n$ have a special role in consciousness theory?

   (a) For some SSRs the increase of the size of CD reveals new $t = r_n$ plane inside CD. One can argue that these SSRS define very special events in the life of self. This would not modify the original ZEO considerably but could give a classical signature for how many ver special moments of consciousness have occurred: the number of the roots of P would be a measure for the lifetime of self and there would be the largest root after which BSR would occur.

   (b) Second possibility is more radical. One could one think of replacing CD with single truncated future- or past-directed light-cone containing the 6-D universal roots of P up to some r_n defining the upper boundary of the truncated cone? Could $t = r_n$ define a sequence of moments of consciousness? To me it looks more natural to assume that they are associated with very special moments of consciousness.

2. For both options SSRs increase the number of roots r_n inside CD/truncated light-one gradually and thus its size? When all roots of $P(o)$ would have been measured - meaning that the largest value r_{max} of r_n is reached -, BSR would be unavoidable.

   BSR could replace $P(o)$ with $P_1(r_1 - o)$: r_1 must be real and one should have $r_1 > r_{max}$. The new CD/truncated light-cone would be in opposite direction and time evolution would be reversed. Note that the new CD could have much smaller size size if it contains only the smallest root r_0. One important modification of ZEO becomes indeed possible. The size of CD after BSR could be much smaller than before it. This would mean that the re-incarnated self would have "childhood" rather than beginning its life at the age of previous self - kind of fresh start wiping the slate clean.

   One can consider also a less radical BSR preserving the arrow of time and replacing the polynomial with a new one, say a polynomial having higher degree (certainly in statistical sense so that algebraic complexity would increase).

Could one give up the notion of CD?

A possible alternative view could be that one the boundaries of CD are replaced by a pair of two $t = r_N$ snapshots $t = r_0$ and $t = r_N$. Or at least that these surfaces somehow serve as correlates for mental images. The theory might allow reformulation also in this case, and I have actually used this formulation in popular lectures since it is easier to understand by laymen.

1. Single truncated light-cone, whose size would increase in each SSR would be present now since the spheres correspond to balls of radius r_n at times r_n. If $r_0 = 0$, which is the case for $P(o) \propto o$, the tip of the light-cone boundary is one root. One cannot avoid association with big bang cosmology. For $P(0) \neq r_0$ the first conscious moment of the cosmology corresponds to $t = r_0$. One can wonder whether the emergence of consciousness in various scales could be described in terms of the varying value of the smallest root r_0 of $P(o)$.

   If one allows BSR:s this picture differs from the earlier one in that CDs are replaced with alternation of light-cones with opposite directions and their intersections would define CD.

2. For this option the preferred values of t for SSRs would naturally correspond to the roots of the polynomial defining $X^4 \subset M^8$. Moments of consciousness as state function reductions would be due to collisions of 4-D space-time surfaces X^4 with 6-D branes! They would

replace the sequence of scaled CD sizes. CD could be replaced with light-one and with the increasing sequence $(r_0, ...r_n)$ of roots defining the ticks of clock and having positive and negative energy states at the boundaries r_0 and r_n.

3. What could be the interpretation for BSRs representing death of a conscious entity in the new variant of ZEO? Why the arrow of time would change? Could it be because there are no further roots of $P(o)$? The number of roots of $P(o)$ would give the number of small state function reductions?

   What would happen to $P(o)$ in BSR? The vision about algebraic evolution as increase of the dimension for the extension of rationals would suggest that the degree of $P(o)$ increases as also the number of roots if all complex roots are allowed. Could the evolution continue in the same direction or would it start to shift the part of boundary corresponding to the lowest root in opposite direction of time. Now one would have more roots and more algebraic complexity so that evolutionary step would occur.

   In the time reversal one would have naturally $t_{max} \geq r_{n_{max}}$ for the new polynomial $P(t-t_{max})$ having $r_{n_{max}}$ as its smallest root. The light-cone in M^8 with tip at $t = t_{max}$ would be in opposite direction now and also the slices $t - t_{max} = r'_n$ would increase in opposite direction! One would have two light-cones with opposite directions and the $t = r_n$ sections would replace boundaries of CDs. The reborn conscious entity would start from the lowest root so that also it would experience childhood.

This option could solve the argued problems of the previous scenario and give concrete connection with the classical physics in accordance with QCC. On the other hand, a minimal modification of original scenario combined with $M^8 - H$ duality with moments $t = r_n$ as special moments in the life of conscious entity allows also to solve these problems if the active boundary of CD is interpreted as boundary beyond which classical signals cannot contribute to perceptions.

What could be the minimal modification of ZEO based view about consciousness?

What would be the minimal modification of the earlier picture? Could one *assume* that CDs serve as embedding space correlates for the perceptive field?

1. Zero energy states would be defined as before that is in terms of 3-surfaces at boundaries of CD: this would allow a realization of huge symmetries of WCW and the active boundary A of CD would define the boundary of the region from which self can receive classical information about environment. The passive boundary P of CD would define the boundary of the region providing classical information about the state of self. Also now BSR would mean death and reincarnation with an opposite arrow of time. Now however CD would shrink in BSR before starting to grow in opposite time direction. Conscious entity would have "childhood".

2. If the geometry of CD were fixed, the size scale of the $t = r_n$ balls of M^4 would first increase and then start to decrease and contract to a point eventually at the tip of CD. One must however remember that the size of $t = r_n$ planes increases all the time as also the size of CD in the sequences of SSRs. Moments $t = r_n$ could represent special moments in the life of conscious entity taking place in SSRs in which $t = r_n$ hyperplane emerges inside CD with increased size. The recent surprising findings challenging the Bohrian view about quantum jumps [L99] can be understood in this picture [L99].

3. $t = r_n$ planes could also serve as correlates for memories. As CD increases at active boundary new events as $t = r_n$ planes would take place and give rise to memories. The states at $t = r_n$ planes are analogous to seats of boundary conditions in strong holography and the states at these planes might change in state function reductions - this would conform with the observations that our memories are not absolute.

To sum up, the original view about ZEO seems to be essentially correct. The introduction of moments $t = r_n$ as special moments in the life of self looks highly attractive as also the possibility of wiping the slate clear by reduction of the size of CD in BSR.

15.5 Some comments related to Zero Energy Ontology (ZEO)

Zero energy ontology (ZEO) lies behind TGD based quantum measurement theory in turn giving rise to a theory of consciousness by making observed part of system as a conscious entity - self [L72]. ZEO solves the basic paradox of quantum measurement theory forcing to give up ontology altogether in the Copenhagen interpretation. ZEO has become a key aspect of the entire TGD based physics.

The basic prediction of ZEO is that ordinary ("big") state function reductions (BSFRs) involve change of the arrow of time. There is a lot of support for this prediction. The recent highly counterintuitive findings of Minev *et all* provided support for the time reversal in atomic systems [L99] [L99]. Fantappie [J121] proposed decades ago time reversal in living systems and introduced syntropy as time reversed entropy. In living matter the generation of more complex molecules from their building bricks can be seen as decay in time reversed direction. Phase conjugate laser beams are known to obey time reversed second law.

Also Libet's findings [J44] related to the active aspects of conscious experience find a nice explanation in terms of the time reversal. The latest application is to the understanding of the mysterious looking findings about earthquakes and volcanic eruptions suggesting that macroscopic quantum jumps involving time reversal are in question [L101]. This suggest that experimental verification of the time reversal and occurrence of macroscopic quantum jumps is possible by studying causal anomalies. For these reasons is important to try to develop the details of the view about ZEO as precise as possible.

In the sequel I will consider more precise mathematical formulation and physical interpretation of ZEO. ZEO forms also the cornerstone of TGD inspired theory of consciousness and quantum biology and I will consider also some related aspects of ZEO such as the notions of free will and intentionality, the notions of memory and precognition as its time reversal, intuitive in contrast to formal reasoning, and remote metabolism as a universal thermodynamical mechanism of metabolism in ZEO based thermodynamics.

15.5.1 General view about ZEO

The details of ZEO - in particular the technical details related to the conservation laws BSFR and SSFR - are from well-understood and the following is an attempt to fix these details by using analogy with cosmology.

Rough view about ZEO

Consider first what ZEO roughly means.

1. The realization of ZEO [L111, L72, L84, L107] involves besides the notions of "small" (SSFR) and "big" state function reduction (BSFR) also the notion of causal diamond (CD). CD defines perceptive field of conscious entity as a 8-D region $cd \times CP_2$, where cd is the 4-D causal diamond of M^4 defined as the intersection of future and past directed light-cones.

2. At the classical level the basic entity is space-time surface connecting 3-surfaces at the opposite boundaries of CD. The space-time surfaces inside sub-CD continue outside and there is a hierarchy of CDs with largest CD beyond which space-time surfaces do not continue. This defines a space-time correlate for the hierarchy of selves.

   Space-time surfaces are preferred extremals of the basic action principle defined by the twistor lift of TGD [L88]. Minimal surfaces with 2-D string world sheets as singularities would be in question. They connect 3-surfaces at the boundaries of CD and are analogous to Bohr orbits so that not any pair is possible and the conditions characterizing preferred extremal property might even imply 1-1 correspondence between these 3-surfaces.

3. Zero energy states are superpositions of preferred extremals. One can also understand zero energy states as superpositions of deterministic programs - quantum programs, functions in the sense of quantum biology, or quantum behaviors. ZEO allows to solve the basic paradox of quantum measurement theory since the non-determinism of quantum jump between zero energy states corresponds to the causality of free will and is not in conflict with the classical

determinism realizing the causality of field equations. Experienced time and geometric time are not same but there is a strong correlation between them.

4. In SSFRs the active boundary of CD shifts to future - at least in statistical sense. This is preceded by a unitary time evolution generating superposition of CDs with different sizes but having fixed passive boundary and same superposition of 3-surfaces at it. SSFR involves time-localization to single CD with fixed temporal distance between its tips. Essentially time measurement is in question.

5. In BSFR the arrow of time changes and one can say that state function reduction measuring set of observables takes place at the active boundary of CD, which becomes a passive boundary at which state does not change during subsequent SSFRs in which CD increases in opposite direction with the former passive boundary becoming an active boundary. The change of the arrow of time in BSFR creates the illusion that instantaneous quantum jump corresponds to a smooth and deterministic time evolution leading to the final state [L99] [L99].

The mathematical and physical details of the picture are not completely nailed down, and the best manner to proceed is to return to basic questions again and again and to challenge the details of the existing picture. In the following I will do my best to invent nasty arguments against ZEO.

ZEO and conservation laws

The geometry of CD breaks Poincare invariance. Lorentz invariance with respect to the either tip of CD is exact symmetry and is extremely attractive in the construction of members of state pairs in ZEO. Classically Poincare invariance is exact and one can deduce expressions for conserved quantities for both bosonic and fermionic sector: the latter have interpretation as operators, whose eigenvalues in Cartan algebra are by quantum classical correspondence (QCC) identified as classical values of conserved quantities.

ZEO involves the somewhat questionable assumption that one can assign well-defined Poincare quantum numbers to both boundaries and that these quantum numbers are opposite: this motivates the term ZEO.

1. $M^8 - H$ duality [L103] allows to assign to CDs with either boundary fixed a moduli space, which corresponds to Poincare group. The proposal is that Poincare invariance is realized at this level and that the values of conserved charges in Cartan algebra correspond to the Poincare quantum numbers labelling these wave functions. The wave functions at the boundaries of CD could be arranged in representations of Lorentz group acting as exact symmetry of the boundary.

2. There is further little nuisance involved. Only time translations, which correspond to a non-negative time value as distance from the fixed boundary of CD are possible. One would obtain momentum eigenstates restricted to a future or past light-cone. This is of course what happens in TGD based cosmology. Maybe one must just accept this as a physical fact forcing to give up mathematical idealization.

   Formally one would replace the plane wave basis with a basis multiplied by characteristic function for future or past light-cone equal to 1 inside the light-cone and vanishing elsewhere. This basis is closed with respect to summation. This would mean that the states are not anymore exact eigenstates of momentum globally but superposition of Lorentz boosts of the basic momentum obtained by Fourier expanding the characteristic function of future/past light-cone.

   But what about CD which is intersection of future and past directed light-cones? Can one really assign to both boundaries wave functions defined in entire future (or past) directed light-cone? It seems that this is the case. Zero energy state would be entangled state as a superposition of products of boosted momentum eigenstates with opposite momenta representing the characteristic function of CD.

   The usual idea about unitary time evolution for Schrödinger amplitude would be given up inside CD, and replaced by a sequence of unitary time evolutions producing de-localization of the active boundary of CD and followed by a localization.

3. There is still a problem. A complete de-localization for the boundaries of CD is not consistent with the intuitive idea that CD has definite size scale. In wave mechanics the plane waves are only idealizations and in the real world one replaces plane waves with wave packets. Gaussian wave packets have the nice feature that they remain Gaussian in Fourier transformation.

   If one has Gaussian wave packet for the temporal distance between the tips of CD concentrated on certain value of time, the Fourier transform for this is Gaussian wave packet concentrated around certain relative energy, which is two times the energy assignable to say passive boundary of CD. Instead of sharp value of time as distance between the tips of CD one would have Gaussian distribution for its value. This is consistent with Lorentz invariance since zero energy states allow superposition over states with varying momenta assignable to say active boundary. The wave function would be essentially Gaussian in energy in the rest system and one can consider also wave functions in Lorentz group leaving the passive boundary of CD invariant.

SSFRs in ZEO

In the proposed picture the sequence of SSFRs could mean gradual widening of the Gaussian wave packet for the value of measured time as the temporal distance between the tips of CD by discrete steps.

The basic condition is that the states at passive boundary of CD identified as superpositions of 3-surfaces remain unaffected during the sequences of SSFRs increasing the size of CD. This corresponds to generalized Zeno effect and in consciousness theory thr unchanging part of zero energy state corresponds to unchanging part of self, one might call it soul. One can imagine two options.

Option I: CD increases statistically in SSFRs but classical energy is conserved for space-time surfaces connecting its boundaries. Energy density would decreases as CD increases. This does not seem too bad actually: it would be analogous to matter dominated cosmology.

Not only superpositions of 3-surfaces at passive boundary of CD would be conserved but also their 4-D tangent spaces would be unaffected: this is unnecessarily strong a condition for generalized Zeno effect.

Option II: CD increases but classical energies decrease. This looks more plausible- if not the only - option and is strongly favoured by the analogy of CD with expanding cosmology. It also conforms with uncertainty principle. The process would be essentially quantum analog of cooling or analog for what happens for particle in a box expanding adiabatially. The classical energies of the space-time surfaces in zero energy state would thus decrease as CD increases.

Also this option allows the states as superpositions of 3-surfaces to at passive boundary of CD to remain unffected in expansion of CD. The classical energies can however decrease because the space-time surfaces - tangent spaces of space-time surfaces at passive boundary - can change so that also energies can change.

This option is completely analogous to quantum adiabatic change in which the coefficients in the superposition of energy eigenstates are unaffected but energies change.

Option II looks more natural and will be considered in more detail.

1. The constraint that SSFRs as quantum measurements are for observables, which commute with observables, whose eigenstate the state at the passive boundary is, poses very strong constraints on what happens SSFR. Furthermore, preferred extremal is analog of Bohr orbit and cannot cannot be arbitrary pair of 3-surfaces. Therefore, when the CD changes, the preferred extremal also changes as a whole meaning also that also energy changes. These conditions could force adiabatic picture and the analog of Uncertainty Principle for classical energies as function of CD size.

2. The sequence of SSFRs could be also analogous analogous to what happens for a particle in box as the size of the box increases adiabatically: adiabaticity would actually be a hypothesis about what happens in the steps consisting of unitary evolution and SSFR. In adiabatic approximation the coefficients in the superposition of the energy eigenstates do not change at all: only the energies would change.

3. In thermodynamics this kind of process would correspond to a cooling, which could serve as a natural quantum correlate for the cooling in cosmology. In accordance with the idea that quantum TGD in ZEO corresponds to a complex square root of thermodynamics, one could interpret zero energy state as complex square root of thermal partition function for cosmology assignable to CD. The hierarchy of CDs would define Russian doll cosmology.

4. A further manner to understand this is in terms of Uncertainty Principle. As the size scale of CD given by temporal distance between its dips increases, the classical energy decreases. Intuitively the reduction of the classical energy is easy to understand. Increasing CD and keeping the 3-surface as such at passive boundary reduces time gradients at the passive boundary and space-time surface becomes more flat. Energy density is proportional to time gradients of coordinates and its therefore reduced. This argument is also used in inflation theories.

5. Change is the prerequisite of conscious experience and there would be indeed change also at the passive boundary of CD contributing to conscious experience. But in some sense this contribution - the "soul" - should *not* be changing! "Adiabaticity" would translate this idea to the language of physics.

What happens to CD in long run? There are two options.

1. The original assumption was that the location of formerly passive boundary is not changed. This would mean that the size of CD would increase steadily and the outcome would be eventually cosmology: this sounds counter-intuitive. Classically energy and other Poincare charges are conserved for single preferred extremal could fail in BSFRs due to the fact that zero energy states cannot be energy eigenstates.

2. The alternative view suggested strongly $M^8 - H$ duality [L61] is that the size of CD is reduced in BSFR so that the new active boundary can be rather near to the new passive boundary. One could say that the reincarnated self experiences childhood. In this case the size of CD can remain finite and its location in M^8 more or less fixed. One can say that the self associated with the CD is in a kind of Karma's cycle living its life again and again. Since the extension of rationals can change in BSFR and since the number of extensions larger than given extension is infinitely larger than those smaller than it, the dimension of extension identifiable in terms of effective Planck constant increases. Since $n = h_{eff}/h_0$ serves as a kind of IQ, one can say that the system becomes more intelligent.

   Also the temperature assignable to CD remains finite. In cosmological scales it could correspond to the analog of the temperature assignable to CMB. TGD based view about stars as blackhole like entities [L100] leads to the identification of the Hagedorn temperature assignable to the volume filling flux tube giving rise to star with the Hawking temperature of dark radiation at gravitational flux tubes. Even CMB temperature could be assigned with dark photons at gravitational flux tubes. The asymptotic temperature for CD before BSFR could correspond to this temperature.

   One expects that the center of mass coordinates of cm do not appreciably change during the quantum evolution. The hierarchy of CDs would imply that the Universe decomposes effectively to sub-Universes behaving to some degree independently. The view about Karma's cycles provides a more precise formulation of the pre-ZEO idea that systems are artists building themselves as 4-D sculptures. In particular, this applies to mental images in TGD based view about brain. The assumption that stars correspond to repeatedly re-incarnating conscious entities allows to solve several time anomalies in cosmology [L100] so that there would be a direct connection between cosmology and theory of consciousness.

There could be a relationship between quantal flow of geometric time by SSFRs and p-adic variant of time coordinates giving a reason why for p-adicity.

1. TGD predicts geometric time as a real variant and p-adic variants in extensions of various p-adics induced by given extension of rationals (adelic space-time and adelic geometric time). Real and p-adic times share discrete points in the extension of rationals considered: roots of

octonionic polynomials defining space-time surfaces as roots for their "real" and "imaginary" parts in quaternionic sense [L102]. The roots of the real polynomial with rational coefficients giving octonionic polynomial as its continuation define space moments of M^4 linear time assignable to special SSFRs. p-Adic time associated with the p-adic balls assignable the points are not well-ordered. One cannot tell about two moments of time which is earlier and which later.

2. This could relate to the corresponding lack of well ordering related to "clock time" associated with self at given level of evolutionary hierarchy defined by the extension of rationals. The increase of "clock time" as a distance between tips of CD for a sequence of small state function reductions (weak measurements) occurs only in statistical sense and "clock time" can also decrease. The moments of time correspond to roots of the real polynomial define "special moments in the life of self", one might say.

   At the limit of infinite-D extension the roots of the polynomial define algebraic numbers forming a dense set in the set of reals. Cognitive representation becomes dense set. These "special moments" need not however become dense.

3. One can raise an interesting question inspired by self inspection. As one types text, it often happen that the letters of the word become in wrong order, change places, and even jump from a word to another one. The experienced order of letters assignable to a sequence of SSFRs is not the same as the order of letters representing the order for the moments of geometric time. When one is tired, the phenomenon is enhanced.

   Neuroscientists can certainly propose an explanation for this. But could this be at deeper level quantum effect based on the above mechanism and have a description in terms of p-adicity assignable to prime p defining a ramified prime for the extension of rationals involved? When one is tired the metabolic resources have petered out and the IQs $n = h_{eff}/h_0$ defined by dimensions of extensions of rationals for the distribution of extensions tend to reduce, cognitive resolution for time becomes lower and mistakes of this kind become worse.

There is a further technical detail involved. For SSFRs the temporal distance between active boundary and passive boundary increases at least in statistical sense. It seems that one must define the inner product in S-matrix elements for the unitary step preceding SSFR using the previous state basis as sub-basis of the new state basis in the case that CD increases. In adiabatic approximation the S-matrix elements would be overlaps for the states with different size of CD and analogous to matrix elements between states of particle in boxes with the same fixed end but different moving end.

BSFRs in ZEO

Details of BSFR are not completely fixed. One can consider two options. Both options must satisfy the condition that the states at passive boundary of CD identified as superpositions of 3-surfaces remain invariant during the sequence of SSFRs. The tangent space-to the space-time surfaces need not however remain invariant. Therefore the classical energies of space-time surfaces can change since the energy densities are proportional to time derivatives of embedding space coordinates.

1. The size of CD increases steadily as was the original proposal and is thus not reduce in BSFRs. The problem with the steady increase seems to be that the size of CD becomes infinite eventually and the state evolves to what looks like cosmology. If the energy assignable with zero energy state is conserved, the energy density of matter inside CD increasing without limit becomes arbitrarily small. Is this a catastrophe?

   For TGD inspired cosmology this is the case at the limit of big bang in the sense that the energy density goes like $1/a^2$ (cosmic string dominance) and energy in a co-moving volume vanishes like a, where a is light-cone proper time. One can think that CD defines only perceptive field and that space-time surfaces continue also outside CD up to the maximal size of CD in the hierarchy of selves involved. The zero energy state would have finite energy energy but density of energy would go to zero at the boundary of CD. The perceptive field of conscious entity would increase steadily in size.

As found, energy need not be conserved in the subsequence SSFRs because Gaussian wave packets of CDs around given size are required so that eigenstates of energy are not in question and the reduction of the width of Gaussian in the sequence of SSFRs implies reduction of average energy. Only the superpositions of 3-surfaces at the passive boundary of CD would be conserved.

Even the conservation of energy combined with the increase of CD need not be a catastrophe. In matter dominated cosmology the conservation of mass takes place with respect to cosmological time which corresponds to the proper time measured as temporal distance from the passive tip of CD. This cosmological mass is not energy but closely relates to it. What looks of course counter-intuitive is that every self would evolve to a cosmology.

2. The size of CD could be also reduced in BFSR [L102]. $M^8 - H$ duality and existence of "braney" solutions encourages to take this option serious. The 6-D brane like entities correspond to $t = constant$ sections for linear M^4 time t. They would represent special moments in the life of self. The exceptional 6-D roots of octonionic polynomials as branes would emerge to the perceptive field conscious entity at these moment. Discontinuity of classical space-time evolution as SSFR. Every time-reversed re-incarnation of self would have have "childhood" and experience increase of CD from some minimal size to maximal size.

   Since the size of CD can be reduced, it could happen that the CD remains stuck below certain maximal size for ever. The associated mental images would continue living in the geometric past of bigger CD associated with self. The sub-CDs in past would represent memories of self. Cosmos in 4-D sense would be full of life. The interpretation of CD as perceptive field allows this. CD could also increase and become even a cosmology! This picture looks attractive from the view point of consciousness.

3. One can however invent an objection against ZEO, one might even speak about paradox.

   (a) Suppose that in biological death I indeed re-incarnate with opposite arrow of time and continue to live towards geometric past. Suppose also that I re-incarnate as more advanced human being - at least in statistical sense. Human beings have parents. But how can I have parents in the former geometric future, if my parents how have already died live in the former geometric past?

   (b) The only solution of the paradox seems to be that the magnetic body (MB) - the boss - does not disappear in the death of biological body (BB). The MBs of my parents continue their existence and in my biological death means their separation in stanard time direction and meeting in the new time direction. They meet, fall in love, and give rise to my birth but all this in opposite time direction.

   This would provide an answer to a long-standing question about whether MBs are preserved in biological death or not. My view has been that biological death is more or less that MB loses interest in my BB and directs attention to something more interesting. One could however argue that also MB is generated in birth and genes code also for it so that it would die. If directing attention corresponds to BSFR MB would continue to exist after biological death. This particular reincarnation - CD - would be like vortex in the flow of time.

   (c) Can one find any support for this crazy looking proposal? TGD Universe is fractal and lower levels in the length scale hierarchies are slaves. In particular, bio-chemical level serves as the slave of MB expected to obey kind of shadow dynamics. If the proposed topological dynamics of MBs solving the above paradox has a miniature representation at the level of DNA, one could take the proposal with some seriousness.

   In meiosis (`http://tinyurl.com/n5eqkdn`) germ cells, whose chromosomes are coctails of paternal and maternal chromoses (PCs and MCs), are formed. In fertilization (`http://tinyurl.com/ngzwhcq`) - in some sense a (time?) reversal of meiosis - pairs of PCs and MCs are formed. The fusion of paternal and maternal germ cells could be indeed seen in topological sense as a time reversal of replication. The replication of soma cells

involves mitosis (http://tinyurl.com/p35lkwr) forming pairs of chromosomes of PCs and MCs.

Could the chromosomal dynamics be a miniature version of the proposed dynamics at the level of MB even at the level of organisms? If so, mitosis at the level of MB would correspond to a loose pairing of paternal and maternal MBs - formation of a relationship. Our personal MBs as analogs of germ cells would be coctails of MBs of PCs and MCs formed by reconnection process.

What about replication? In the case of asexual reproduction (http://tinyurl.com/y8odomtf) one could speak about replication at the level of MB of the entire organism. Also cell - and DNA replication would represent examples of asexual reproduction and in meiosis sexual reproduction of also DNA would take place.

When does BSFR occur? I have imagined several options, which need not exclude each other.

1. Could BSFR occur, when there are no observables at the active boundary commuting with those diagonalized at passive boundary. Measurement of observable at means generation of eigenstate in the extension of rationals and it typically occurs that the resulting state is outside the extension. Could BSFR occur when there are no observables in the extension of rationals in question.

2. $M^8 - H$ duality predicts universal special solutions besides 4-D space-time surfaces. These 6-D analogs of branes correspond to n moments of linear M^4 time, where n is the polynomial whose octonionic continuation defines space-time surfaces in M^4 as roots of its real or imaginary part in quaternionic sense. At these branes 4-D space-time surfaces are glued together along their ends- space-time looks is analogous to piecewise continuous curve in time direction - and they would correspond to "special moments in the life of self" [L102]. When all these moments as special roots of the octonionic polynomial are experienced, BSFR would be the only possibility. The polynomial with rationals coefficients defining the octonionic polynomial defines the extension of rationals used so that this option could be consistent with the first option.

3. Is BSFR is forced to occur because there are no preferred extremals connecting the pairs of 3-surfaces exists anymore. Could it happen that the state becomes increasingly classical during the sequence of SSFRs and thus becoming more and more local in WCW (the "world of classical worlds", which is essentially the space of 3-surfaces at either boundary of CD). The unchanging part of the zero energy state associated with the time-reversed state as outcome of BSFR at the new passive boundary would be maximally classical. This might relate to the fact that the world looks so classical. Also the fact BSFRs themselves look classical smooth time evolution ending to the outcome of BSFR, creates the illusion of classicality [L99].

15.5.2 ZEO, life, and consciousness

The most important implications of ZEO relate to consciousness and quantum biology. One can understand act of free will and motor action in terms of BSFR. BSFR corresponds to motor action and its time-reversal. SSFRs correspond to sensory perception in either direction of time [L86]. Model for memory is one prediction and predicts precognition as time reversal of memory [K101] [L114]. Also the relationship between generation of insight and mechanical logic deductions can be understood. In biology ZEO leads to remote metabolism as a universal purely thermodynamical mechanism of metabolism. One can also understand zero energy states as superpositions of deterministic programs - quantum programs, functions in the sense of quantum biology, or quantum behaviors.

Act of free will, intentionality, and ZEO

Act of free will would correspond to BSFR that is quantum jump leading to final state with opposite arrow of time. Final state is a superposition of deterministic time evolution connecting

the 3-surfaces in the superpositions defining initial and the final states. In this picture state function reduction leads to final state inducing time reversed time evolution so that classically the causal order is changed. What in standard picture - say neural activities - causes the outcome, is caused by the outcome. Could it be that mere volitional act with sharp enough intention is needed? The correct deterministic time evolution is dictated by intention as consequence rather than cause!

Here I cannot avoid the temptation to tell about my own strange experiences. At this age one must remember to take the pills every morning. I have the habit of filling my pill dispenser every Monday morning. I do not bother to count the pills one by one. I just take randomly a bunch of them hoping that their number is correct. And it is! Quite too often! Similar thing happens in market when I pay with coins: I do not count the coins but just take a handful of them. The sum of the coins is correct quite too often! Could a mere sharp intention dictate the outcome. Could one learn gradually this kind of sharp intentions.

Could this be crucial for various skills like playing tennis or computer game, where one simply cannot react rapidly by computing the outcome since time does not allow it? Could this explain also mathematical/physical/.. intuition as skill to solve problems by making quantum jump directly to the solution of the problem.

Precognition and ZEO

It seems that neuroscientists are beginning to take remote mental interactions such as precognition, telepathy, and psychokinesis seriously. The popular article entitled "*Scientists Discover That The Heart & Brain Respond To Future Events – Before They Happen*" (see `http://preview.tinyurl.com/y494hw5u`) describes changing views of neuroscientists towards precognition.

In ZEO precognitions are naturally time-reversed memories. Classical signals giving rise to sensory experience arrive from geometry future in the standard frame. During sleep state precognition should be possible if sleep corresponds to time-reversed state for the self.

In the associative and computational models of brain our ability to predict the future is taken to be an extrapolation based on memories and experience of earlier life. This looks very reasonable but when one asks how these memories are represented, problems begin to appear. In TGD framework ZEO predicts that memories correspond to mental images in geometric past, in the simplest case, when the original event took place. This solves a huge problem of standard since memory storage becomes brain in 4-D sense rather than in 3-D sense [K101].

ZEO however implies that also time reversed memories are possible. If sleep state correspond to time reversed self about which we do not have direct memories, memories with reversed arrow of time would be possible in this state. Precognition becomes possible if these memories can be communicated to the wake-up state with the ordinary arrow of time. In dreams some parts of brain are awake and they could make possible this communication. The communicated information could be also conscious to some selves above or below us in the hierarchy. Dreams can indeed predict what happens during the next day. The classical book "*An Experiment with Time* " (see `http://tinyurl.com/jtqysty`) of J. W. Dunne tells about precognitive dreams that he experienced.

Intuitive and formal logical reasoning in ZEO

The basic vision is that adelic space-time geometry provides correlates for sensory experience and cognition/imagination. Fermionic degrees of freedom would represent quantal Boolean mind. In ZEO given deterministic time evolution for 3-surface and induced spinor fields would give rise to sensory and cognitive time evolution and to Boolean evolution having interpretation as analog of logical deduction leading from premises to conclusions.

1. The basis of fermionic Fock states can be regarded as Boolean algebra. Superpositions and thus entanglement of fermionic qubits are however possible and one can speak about quantum Boolean logic. In standard view concepts are formally regarded as sets containing the instances of concept as elements. Quantum concepts could be superposition of quantum states representing the instances so that quantum abstraction would be much more complex notion than ordinary abstraction. Non-classical Boolean states would be superpositions of statements identifiable as abstractions. Schrödinger cat would be seen abstraction. "Dead" and "alive" would represent instances of this abstraction.

2. Zero energy states are superpositions of initial and final fermion states and there is also a superposition over 3-surfaces, and could be interpreted as representations for implications. The sum $\sum_n S_{mn}|n\rangle$, where S denotes unitary S-matrix, represents a superposition over all transitions $|m\rangle \to |n\rangle$ allowed by laws of physics. These transitions could be interpreted as logical implications.

   One could argue that by diagonalizing S-matrix one obtains only diagonal transitions and the situation is rather trivial: just logical identities. The point is however that in number theoretical physics the diagonalization of S would in general lead outside the extension of rationals determining the adele and is therefore not possible. Same number theoretical mechanism would also stabilize negentropic entanglement and could force BSFR. Only state big state function reduction extending the extension of rationals can reduce this kind of entanglement.

3. Probably every mathematician has pondered the mystery of mathematical insight. How for instance mathematical insight is generated? What eureka experience is basically? Insight would correspond naturally to a big state function reduction leading to a new state reversing the arrow of time.

   Truth can be deduced in given system of axioms also mechanically - at least in principle. How does insight relate to a logical deduction leading to a theorem? The final state of quantum jump is superposition of classical time evolutions leading from the final state to geometric past. With respect to standard arrow of time it is superposition of logical deductions leading from various initial states- initial assumptions - to the final state - to the outcome of the deduction. Superposition of states at boundary of CD could be seen as an abstraction. Deterministic time evolutions would represent the mechanical deductions.

   Note however that in the time reversed state arbitrary long time evolution in opposite time direction is in principle possible and would correspond to an arbitrary long ordinary deduction or computation [L49]. After that a return to the original arrow of time would take place and provide the solution. The formal deduction leading to the outcome would be indeed forced by the outcome rather than vice versa?

Metabolism in ZEO

ZEO has also deep implications for biology. As already explained, ZEO allows to understand what behaviors, biological functions are at fundamental level.

Why metabolism is needed can be understood in TGD view about dark matter as phases of ordinary matter labelled by the value of effective Planck constant $h_{eff} = n \times h_0$, where n has also interpretation as dimension of extension of rationals giving rise to the extension of adeles [L70, L69]. n serves as a kind of IQ labelling different evolutionary levels and is bound to increase in statistical sense. Not only biology but also self-organization involving also energy feed could be understand in terms of the hierarchy of Planck constant.

In ZEO remote metabolism suggests itself as a completely universal purely thermodynamical mechanism of metabolism. Usually system loses its energy by dissipation. If the arrow of time is non-standard, systems seems to receive energy from environment. Note that the duration of time spent in time reversed state does not matter! What matters is the increment of time between states with same arrow of time! Sleep state could be seen also as a way to collect metabolic energy. BSFR can be seen as an act of free will - motor action and sucking of metabolic energy from "environment" would be very natural.

The interpretation for the return to the original time direction by second BSFR would be as beginning of sensory perceptions in standard arrow of time as sequences of SSFRs. During this period subsystem would be dissipating energy to environment.

15.5.3 Under what conditions does BSFR take place and what happens in it?

In the following the question under what conditions "Big" state function reduction (BSFR) takes place and what happens in it.

Two kinds of state function reductions

The discussion however requires the basic ideas of ZEO as background.

1. "Small" state function reductions (SSFRs)

Small state function reductions (SSFRs) are counterparts of so called "weak measurements", which are rather near to classical measurements in the sense that nothing drastic happens.

1. The passive boundary of CD does not shift but changes in size because active boundary shifts and this induces change of size. For state pairs defining zero energy states the members at passive boundary do not change and the coefficients of possibly time-entangled state defined as their superposition do not change. The members of state pairs at active boundary change and this change is induced by unitary time evolution between too SSFRs. This time evolution could be regarded as a generalization of adiabatic time evolution.

2. In statistical sense the active boundary shifts towards future and the size of CD increases. The temporal distance between the tips defines clock time in one-one correspondence with SSFRs. Note that the unitary evolution forms a superposition of CDs with different sizes and SSFR means localization to single CD size.

3. The moment "Now" of self would naturally correspond to the M^4 hyper-plane dividing CD into two pieces of identical size. The radius of this 3-ball would be $r = T/2$, where T is the temporal distance between the tips of CD. At this hyperplane expansion of 3-ball with light-velocity would transform to contraction.

4. The mental images of self would correspond sub-CDs and also they would shifts towards geometric future in the sequence SSFRs. They would form a kind of log file about the life history of self such that geometric time order would be opposite to subjective time order. Self could remember these experiences by sending signals to geometric future reflecting back in time direction - seeing in time direction would be in question.

   What is in sharp conflict with natural expectation is that the memories would be stored in geometric future and part of them would become un-changing permanent part for the time reversed re-incarnation of self- kind of Karma.

   Note however that self might have also mental images represented as sub-CDs in geometric past.

$M^8 - H$-duality suggests space-time picture about the "log files".

1. 4-D space-time surfaces in complexified M^8 having interpretation as complexified octonions are 4-D roots for octonion valued polynomial obtained as an algebraic continuation of a real polynomial with rational or even algebraic coefficients. $M^8 - H$ correspondence maps thee surfaces to minimal surfaces with 2-D singularities in H [L103, L102].

2. Besides this one obtains for any polynomial also special solutions as analogs of branes in M-theory. They have topology of 6-D ball and their projection to M^4 is $t = r_n$ hyperplane intersecting CD and with topology of 3-ball. r_n is a root of P and thus an algebraic number. I have called $t = r_n$ "very special moments in the life of self". Generalized vertices for particle reactions would correspond to partonic 2-surfaces localized at these 6-surfaces. At these surfaces incoming and outgoing partonic orbits would be glued together along their ends. The roots define positions of external particles at the boundaries of CD.

3. In SSFRs these balls at the active half of CD would shift towards future and new roots would emerge. These roots wold define a geometric representation of the memories of CD as "log file" increasing in size. If there are sub-CDs associate with them, one would have mental images shifting towards future.

2. "Big" state function reductions (BSFRs)

"Big" state function reductions (BSFRs) correspond to ordinary state function reductions (SFRs) in ZEO. In BSFR the roles of active and passive boundaries of CD are changed and the

arrow of geometric time changes since the formerly passive boundary starts to shift to opposite time direction. State function reduction not commuting with the observables defining states at passive boundary as their eigenstates would takes place and the state at passive boundary would be changed. It would be however fixed by quantum dynamics. The findings of Minev *et al* provide support for the change of the arrow of time in ordinary SFR [L99].

The passive boundary can be shifted towards future so that the size of CD would decrease. One can say that the re-incarnate would be experience childhood. Note that also part of the "log file" about often personal experiences of self towards end of its life defining the permanent part of self-hood of the re-incarnate would disappear. The interpretation in terms of Karma is suggestive.

Remark: During a discussion with Marko Manninen, Marko noticed that people who have had near death experience often report that they experienced their entire life like a film during these moments. Could the "log file" representing stored mental images give rise to this experience at the moment of death?

What happens in biological death from TGD perspective?

What happens in biological death can be taken as a guideline in attempts to understand what happens in BSFR.

1. Death certainly occurs if there is no metabolic energy feed to the system. Metabolic energy feed is guaranteed by nutrition using basic molecules as metabolites. Since the increase of h_{eff} quite generally requires energy if other parameters are kept constant and since the reduction of h_{eff} can take spontaneously, the metabolic energy is needed to keep the distribution of values of h_{eff} stationary or even increase it - at least during the growth of organism and perhaps also during the mature age when it would go to increase of h_{eff} at MB.

   If the size of CD for at least MB correlates with the maximum value of h_{eff} or its average, the size of CD cannot grow and can be even reduced if the metabolic energy feed is too low. The starving organism withers and its mental abilities are reduced. This could correspond to the reduction of maximum/average value of h_{eff} and also size of CD.

   One can argue that if the organism loses metabolic energy feed or is not able to utilize the metabolic energy death and therefore also BSFR must take place.

2. In ZEO self-organization reduces to the second law in reversed direction of geometric time at the level of MB inducing effective change of arrow of time at the level of biological body [L104]. The necessary energy feed correspond to dissipation of energy in opposite time direction. In biological matter energy feed means its extraction from the metabolites fed to the system. One could say that system sends negative energy to the systems able to receive it. A more precise statement is that time reversed subs-system dissipates and metabolites receive the energy but in reversed time direction.

   In living matter sub-systems with non-standard arrow of time are necessary since their dissipation is needed to extract metabolic energy. The highest level dissipates in standard time direction and there must be a transfer of energy between different levels. This hierarchy of levels with opposite arrows of geometric time would be realized at the level of MB.

Death as a re-incarnation with opposite arrow of time

These observations suggest that one should consider the reincarnation with opposite arrow of time with wisdom coming from the death of biological systems.

1. We know what happens in death and birth in biological systems. What happens in biological death should have analogy at general level. In particular, in death the decay of the system to components should occur. Also the opposite of this process with reversed arrow of time should take place and lead at molecular level to the replication of DNA and RNA and build-up of basic biomolecules and at the cell level to cell replications and development of organs. How these processes could correspond to each other?

2. The perceived time corresponds to the hyperplane $t = T/2$ dividing CD to parts of same size. Here T is the distance between the tips of CD and therefore to maximal diameter of

temporal slice of cd, which is 3-ball. The part of CD above it shifts towards future in SSFRs. In BSFR parts of the boundary of space-time surfaces at the active boundary of CD become unchanging permanent parts of the re-incarnate - kind of log file about the previous life. One can say that the law of Karma is realized.

If CD decreases in size in BSFR the former active boundary keeps its position but its size as distance between its tips is scaled down: $T \to T_1 \leq T$. The re-incarnate would start from childhood at $T - T_1/2$ and would get partially rid of the permanent part of unchanging self-hood corresponding to interval $[T - T_1/2, T/2]$ so that the permanent part of reincarnate would correspond to $[T - T_1/2, T]$. Reincarnate would start almost from scratch, so to say. The part between $T - T_1/2$ and T would be preserved as analog of what was called BIOS in personal computers.

3. At the moment of birth CD possibly would thus decrease in size and the former passive boundary now in the range $[T - T_1/2, T - T_1]$ and lower tip of new CD at $T - T_1$ would become active and the seat of sensory experience. Arrow of time would change. Where the analog of biological decay is located? The region of CD in the range $[T/2, T - T_1/2]$ disappearing from "log file" is the natural candidate. This region is also the place, where the events related to birth in opposite time direction should take place.

4. The decay of the organism should therefore correspond to the development and birth of re-incarnated organism at the level of MB (it must be also remembered that genuine time reversal takes place at the level of MB and induces only effective time reversal at the level of ordinary bio-matter). The decay of organism dissipates energy in standard time direction: this energy could used by the re-incarnate as metabolic energy. How long lasting biochemical processes have effective time reversals depends on the quantum coherence scale determined by the size scale of corresponding CD.

Could the re-incarnations with opposite arrow of time be seen in bio-chemistry?

The possible occurrence of effective time reversals at the level of bio-chemistry could be perhaps tested experimentally.

1. Could the replication of DNA and RNA and build-up of various bio-molecules be effective time-reversals for their decays. Could the same apply to the replication of cells and generation of organs. Replication of DNA is self-organization process in which second DNA strand serves as a template for a new one. The decay of DNA should therefore involve two DNA strands such that the second DNA strand serves as a template for the effectively time reversed replication. The double strand structure indeed makes possible for the other strand to decay first. Cell replication should use another cell as replicate and same would happen in the cell decay.

2. An interesting mental exercise is to imagine the time reversals of various basic processes like transcription and translation. In the time reversal of translation of mRNA to amino-acid sequence the amino-acid sequence and mRNA would return to ribosome machinery, and amino-acid and tRNA codon associated with tRNA would return to form tRNA. mRNA strand would shift one step backwards and the process would repeat itself and finally mRNA strand would return to open DNA strand. In the time reversal of transcription of DNA to mRNA, mRNA strand would return to open part of DNA strand, decay to RNA codons and eventually DNA strand would close. It should be easy to check whether these processes really occur in the decay process.

3. The formation of stem cells involves de-differentiation. Could it mean time reversal of the entire process leading to a differentiated cell? Also this idea could be tested.

In biology pairs of various structures often occur. Could they correspond in some sense to effective time reversals of each other whereas at the level of magnetic body one would have genuine time reversals

1. Could the opposite inherent chiralities of MBs of DNA strands correspond to opposite arrows of time at the level of MB of DNA realizing dark genetic code [L42]? Could this be seen as a kind of explanation for the double strand structure of DNA. Could the passivity of DNA strand with respect to transcription correspond to opposite arrow of time at the level of MB? Could the passive strand become active in time reversal?

2. Even brain has this kind of pairing. Right brain hemisphere is passive in the sense that it does not seem to contribute to wake-up intelligence (presumably identified as analytic intelligence). Could either hemisphere serve as a template in the development of brain or could this happen only at the level of MB of brain? Could different time arrows at the level of MB be used to understand the strange passive character of right brain and could one one understand the holism of right brain *viz.* analytic reductionism of left brain as reflection of the fact that dissipation as decay corresponds to time reversal for self-organization generating structures at the level of MB.

What about ordinary re-incarnation?

A couple of comments relating to the notion of re-incarnation in standard sense are in order.

1. Eastern philosophies talk about the possibility of liberation from Karma's cycle. Can one imagine something like this? The above picture would suggest that in this kind of process the reduction of the size of CD does not occur at all and therefore there would be no decay process equivalent to the growth of time reversed organism. This would serve as an empirical signature for the liberation - if possible at all. CD would continue to increase in size or perhaps keep its size. It would seem that a new kind of non-biological source of metabolic energy would be needed.

2. Reincarnation is a basic notion in Eastern philosophies. In ordinary reincarnation person has memories about life of a person, who lived earlier. There is evidence for this. This cannot be understood in terms of time reversed re-incarnation.

   Recall that there would be a hierarchy of selves and corresponding CDs within CDs. It has remained an open question whether CDs could also overlap? Could re-incarnation in ordinary sense be explained in terms of this kind of overlap?

   Suppose that one has two overlapping CDs: CD_1 and CD_2 and that CD_2 extends farther to the future of CD_1. The sub-CDs of CD_1 shift to future as the active part of CD_1 shifts to future and increases in size giving rise to a kind of log file defining the personal memories of CD_1. In this kind of situation the mental images of CD_1 can enter to CD_2 and become mental images of CD_2. This would be sharing of mental images but in different sense as compared to the fusion of mental images by entanglement, which could also require intersection of sub-CDs of mental images.

   Could one imagine that the cosmos is full of selves serving as counterparts of memes wandering around and finding for selves hosting them by providing metabolic energy? Note that ZEO means that CD center of mass degrees of freedom do not carry any conserved quantum numbers so that the motion of these lonely CDs would not be restricted by conservation laws!

3. This picture suggests that CD:s form a conscious fractal atlas consisting of charts with various resolutions analogous to the atlas defining a covering of manifold by open sets. The earlier proposal was that in biological death MB redirects its attention to a new system. This picture would be modified: the MB of of CD_1 would still attend the time-reversed system and experience time-reversed life. Some sub-CDs of CD_1 would however belong to a new CD in its geometric future - CD_2. This conforms with the intuitive expectation that space-time surfaces continue outside CD and only the perceptive field of conscious entity is restricted to CD.

4. Mental images should correspond to sub-selves and therefore sub-CDs of CD. Contrary to what I have proposed earlier, it seems that after images cannot correspond to BSFR type re-incarnations of mental images nor re-incarnations in standard sense.

Mental images would shift towards the future together with active part of CD and form a kind of log file. Could after images be memories of previous mental images involving a signal time reflect from the the mental image in log file and creating the after image as a sensory memory of the earlier visual mental image? Or could one understand after images in terms of propagation of dark photon signals along closed magnetic loops giving rise to periodically occurring mental images.

In [L130] I discussed how the evolution of self by BSFRs could correspond to a transition to chaos as iteration of the polynomial defining the space-time surface. The proposed picture was that the evolution by SSFRs corresponds to iteration of a polynomial P assignable to the active boundary of CD. This would predict a continual increase of the degree of the polynomial involved. This is however only one possibility to interpret the evolution of self as iteration leading to chaos.

1. One could argue that the polynomial $P_{nk} = P_n \circ .... \circ P_n$ associated with the active boundary remains the same during SSFRs as long as possible. This because the increase of degree from nk to $n(k+1)$ in $P_{nk} \to P_{nk} \circ P_n$ increases h_{eff} by factor $(k+1)/k$ so that the metabolic feed needed to preserve the value of h_{eff} increases.

   Rather, when all roots of the polynomials P assignable to the active boundary of CD are revealed in the gradual increase of CD preserving P_{nk}, the transition $P_{nk} \to P_{nk} \circ P_n$ could occur provided the metabolic resources allow this. Otherwise BSFR occurs and self dies and re-incarnates. The idea that BSFR occurs when metabolic resources are not available is very natural for this option.

2. Could $P_{nk} \to P_{nk} \circ P_n$occur only in BSFRs so that the degree n of P would be preserved during single life cycle of self - that n can increase only in BSFRs was indeed the original guess.

While preparing this contribution I learned about a highly interesting claim (`https://tinyurl.com/yap8ss4p`) made by the research group led by Harold Katcher. The claim is that the epigenetic age (there are several measures for it such as methylation level of DNA) of rats has been reduced up to 50 percent. The theory goes that epigenetic age of molecules would be controllable by hormonal signalling globally.

BSFR would mean death of conscious entity and its reincarnation with opposite arrow of time. The system would rejuvenate in the transition starting a new life in opposite time direction from childhood so to say - rejuvenation would be in question. Doing this twice would lead to life with original arrow of time but starting in rejuvenated state. The claim of the group suggests that living matter could do this systematically using hormonal control.

Tukdam and TGD

This piece of text was inspired by a document (`https://rb.gy/abt8za`) about a strange phenomenon known as Tukdam. What happens is that in Tukdam the person is physically dead but is believe to be in a continued meditation. There is no EEG, the heart does not beat, and there is no normal metabolism. However, the decomposition processes do not start. The condition can last up to a couple of weeks. Similar longer-lasting ones have been reported: a yogi can be buried underground for months in an oxygen-free state and then wake up.

This challenges neuroscience's view of the brain as the seat of consciousness. According to reports there could be awareness and a sensory experience consisting of different light sensations. The Tibetan Book of the Dead describes these experiences. Near-death experiences have many similar features [L152].

In the body in Tukdam, the area of the heart is reported to feel warmer to the touch than the rest of the body, but the thermometer does not detect this difference. This would indicate that the body receives metabolic energy at the cellular level from some other source than in the normal metabolism, and that living matter can detect what measuring devices based on the recent knowledge provided by modern physics cannot detect. Where could this energy come from? If one wants to answer this, one must also ask what happens in death and what is consciousness and what is life.

1. Dark energy and matter are the two basic puzzles of recent day physics. In the TGD approach, I have identified dark matter as a phase of ordinary matter, for which the effective Planck constant h_{eff} is much larger than normally.

   In particular, the gravitational Planck constant $h_{eff} = h_{gr}$ assignable to gravitational flux tubes can be very large and makes quantum coherence possible even on astrophysical scales. Large Planck constants would be associated with the dark matter magnetic body, which would be the TGD counterpart to the magnetic field of Maxwell's theory, but would differ from it in many respects. As a quantum coherent unit, this magnetic body would control the ordinary biological body and induce its coherence. The classical energy of a magnetic body, consisting of volume energy and magnetic energy, would be dark energy.

2. In the TGD Universe dominated by zero energy ontology, consciousness is a universal phenomenon and present on all scales, from elementary particles to the level of the cosmos. Even galaxies, stars and planets would be conscious beings. Also life and death would be universal phenomena. Likewise, the biological decomposition process associated with death would correspond to the universal decomposition process, which would essentially correspond to the decomposition of magnetic monopole flux tubes (magnetic catabolism), which would induce the catabolism of the breakdown of biomolecules. Its time-reversed version would be magnetic anabolism and induce the building of bio-structures such as molecules.

3. The fundamental metabolic processes would be essentially magnetic anabolism and catabolism induced by "big" state function reductions (BSFRs) changing the arrow of time and inducing the biological anabolism and catabolism. Death would mean reincarnation with the opposite arrow of time.

In Tukdam, the biological body would be dead, but the magnetic body would still be alive and prevent the biological decay from starting. The disintegration of the magnetic body would start in Tukdam much later than normally, and initiate the disintegration of the biological body. The content of the conscious experience in Tukdam, light sensations and deep peace, would come from the magnetic body. The dead biological body would not provide contribution from sensory input, motor activity, and cognition.

By a strange accident, just before seeing the document about Tukdam, I wrote an article [L174, L179] about a seemingly completely unrelated topic, solar flares related to the reversal of the direction of the sun's magnetic field in the solar cycle, which has a period of 11+11 years.

The reversal of the Sun's magnetic field would correspond to magnetic catabolism as the breakdown of long monopole flux tubes into very short parts. It would be followed by magnetic anabolism as their re-fusion into long flux tubes. The solar cycle would correspond to the sleep-wake cycle, or more precisely: a series of lives in different directions of time. Death would only be a change of time's arrow, nothing final.

The model unexpectedly leads to a biological analogy and to understanding what might happen to the magnetic body in biological death.

15.5.4 Conditions on the periods with reversed arrow of time

In zero energy ontology (ZEO) falling asleep (death at"my" level of self the hierarchy) corresponds to ordinary - or "big" - state function reduction (BSFR) and also means a reincarnation with opposite arrow of time. We would be therefore conscious during sleep and wake-up would correspond to falling sleep of that other, time reversed self.

When I fall asleep, I wake-up later tomorrow morning for instance, not yesterday morning. It is interesting to see what kind of conditions this implies and whether it is possible to satisfy this easily and even more interesting is to see whether a time travel to the geometric past - maybe the Golden Youth - could be possible.

The following assumptions are made about what happens in BSFR.

1. Causal diamond (CD) is a correlate for self. CD is obtained by gluing together two identical half-cones along their bottoms. Moment "Now" corresponds to the largest hyperplane $T_{now} = T$ (origin of time coordinate is at either (call it "lower") tip of CD) .

2. During the sequence of SSFRs defining self, the 3-surfaces at the passive boundary of self are fixed although their 4-D tangent space changes and corresponds to the unchanging part of selfhood - soul one might say. The opposite active boundary of CD and 3-surfaces at it change and shift towards geometric future.This gives rise to wake-up consciousness involving sensory input and thoughts, emotions etc. induced by it. Each SSFR is preceded by the analog of unitary time evolution.

3. BSFR means a death of self (subself) and its reincarnation with an opposite arrow of time. One can equally well speak about the analog of falling in sleep and waking up after that for some level of hierarchy of selves. The self born in the death of the self with an opposite arrow of time self has no direct memories about the state. Self can however have memories about dreams in which part of say brain is awake. These memories store information about what self experienced during the sleep.

   In BSFR the active boundary of the CD becomes passive and is frozen. The size of CD is scaled down so that CD becomes small: this implies that the reincarnated self has a childhood and much of the memories - often not pleasant - stored near the active boundary as subselves living forth and back as conscious entities disappear. The surviving memories of self become "silent wisdom" of the reincarnated self.

4. If CD belongs to a larger CD, call it CD_{super} representing a larger unit of consciousness, the sub-CDs must shift to the same direction as the active boundary of CD_{super}. Otherwise the sub-CDs would drop from the flow of consciousness. This is analogous to co-movement of matter in cosmology.

   Note that the mental images of self correspond to sub-CDs around T_{now} and shift towards geometric future as CD increases and new mental images emerges at T_{now} plane: by $M^8 - H$ correspondence these special moments in the life of self correspond to roots of the polynomial defining space-time surface and reside are the upper half-cone of the CD. As CD increases, new roots pop up inside the upper half-cone near the T_{now} hyper-plane for some particular SSFRs. Completely counterintuitively, the mental images about past experiences are therefore in the geometric future of T_{now} hyperplane!

The proposed picture must be consistent with everyday experience. Call the two periods of self sleep wake-up and sleep label the two different BSFRs by "sleep" and "wake-up".

1. In each SSFR CD size increases - at least in statistical sense this implies that T grows. Each SSFR corresponds to a scaling for the CD shifting its active boundary towards the geometric future. During its life cycle CD experiences scaling Λ:

$$T_{now} \to T_{now,sleep_1} = \Lambda(SSFR) T_{now} \quad , \quad \Lambda(SSFR) > 1 \quad .$$

2. When the system falls in sleep the size of CD is scaled down so that also the value of T_{now} is scaled down by $\Lambda_{BSFR} < 1$:

$$T_{now,sleep_2} = (1-\Lambda(BSFR))2T_{now,sleep_1} = (1-\Lambda(BSFR))\Lambda(SSFR)2T_{now} \quad , \quad \Lambda(BSFR) < 1 \quad .$$

   After that the CD begins to increase in size by small scalings in SSFRs to opposite time direction and T_{now} begins to decrease from its value $T_{now,sleep}$ begins to decrease.

3. If CD belongs to a bigger CD - call it super-CD - representing a larger unit of consciousness with a longer life cycle, one can argue that the CD must shift to the same direction as the larger CD increases. Otherwise the CD would drop from the flow of consciousness defined by super-CD. This is analogous to co-movement of matter in cosmology. Therefore a given life cycle corresponds also a shift ΔT of sub-CDs towards the growth direction of super-CD takes place and one has for the time coordinate $T_{super,now}$ of the super-CD. Therefore one must perform shift$T \to T + \Delta T$ for $T_{now,sleep_1}$ and $T_{now,sleep_2}$ to take into account the drifting. This gives for the moments "Now" before ad after the shrinking of CD in BSFR (falling asleep):

$$T_{super,now,sleep_1} = T_0 + T_{now,sleep_1} + \Delta T \ ,$$

$$T_{super,now,sleep_2} = T_0 + (1 - \Lambda(BSFR))2T_{now,sleep_1} + \Delta T \ .$$

4. Similar formula holds true for the moment of wake-up. In the previous formula T_{now} is replaced with $T_{now,sleep_2}$ and one has

$$T_{super,now,wakeup_1} = T_0 + \Lambda^{1)}(SSFR)T_{now,sleep_2} + \Delta T^{1)} \ ,$$

$$T_{super,now,wakeup_2} = T_0 + (1 - \Lambda^{1)}(BSFR))\Lambda^{1)}(SSFR)2T_{now,sleep_2} + \Delta T^{1)} \ .$$

The parameter T_0 depends on the choice of the origin of time for super-CD but is irrelevant.

One can deduce a consistency condition for the parameters of the model.

1. During the sleep period the time coordinate $T_{super,now}$ for moment "Now" in the coordinates of larger CD changes in the following manner:

$$T_{super,now,sleep} = T_0 + T_{now,sleep_1} \to T_{super,now,wakeup}$$

$$= T_0 + \Lambda^{1)}(BSFR)T_{super,now,sleep_2} + \Delta T^{1)} \ .$$

T_0 is an irrelevant parameter associated with super-CD. Note that there is breaking of time reversal symmetry since self associated with CD_{super} has fixed arrow of time unlike CD. Hence ΔT has at least in a statistical sense the same sign irrespective of the arrow of time of self.

2. This picture should be consistent with what we observe. When the tired average self fall a sleep at the evening, it wakes wake-up at the morning and is full of energy. Quite generally, wake-up occurs after time $\Delta T(sleep)$ meaning that the value of time T_{super} has increased by

$$T_{super,now,wakeup} = T_{super,now}(sleep_1) + \Delta T(sleep) \ .$$

These two expressions for the value of $T_{super,now}(wakeup)$ must be consistent and this gives a conditions on the parameters involved:

$$(1 - \Lambda^{1)}(BSFR))\Lambda^{1)}(SSFR)2T_{now,sleep_1} + \Delta T^{1)}$$

$$= T_{now,sleep_1} + \Delta T + \Delta T(sleep) \ .$$

$\Delta T(sleep)$ is given by

$$\Delta T(sleep) = [(1 - \Lambda^{1)}(BSFR))\Lambda^{1)}(SSFR)2 - 1]T_{now,sleep_1} + \Delta T^{1)} - \Delta T \ .$$

Intuitively it seems clear that for a given arrow of time it is not possible to wake-up before one falls asleep, and the condition $\Delta T(sleep) > 0$ for the standard arrow of time gives a constraint on the parameters. One cannot however exclude the possibility of time travel without dying or falling asleep first of the duration of time travel is much longer than that of wave-up period: $\Delta T^{1)} - \Delta T$.

A special solution corresponds to $\Delta T(sleep) = \Delta T^{1)} - \Delta T$ and $(1 - \Lambda^{1)}(BSFR))2\Lambda^{1)}(SSFR) = 1$ giving $T_{now,sleep_2} = T_{now}$.

15.6 Some questions concerning zero energy ontology

Zero energy ontology (ZEO) [L108] gives rise to quantum measurement theory, which naturally extends to a theory of consciousness. In this article also consciousness aspect is central and my sincere hope is that it would not expel those physicist readers for whom consciousness still remains an unscientific notion.

Zero energy ontology (ZEO) briefly

ZEO provides a new ontology solving the key problem of the standard quantum measurement theory and quantum theory itself. It must be emphasized that ZEO is not a new interpretation created to put under the rug the logical paradox due to the conflict between non-determinism of state function reduction (SFR) and the determinism of unitary time evolution. Also the problem about the scale in which quantum world becomes classical disappers: the Universe is quantal im all scales and ZEO view about quantum jump makes the Universe to look like classical.

1. At the level of space-time dynamics, the notion of preferred extremal (PE) as a space-time surface is central: PE is an extremal of an action principle, which by general coordinate invariance must be highly unique once its intersection with either boundary of causal CD $= cd \times CP_2$ (cd is the intersection of future and past directed light-cones of M^4) is given. In the ideal situation this implies holography. Space-time surface is an analog of Bohr orbit and classical theory is an exact part of quantum theory.

   There is probably a finite and discrete non-determinism analogous to that associated with soap films spanned by a frame: space-time is indeed a minimal surface as also soap films, and the 3-surfaces at its ends at boundaries of CD are part of the frame. Besides space-time surface is an extermal for Kähler action analogous to Maxwell action. The challenge is to interpret this finite non-determinism.

2. Quantum states, which I call zero energy states, can be interpreted as pairs of analogs of ordinary 3-D quantum states with positive energy. The members of the pair are at the opposite boundaries of CD. The convenient convention used also in quantum field theories (QFTs) is that the conserved quantum numbers at opposite boundaries sum up to zero classically: this brings in nothing new. At quantum level, 4-momenta are conserved only at the limit when CD has infinite size whereas classically the conservation holds true for all CD sizes: this reflects the Uncertainty Principle [L159]. Also in QFTs exact momentum conservation is obtained only at the limit of infinite quantization volume.

   At the space-time level, zero energy states can be regarded also as superpositions of deterministic time evolutions: this is central for the interpretation.

3. SFRs are quantum jumps between zero energy states. SFR does not affect any deterministic time evolution but only replaces their superposition with a new one. This solves the paradox that was one of the key motivations for ZEO.

4. Zeno effect strongly suggests that there are 2 kinds of quantum measurements assignable to SFRs. For "weak measurements", "small" SFRs (SSFRs), the component of zero energy state at the either boundary of CD, to be called passive boundary (PB), is unaffected. Also the PB is unaffected apart from scaling. At the active boundary (AP) state changes and AP is scaled up (at least in statistical sense) and due to the scaling shifts to the geometric future.

   The unitary time evolution preceding each SSFR corresponds to a scaling of CD (or rather, its M^4 projection cd) rather than time translation as its counterpart in string models. In A unitary evolution B between two SSFRs a superposition of CDs with varying sizes is formed and SFR localizes CD to a fixed size, which means the measurement of geometric time identifiable as the distance between the tips of CD. This geometric time correlates with the subjective time defined by the sequences of SSFRs. Subjective and geometric times are not identical as in standard ontology but only correlated.

5. "Big" SFRs (BSFRs) are the counterparts of ordinary quantum measurements. In the BSFR the roles of AB and PB of CD change so that the arrow of time changes since CD increases in the opposite direction of time (at least in statistical sense). For an observer with an opposite arrow of time, BSFR looks like an average deterministic time evolution leading to the final state of BSFR as observed experimentally by Minev *et al* [L99] [L99]. This illusion makes BSFR look classical in all scales although the TGD based dynamics is quantal in all scales due to the hierarchy of Planck constants predicted by TGD.

   The possibility of time reversal forces a generalization of thermodynamics to allow both arrows of time: this kind of generalization was proposed long ago by Fantappie [J121] with

motivation coming from biology. Quite generally, self-organization processes seem to violate the arrow of time. External energy feed explains this partially but BSFR would be an important additional element of self-organization [L104, L157], especially so in living matter.

The assignment of "free will" to BSFR allows us to understand how free will can be consistent with the classical non-determinism of physics which would be exact.

ZEO based quantum measurement theory and therefore also physics naturally extends to a theory of consciousness, and one cannot avoid using this word, which is still a cursed word in the physicalistic camp.

Problems related to the mathematical realization of ZEO

There are several open questions related to ZEO and TGD inspired theory of consciousness and the existing view involves several working hypothesis which should be reduced to deeper principles or shown to be wrong.

At least the following questions related to physical interpretation of ZEO are still waiting for a detailed answer.

1. Preferred extremal (PE) property of space-time surfaces is central for quantum TGD [L133]. It follows from holography forced by general coordinate invariance (GCI), which however need not be ideal. How uniquely does the PE property of the space-time surface fix the space-time surface inside a given CD? The simplest situation is that the data at the end of the space-time surface at either boundary of the CD,fixes it completely. Space-time surface would be an analog of Bohr orbit.

   Full determinism would imply that WCW for CD effectively reduces to the space of 3-surfaces assignable to either end of CD. The dynamics of SSFRs would reduces to that in fermionic degrees of freedom assignable to Boolean cognition since WCW degrees of freedom assignable to sensory perception would be fixed.

   However, the dynamics of soap films spanned by frames suggests that this is not the case. The 3-D ends of the space-time surface define a frame and also dynamically generated portions of frame are allowed by the variational principle defined by the sum of a volume term and Kähler action as an analog of Maxwell action. The coefficient of the volume term has an interpretation in terms of a length scale dependent cosmological constant Λ.

   Outside the frame space-time surface would be at least for a very large portion of extremals an analog of complex surface and therefore a minimal surface [L162] and also an extremal of Kähler action. At the frames only the equations for the entire action (sum of volume term and Kähler action) would be satisfied. The divergences of the conserved isometry currents for the volume term and Kähler action would have delta function type singularities but they would cancel each other. The portions of the frame could be analogous to singularities of analytic functions such as cuts and poles.

2. Number theoretic universality [L70, L69] in turn suggests that the inherent non-determinism of p-adic differential equations [K81] [L108] proposed to be a correlate of imagination could also relate to this non-determinism. How do the non-determinism of space-time surface, p-adic non-determinism, and non-determinism of the state function reduction relate to each other: could they be even one and the same thing?

ZEO based quantum measurement theory defines a theory of consciousness. How unique is the interpretation of zero energy ontology (ZEO) [L108]? Here 3 options suggest themselves corresponding to "western" and "eastern" world views and their hybrid.

1. For the western option, the space-time surface continues outside any CD as external world, in particular sub-CD and sub-CD is a correlate for the perceptive field of self.

2. For the eastern option, space-time ends at the boundary of any CD and sub-CD is not a correlate for the perceptive field of self and there is no constraint from the external world at boundaries of CD.

3. For the hybrid of these two options, conscious entity corresponds to a hierarchy of CD for which the highest level corresponds to CD for which space-time does not continue outside the CD. The highest level represents a God-like entity.

Problems related to ZEO based theory of consciousness

The new picture about sub-CDs at WCW level raises questions related to the TGD inspired theory of consciousness. This view involves several ad hoc assumptions related to the notions such as attention, mental image, memory, volition and intentions. Do these assumptions follow from more general assumptions or can some of them be simply wrong?

1. CD is a correlate for the perceptive field of self. Sub-CDs of CD define perceptive fields of subselves identified as mental images. What is the precise definition of sub-CD? Can one say that a sub-CD is created when a mental image is created. How does this happen? What determines the position and size of the sub-CD?

   The sub-CD is defined by the restriction of zero energy state to sub-CDs so that sub-CDs are induced by CD. This condition is analogous to boundary condition in classical physics and freezes WCW degrees of freedom of sub-CD at the passive boundary (PB) but the failure of determinism leaves discrete degrees of freedom at the active boundary (AB) so that the dynamics of SSFRs is restricted to these sub-WCW degrees of freedom and fermionic degrees of freedom.

2. Where sub-CDs and subselves are located? The natural location for a minimal sub-CD and mental images is around 3-surface at which the classical non-determinism fails: the frames of the soap film in soap film analogy. One can develop a rather detailed picture about frames [L162] based on number theoretic vision realized in terms of $M^8 - H$ duality [L127, L128, L150].

3. How sub-selves (sub-CDs) are created? Can they disappear? The notion of attention as generation of sub-CD achieved by a location of WCW ("world of classical worlds") spinor field at spacetime surfaces having their intersection with the PB of CD in a fixed set of 3-surfaces defining the sub-WCW is highly suggestive. This also affects the WCW spinor field of CD.

   The attention can be directed in several ways. Redirection of attention means a movement of the region defining the content of mental images in the interior of a CD. Entanglement and classical communications would be naturally associated with attention defined in this manner. If minimal subselves are associated with the frames as loci of classical non-determinism, the set of targets of attention is discrete and finite.

   This view about attention makes it possible to see also memory, anticipation, and intentions as special cases of attention.

4. The time evolution of CD itself would correspond to a scaling of CD (rather than translation), which by the failure of strict determinism brings in new discrete degrees of freedom related to the new frames becoming into the daylight as space-time surfaces increase. In the new picture, the sub-WCW property poses strong restrictions to the earlier picture about the development of sub-CD. The idea about silent wisdom as mental images preserved from the previous life after BSFR is not lost but is considerably modified.

   In this picture, the small failure of classical determinism would be an absolutely essential element in that it makes possible a non-trivial theory of consciousness at the level of CD and at space-time level. Otherwise would have only fermionic degrees of freedom forgiven sub-CD. What is intriguing is that everything would be finite. SFRs would involve choices between finitely many alternatives and in this respect the theory would be analogous to the computationalistic approach: in fact, preferred extremals are analogous to computer programs.

15.6.1 Some background

In the sequel, some understanding of the basic ideas and notions of TGD proper [L133] is needed. Also ZEO as the target of critical discussion is briefly summarized.

TGD view briefly

Very concisely, TGD emerges as fusion of special and general relativities and has Poincare invariance of special relativity and General Coordinate Invariance (GCI) and Equivalence Principle (EP) as basic principles. Also the interpretation as a generalization of string models is possible: point-like particles are replaced by 3-surfaces instead of strings and world lines become space-time surfaces.

The notion of induction makes it possible to eliminate classical boson fields as primary dynamical variables and reduce them to the sub-manifold geometry of the space-time surface. For the simplest option, free second quantized quark fields of the embedding space $H = M^4 \times CP_2$ induced to the space-time surface remain as fundamental fermion fields and quarks serve as basic building bricks of both bosons and fermions as elementary particles [L109, L151].

Some understanding of notions such as the "world of classical worlds" (WCW) [K104], preferred extremal (PE) [K11], and various variants of holography [L127, L128] implied by general coordinate invariance (GCI) in TGD framework is assumed. Inclusions of hyperfinite factors of type II_1 (HFFs) [K138, K47] are central elements of quantum TGD proper.

Adelic physics [L69, L70] replacing real number based with number theoretical universal physics based on the hierarchy of adeles defined by extensions of rationals (EQs) and $M^8 - H$ duality (see Appendix 15.6.6) allowing number theoretic and geometric views about physics dual to each other is also assumed as the background.

Hierarchy of Planck constants $h_{eff} = n \times h_0$, with n identified as dimension of EQ, is the basic implication of adelic physics and central for quantum TGD. The phases labelled by h_{eff} behave like dark matter [K31, K32, K33, K34]. This hierarchy serves as a correlate for quantum criticality in arbitrarily long length scales.

Cognitive representations identified as points of space-time surface for which preferred coordinates of embedding space are in an extension of rationals are also central for the construction of the theory using M^8-H duality [L127, L128].Galois group of EQ becomes number theoretical symmetry and is central in the description of quantum variants of cognitive representations [L25, L134].

Zero energy ontology (ZEO) [L108] is a key notion of quantum measurement theory. The basic prediction is that time reversal occurs in the ordinary state function reduction (SFR). This has profound implications for the interpretation of the quantum measurement theory [L99].

TGD inspired theory of consciousness can be seen as an extension of quantum measurement theory and relies on Negentropy Maximization Principle (NMP) as a basic dynamical principle [K73] [L157] implying second law for ordinary entanglement entropy.

$M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix 15.6.6) has changed considerably towards the end 2021 [L159] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \to m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L159] of the M^8-H duality map takes mass shells $p^2 = m^2$ of $M^4 \subset M^8$ to cds with size $L(m) = \hbar_{eff}/m$ with a common center. The slicing by mass shells is mapped to a Russian doll like slicing by cds. Therefore would be no CDs in M^8 contrary to what I believed first.

Quantum classical correspondence (QCC) inspires the proposal that the point $p^k \in M^8$ is mapped to a geodesic line corresponding to momentum p^k starting from the common center of cds. Its intersection with the opposite boundary of cd with size $L(m)$ defines the image point. This is not yet quite enough to satisfy UP but the additional details [L159] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M_c^8$ (M^8 is complexified to M_c^8) as a "root" of its octonionic continuation [L127, L128]. E_n has an interpretation as energy, which can be complex. The original interpretation was as moment of time. For this interpretation, $M^8 - H$ duality would be a linear identification and these hyper planes would be mapped to hyperplanes in $M^4 \subset H$. This motivated the term "very special moment in the life of self" for the image of the $E = E_n$ section of $X^4 \subset M^8$ [L102]. This notion does not make sense at the level M^8 anymore.

The modified $M^8 - H$ duality forces us to modify the original interpretation [L159]. The point $(E_n, p = 0)$ is mapped $(t_n = \hbar_{eff}/E_n, 0)$. The momenta (E_n, p) in $E = E_n$ plane are mapped to the boundary of cd and correspond to a continuous time interval at the boundary of CD: "very special moment" becomes a "very special time interval".

The quantum state however corresponds to a set of points corresponding to quark momenta, which belong to a cognitive representation and are therefore algebraic integers in the extension determined by the polynomial. These active points in E_n are mapped to a discrete set at the boundary of cd(m). A "very special moment" is replaced with a sequence of "very special moments".

So called Galois confinement [L150] forces the total momenta for bound states of quarks and antiquarks to be rational integers invariant under Galois group of extension of rationals determined by the polynomial P [L159]. These states correspond to states at boundaries of sub-CDs so that one obtains a hierarchy. Galois confinement provides a universal number theoretic mechanism for the formation of bound states.

ZEO

The TGD based view of consciousness relies on ZEO solving the basic paradox of quantum measurement theory. First, a brief summary of the recent view of ZEO [L108] is required. Some aspects of this view will be challenged in the sequel for sub-CDs.

1. The notion of a causal diamond (CD) (see **Fig. 16.11**) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms (3-D balls). The half-cones are mirror images of each other. CD=$cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2. The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics [L70])via the $M^8 - H$ duality [L103, L127, L128].

2. In the ZEO, quantum states are not 3-dimensional if the classical determinism does not fail as it actually does, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. By holography forced by general coordinate invariance, time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving the arrow of time that give rise to an analog of the Zeno effect (`https://cutt.ly/yl7oIUy`) [L108]. The findings of Minev *et al* [L99] provide strong support for ZEO [L99].

   To avoid confusion, one may emphasize some aspects of ZEO.

1. ZEO does not mean that the physical states identified in standard quantum theory as 3-D time= constant snapshots - and assigned in ZEO to the opposite boundaries of a causal diamond (CD) - would have zero energy. Rather, these 3-D states have the same conserved quantities, such as energy. Conservation laws allow us to adopt the convention that the values of conserved quantities are opposite for these states so that their sum vanishes.

   This is not new: in quantum field theories (QFTs), one speaks, instead of incoming and outgoing particles, external particles arriving from the geometric past and future and having

opposite signs of energy. That conserved quantities vanish in the *4-D* sense, expresses only the content of conservation laws. A weaker form of this condition [L155] states that the total conserved Poincare charges are opposite only at the limit of infinitely large CD. CD would be an analog of quantization volume in QFTs, whose finiteness implies a small conservation of momentum.

2. ZEO implies *two* times: subjective time as a sequence of quantum jumps and geometric time as a space-time coordinate: for instance, the proper time of the observer. Since subjective time does not correspond to a real continuum, these times are not identifiable but are strongly correlated. This correlation has led to their identification although they are different.

15.6.2 How uniquely PE property fixes the space-time surface?

How uniquely the PE property fixes the space-time surface if its 3-D intersections with the boundaries of CD are given? This is the key question in this section.

Various variants of holography

General coordinate invariance (GCI) forces holography in the TGD framework. One can however consider several variants of holography [L127, L128, L157].

1. Holography in the standard sense would fix the space-time surface from the data of its intersection with either boundary of CD or the data associated with the light-like 3-surfaces at which the signature of the induced metric changes.

2. Strong form of holography (SH) states that 2-D data at the intersections of the light-like 3-surfaces and boundary of CD are enough to determine the space-time surface.

3. The strongest form of holography inspired by $M^8 - H$ duality [L127, L128, L155] states that space-time region is determined by a rational value coefficients of a real polynomial extended to an octonionic polynomials, whose "root" is the space-time surface in M^8. The n roots of a real polynomial would determine a 4-D region in M^8 and its image in $H = M^4 \times CP_2$ would be interpreted as space-time surface.

4. There is a variant of holography, which gives up the full determinism of classical field equations and gives rise to what look like classical topological analogs of Feynman diagrams.

   (a) Consider first the particle level at the level of H. Particle lines generalized to 4-D orbits of 3-D surfaces representing particles. Particles as 4-D orbits of 3-surfaces contain light-line 3- D orbits of partonic 2-surfaces.

   (b) Partons as building bricks of particles in the information theoretic sense, and correspond to partonic 2-surfaces at which the orbits of partonic 2-surfaces meet. Their orbits are 3-D light-like surfaces at which the signature of the induced metric of the space-time surface changes.

   The partonic 2-D surfaces defining topological vertices belong to the 3-D sections of space-time surface with a constant value of M^4 time coordinate t to which one can map the 6-D brane-like entities of M^8 predicted by $M^8 - H$ duality [**?**]

   This picture suggests that, besides the data at the boundaries of CD, also the data at the partonic 2-surfaces in the interior of CD are needed. This failure of classical determinism brings in the failure of the strongest form of holography. There would be a large number of PEs connecting the 3-surfaces at the ends of CD and they would correspond to the analogs of Feynman diagrams.

   Zero energy state as a scattering amplitude would be a superposition over these diagrams. This superposition would not be however pre-determined as in the path integral but the zero energy state would define the superposition of paths in question.

Is the failure of classical determinism possible?

The possibility of classical non-determinism is suggested by the interpretation of space-time surfaces as generalized Feynman diagrams. These Feynman diagram entities would not however define an analog of path integral in TGD framework. Classical non-determinis would be a space-time correlate for the non-nondetermism at quantum level.

In this framework partonic 2-surfaces or equivalently the 3-D sections of the space-time surfaces with constant value of M^4 time would act as 3-surfaces at which the deterministic time evolution as a minimal surface would fail.

Another option is that light-like 3-surfaces containing the partonic 2-surfaces at very special moments of M^4 time define frames. These special values $t = t_n$ of M^4 time would be associated with 6-D branes predicted by M^8 picture as universal special solutions and their images in H would define "very special moments in the life of self" defined by the sequences of SSFRs defining the self.

1. The first hint comes from the dynamics of soap films. Soap films are minimal surfaces. The soap films spanned by 1-D frames consist of minimal surfaces glued together at the frames and this dynamics is non-deterministic in the sense that it allows several soap film configurations due to the different branchings at frames. At frames the minimal surface equations fail.

2. In TGD framework space-time surfaces as PEs are both minimal surfaces and extremals of Kähler action. In this case the 3-surfaces associated with "very special moments of time" $t = t_n$ could define an analog of a dynamically generated frame defining a 4-D soap film. The 3-surfaces at the ends of the CD would be fixed frames like those for soap films.

   This realizes quantum criticality in the sense that the field equations outside frame do not involve the parameters of the action which sum of volume term and Kähler action. The interpretation as a non-linear analog of massless free field theory outside the frame conforms with the basic spirit of quantum field theory. These solutions of field equations rely on a a generalization of holomorphy to 4-D situation so that field equations reduce to purely algebraic conditions involving only the first derivatives of embedding space coordinates. The analogy is defined by the solution of 2-D Laplacian equation in terms of real or imaginary part of an analytic function.

   Field equations consist of two terms, which are divergences for the conserved currents (4-momentum currents plus color currents) defined by the induced metric in the case of volume term. In the interior of the space-time surface these divergences vanish separately for the volume term and Kähler action but not at the frame.

3. The field equations must hold true also at the 3-D frame but this need not be true for both volume term and Kähler action separately. The coupling parameters of the theory make themselves visible only via the frame. For the volume action the divergences of the conserved currents are orthogonal to the space-time surface. For K "ahler action, the divergences of the conserved currents contain to terms. The first term is proportional to the energy momentum tensor of Kähler action and orthogonal to the space-time surface.

   Second term is not orthogonal to the space-time surface. For twistor lift the Kähler also has an M^4 part with a similar decomposition.

   The sums of the parts of divergences orthogonal to the space-time surface and parallel to it must sum up to zero separately. This gives 8 conditions altogether so that the number of field equations is doubled at the frame.

4. Could it happen that the divergences of these two isometry currents are singular and proportional to 3-D delta function but that their sum vanishes and conservation laws are respected? The part of the frame in the space-time interior would be dynamically generated whereas the part of the frame at the ends of CD would be fixed.

5. The restriction to 3-D frames is not the most general option. The delta function singularities could be located also at 2-D partonic 2-surfaces, at light-like 3-surfaces at which the induced metric changes its signature, and at string world sheets which connect these light-like 3-surfaces and have 1-D light-like boundaries at them. The light-like 3-D surfaces would be

analogs of the cuts for analytic functions. Partonic 2-surfaces at the ends of light-like 3-surfaces could be analogs for the ends of the cuts. String world sheets could serve as analogs of poles.

6. The non-determinism associated with the soap films and with frames suggests that there is a large number of 4-D "soap films with a given frame", which is fixed at the boundaries of CD but not in the interior of CD.

15.6.3 Questions related to the theory of consciousness

At the level of TGD inspired theory of consciousness theory, causal diamond (CD) defines a correlate of self or of its perceptive field. CD has sub-CDs which correspond to subselves experienced by self as mental images [L108, L157].

Concerning the evolution of self, the basic notions of "small" state function reduction (SSFR) as an analog of "weak measurement" and "big" SFR (BSFR) as an analog of ordinary SFR.

1. The first deviation from the standard ontology is that BSFR changes the arrow of time defined by the selection of PB of CD at which 3-D part of zero energy states remains unchaged during SSFRs.

2. The second deviation is that either boundary of CD and states at it remain unaffected in SSFRs whose sequence defines self as a conscious entity. This is the TGD counterpart for the Zeno effect of ordinary quantum theory in which repeated measurements of the same observable leave the state unaffected.

The details of the evolution of self are not fully understood and the proposed general view can be criticized.

1. How the constraint that sub-CD serves as a correlate for a classical perceptive field can be taken into account?

2. What is the precise definition of mental images as subselves? Are they at some special positions inside space-time surface?

3. What are the precise definitions of memories and conscious memory recall? The same question applies to the notions of intention, anticipation and attention.

4. Can the mental images be destroyed or do they only experience BSFR and continue to live with an opposite arrow of time and become unconscious to self? If a mental image can completely disappear, what could be the physical mechanism leading to its disappearance?

5. One can challenge the detailed picture of the notion of time evolution by SSFRs. The assumption about the drift of mental images towards future in the second half-cone of CD is ad hoc. Should it be replaced with a deeper assumption. Could one simply assume that they are stationary.

Three ontological options

The basic problem of ZEO is whether the causal diamond (CD) represents a perceptive field in the sense that the space-time surface continues outside the CD or whether CD is an independent entity in the sense that space-time surfaces do not continue outside CD. Conservation laws do not exclude either option.

ZEO allows 3 ontological options which might be called easter, western, and intermediate views.

Option I: Space-time surfaces are restricted inside CDs. Quantum universe is a collection of CDs containing space-time surfaces, which have ends at the boundaries of CD.

In this framework, space-time in cosmological scales is an idealization and could be perhaps explained in terms of the correlations between CDs. CDs do not form a fractal atlas of something unless one says that the atlas *is* the territory. CD is an independent entity rather than a perceptive field of sub-self.

One can argue that for sub-CDs this picture is problematic since it seems that one loses totally the notion of objective reality as something existing outside CD. There are no sensory perceptions. Could the overlaps with other CDs create the experience about the existence of the external world?

Cosmology would be a mental construct and correspond to a very large CD. One would have a multiverse but only at the level of conscious experience. Option I is consistent with the eastern view that only subjective experience exists but not with the western view.

Option II: Space-time surface continues always outside all CDs and CDs can be interpreted always as perceptive fields. Option II conforms with the westerm option and implies that cosmology is something real.

Option III: Self is a hierarchy of CDs such that for sub-CDs the space-time surfaces continue outside the CD but for the largest CD this would not be the case. Sub-CDs would represent perceptive fields but the largest CD would be a God-like entity experiencing itself as the entire cosmos.

Meditators report altered states of consciousness in which the separation to self and external world ceases and the mind is empty. Also the experience of timelessness is mentioned. Could these states correspond to experiences without mental images (sub-CDs) created by SFRs at this highest level?

Option III is roughly consistent with both western and eastern views about consciousness. If one requires the notion of the external world as objective reality and accepts the proposed explanation of altered states of consciousness, option III remains the only possible option.

A general picture about the dynamics of sub-CDs

The ZEO based view of quantum measurement theory and the theory of consciousness inspired by it have not been precisely formulated for sub-CDs. In particular, the question of how sub-CDs as mental images are created, has remained unanswered.

The following proposal provides such a formulation and is consistent with Options I and III.

1. CDs form a fractal atlas of conscious maps but the map would be the territory since in general the space-time surfaces need not continue outside the CD. There would be no external particles as 4-D lines for generalized Feynman diagrams outside CD.

2. Sub-CDs correspond to mental images of CD as a conscious entity. From the point of view of consciousness theory, there are only experiencers (CDs) which can have experiences as mental images (have sub-CDs), be mental images of experiencers (be sub-CDs) and share mental images (intersecting CDs with common sub-CDs).

3. Consistency conditions for the quantum dynamics of CDs and sub-CDs and for the overlapping CDs give rise to correlations between the regions of the map. The shared regions are geometrically analogs for the intersections of the intersections of a covering of a manifold by open sets.

4. For sub-CD the interpretation of sub-CD as a perceptive field would be natural.

The first question is what does one really mean with sub-CD at the level of space-time surfaces.

1. Do the space-time surfaces of sub-CD continue outside sub-CD as space-time surfaces of CD? Does this imply that the quantum dynamics of sub-CDs in ZEO is completely dictated by that of CD? This is certainly not the case. Fermionic zero energy states associated with the sub-CD are possible and are analogous to quantum fluctuations. Note that in the TGD framework all elementary particles can be constructed from fundamental fermions (quarks).

2. If the PE (PE) property fixes completely the space-time surface, its intersections with the boundary of CD, this seems to be the case. If the classical dynamics is not completely deterministic, as suggested by the analogy with minimal surfaces spanned by frames, the situation changes.

Sub-CD defines a subsystem of CD with boundary conditions at the boundary of CD which do not completely fix the quantum dynamics of sub-CD. Quantum states as WCW spinor fields inside sub-CD could change in SFRs of sub-CD.

The tensor product of sub-CD with CD would not be ordinary tensor product but much more restricted one and Connes tensor product, related to inclusions of HFFs, would be a possible identification. A sub-system would be like an included hyper-finite factor of type II_1 (HFF).

Suppose that the classical dynamics is indeed non-deterministic and sub-CDs are defined in the proposed manner. How the view about WCW spinor fields changes as one restricts the consideration to sub-WCW.

1. The failure of the classical determinism forces to replace each 3-surface at PB with a discrete tree-like structure consisting of all PEs connecting it to AB. Sub-WCW as the space of PEs is larger than the space of 3-surfaces X^3 at PB. Zero energy states are defined in this sub-WCW and assign to a given X^3 a wave function in this discrete set allowing interpretation as wave function in a set of paths of the tree.

   One cannot avoid the association with cognitive representations of adelic physics involving the number theoretic degrees of freedom characterized by Galois group of the extension of rationals associated with the polynomial defining the space-time region [L58, L134].

2. The activation of sub-WCW would mean an SFR selecting in WCW of CD such sub-WCW for which the space-time surfaces are such that their ends at sub-CD are fixed. This would correspond to SFR creating a sub-CD and corresponding mental image. This would answer the long standing question whether and how mental images can appear as if from scratch. This SFR would also represent a third kind of SFR having interpretation as a partial localization in WCW associated with CD. This also suggest that mental images could disappear suddenly. This "activation" could be seen as a directed attention.

3. WCW degrees of freedom at the boundaries of sub-CD are fixed. Also sub-WCW spinor fields make sense. One can allow the tensor product of Fock spaces of many-fermion states associated with the boundaries of CD. One would have a QFT like picture with sub-WCW degrees of freedom fixed at boundaries of sub-CD.

4. The tensor product of fermionic state spaces at the boundaries of sub-WCW makes sense and one can define zero energy states in the same manner as proposed hitherto. The only difference is that WCW degrees of freedom are frozen at the boundaries of sub-CD. At the level of conscious experience this means that the subself experiences the external world as fixed. This would be by definition the meaning of being subself.

   The fermionic Fock state basis has an interpretation as a Boolean algebra so that fermionic zero energy states have an interpretation as Boolean statements of form $A \to B$. This would mean that consciousness of the subself would be Boolean, cognitive consciousness, thinking. This conforms with the Eastern view that ordinary consciousness is essentially thinking and that the higher level of consciousness as that associated with the highest level of the CD hierarchy of self is pure consciousness. Thinking assignable to the fermionic degrees of freedom would be seen as an endless generation of illusions. "Reality" in this interpretation would correspond to WCW degrees of freedom.

What restrictions must one pose on the quantum dynamics of CDs in the case of sub-CDs? Does the subjective evolution of sub-CD states by SSFRs and BSFRs make sense for sub-CDs?

1. The increase of the size of sub-CD makes sense and the proposed subjective evolution by scalings and SSFRs makes sense. The time evolution is also now induced by the increase of the perceptive field of a subself defined by the WCW associated with increasing sub-CD bringing in new 4-surfaces due to the classical non-determinism.

2. What about the interaction between CD and sub-CDs. Does this time evolution respect the condition that the space-time surfaces meet the fixed 3-surfaces at boundaries of sub-CD or is it possible that the SSFRs of CD destroy the subself by delocalization so that sub-CD as a mental images must be regenerated by localization in WCW.

3. Also the interaction between overlapping CDs and the sharing of mental images can be understood in this framework.

15.6.4 Comparison of the revised view of self with the earlier one

The revised view about TGD inspired theory of consciousness relies on the definition of subself at the level of WCW unlike the older view. In the following the new view is compared with the old view.

The view about SSFRs

Earlier picture

The earlier view about SSFRs was inspired by the M^8 picture.

1. The dynamics was assumed to involve both scaling of CD with respect to either tip of CD. The lower half-cone was only scaled whereas the upper half-cone was also shifted as required by the stationarity of the passive boundary. Dynamics at PB was passive in the sense that only a portion of the space-time surface became visible making also new states visible at it (Zeno effect) in the sequence of SSFRs . The idea about scaling leads to a rather concrete proposal for the S-matrix characterizing the scalings of CD.

2. The surfaces inside CD (or sub-CD) were assumed to be mirror symmetric with respect to the middle plane of CD. This assumption does not conform with the assumption that these surfaces define a perceptive field in the sense that they are parts of large space-times and continue outside CD.

The old view had several ad hoc features.

1. The creation of mental images was implicitly assumed without specifying what this could mean mathematically. These mental images were assumed to be created in the upper half-cone just above the $t = T$ mid-plane of CD and shift to the geometric future with the upper half-cone of CD. The asymmetry between upper and half-cone could be seen as reflecting geometrically the future-past asymmetry but was ad hoc.

2. One can criticize the assumption that the memories about the events of the subjective past are located in the geometric future with respect to the mid-plane of CD.

3. Whether mental images can disappear or only die and reincarnate by BSFR, was not specified.

New picture

In the new picture the situation is the following.

1. Also in the new picture, the time evolution by SSFRs would be a sequence of scalings of CD. The assumption about reflection symmetry of space-time surfaces is given up since it is inconsistent with the identification of sub-CD as a perceptive field. Also now the time evolution is passive in the sense that only a new portion of the space-time surface extending outside sub-CD is revealed at each step.

2. As in the previous picture, new discrete WCW degrees of freedom appear during the sequence of SSFRs and complexity increases. For both options only fermionic degrees of freedom remain if full determinism is assumed and if QCC is required also at the level of SFRs.

3. In the new view both directed attention, memory, and intention correspond to a generation of sub-CD by a localization in WCW fixing a subset of 3-surfaces at the PB of CD. Redirecting of attention would allow apparent movement of the sub-CD in the interior of CD and as a special case shifting the mental images in the time direction assumed in the earlier picture.

4. In the new view the loci of mental images are naturally associated with the loci of classical non-determinism that is 3-surfaces at the 4-D minimal surface branches.

5. $M^8 - H$ duality suggests that the branchings occur at H image points of the M^8 cognitive representation defined by the quark momenta which are algebraic integers for the extension of rationals defined by the polynomial defining $X^4 \subset M^8$. The non-determinism at $X^4 \subset H$ point set would correspond to non-determinism assignable to a bound state of quarks at corresponding point of M^8.

   Note that physical states correspond to total quark momenta which are rational integers, one can speak of Galois confinement meaning that physical states are Galois singlets. This gives an infinite hierarchy of bound states formed by a universal, purely number theoretical mechanism. All bound states could be formed in this manner.

   The non-determinism at $X^4 \subset H$ point which corresponds to a subset of points as images of quark momenta composing the bound state would correspond to non-determinism assignable to a bound state of quarks at corresponding point of M^8. There would be a hierarchy of CDs within CDs and hierarchy of mental images corresponding to the hierarchy of bound states.

   The bound state momenta are mapped to $X^4 \subset H$ by $M^8 - H$ duality already described. In particular, the positions of quarks contained in 6-branes X^6 with a constant energy $E = E_n$ are mapped to a sequence of points at the boundary of cd of the system by M^8-duality and it can be said to represent the positions of these quarks. These point sets define sequences of "very special moments in the life of self".

   The targets of attention would therefore form a discrete set assignable to bound states of quarks and antiquarks. Note however that each 3-surface X^3 in the superposition defining the WCW spinor field at the PB of CD has its own discrete set loci of non-determinism. BSFRs can change the superposition of these 3-surfaces. The selection between branches is possible in BSFR but not in SSFRs.

6. An attractive idea motivated by ZEP is that volitional action could be interpreted in the new view as an SFR selecting one path at the node of a tree characterizing the non-determinism. Single deterministic time evolution analogous to a computer program would be selected rather than modifying the deterministic time evolution as in standard ontology. In the M^8 picture, the very special moments $t = r_n$ in the life of self correspond to the roots of a real polynomial. What happens when all roots have been experienced? Does NMP force the BSFR to occur since nothing new can be learned?

Comparison of the views about BSFR

Those aspects of BSFR in which old and new views differ are of special interest.

Earlier view

The fact that the notion of sub-CD and mental image were not properly formulated led to several ad hoc assumptions.

1. The possible failure of a strict determinism was realized. The failure of strict determinism was assigned to "very special moments in the life of self" associated with the images $E = E_n$ planes of $M^4 \subset M^8$ at which the partonic vertices as loci of non-determinism were assigned.

2. The mental images of previous life near the AB of CD were assumed to be inherited as "silent wisdom". Their contents was from the early period of life with opposite arrow of time and one can of course ask whether they were really "wisdom".

3. There were also assumptions about the change of the size scale of CD in BSFR. The idea that the reduction of the size scale guarantees that re-incarnate has childhood was considered. This assumption also prevents unlimited increase of the size scale of sub-CD.

New view

The new view makes it possible to develop a more detailed picture of what happens in BSFR.

1. The WCW localization at the AB of CD selects one of the branches of the space-time surface beginning at the PB. This selection of the branch happens to each 3-surface in the superposition of 3-surfaces at the PB defined by the WCW spinor field before BSFR.

2. The future directed tree becomes a past directed tree beginning from one particular branch at the AB. The initial and final space-time surface share a common space-time surface connecting the roots of the old and new trees. This is essential for having a non-trivial transition amplitude for BSFR at WCW level.

In the earlier view, the mental images interpreted as memory mental images and located near the boundary of CD were assumed to be inherited as "silent wisdom" by the time-reversed reincarnate. What happens now?

The notion of "silent wisdom" as inherited information still makes sense.

1. The new space-time surfaces originate from 3-surface which was selected by WCW localization in BSFR. Therefore the new space-time surfaces carry classical information about previous life.

2. The space-time surfaces originating from the new root are near to the space-time surface connecting the old and new roots. The WCW spinor field before and after BSFR musthave a strong overlap in order to make the transition amplitude large. This implies that information about previous life is transferred to the new life.

3. The nearness property could imply that they are easily re-created as perceptions by directed attention so that they would indeed be "silent" wisdom. These mental images are from the later part of the life cycle rather than from the early life as in the earlier picture. If aging means getting wisdom, then silent wisdom would be in question.

Does the notion of "silent wisdom" as mental images make sense?

1. Mental images - this includes both sensory and memory mental images and intentions) are naturally assignable to the loci of classical non-determinism at the images of the planes $E = E_n$ of the branched space-time surfaces associated with the new root ("very special moments in the life of self").

   For the special space-time surface connecting the roots of old and new space-time surface, the surfaces $E = E_n$ in M^8 would not change and the mental images would carry information about previous life. Could one talk about potentially conscious "silent wisdom".

2. What happens to the mental images of self in BSFR? Can they be preserved or do they disappear or do they reincarmate by BSFR? The idea about preservation makes sense only for space-time surfaces connecting the roots.

3. What can happen to the size scale of CD in BSFR? The extreme option that CD decreases in size by shift of the formerly PB such that the time evolutions are fully determinimistic in the superposition of 3-surfaces. There would be no inherited silent wisdom and the self would start from scratch, live a chilhood. Otherwise these loci would define candidate for inherited silent wistom.

In the earlier picture the mental images corresponding to sub-CD could not disappear although it could die by BSFR and reincarnate with a reversed arrow of time. Can the mental image disappear now? Creation of mental image require metabolic energy feed: this explains 7 ± 2rule for the number of simultaneous mental images. Could this happen when attention is redirected? Therefore one could argue that mental image must totally disappear when the attention is redirected.

On the other hand, time reversed mental image apparently feeds energy to the environment in the original arrow of time, i.e. apparently dissipates. Could this dissipation be interpreted as an energy feed for its time reversal.

Note that the total disappearance of the mental image means delocalization at the level of WCW and seems possible. The new view clearly challenges the idea about the Karma's cycle of self. This cycle appears in many applications of BSFR.

15.6.5 Conclusions

Also the article *Some comments related to Zero Energy Ontology (ZEO)*" [L108] written for few years ago challenged the basic assumptions of ZEO. One tends to forget the unpleasant questions but now it was clear that it is better to face the fear that there might be something badly wrong. ZEO however survived and several ad hoc assumptions were eliminated.

Progress at the level of basic TGD

The basic goal is to improve the understanding about quantum-classical correspondence. The dynamics of soap films serves as an intuitive starting point.

1. In TGD frame 3-surfaces at the boundaries of CD define the analog of frame for a 4-D soap film as a minimal surface outside frame. This minimal surface would be an analog of a holomorphic minimal surface and simultaneous exremal of Kähler action except at the frame where one would have delta function singularities analogous to sources for massless d'Alembert equation.

2. There is also a dynamically generated part of the frame since the action contains also Kähler action. The dynamically generated parts of the frame would mean a failure of mimimal surface property at frame and also the failure of complete determinism localized at these frames.

3. At the frame only the equations for the entire action containing both volume term and Kähler term would be satisfied. This guarantees conservation laws and gives very strong constraints to what can happen at frames.

   The frame portions with various dimensions are analogous to the singularities of analytic functions at which the analyticity fails: cuts and poles are replaced with 3-, 2-, and 1-D singularities acting effectively as sources for volume term or equvavelently Kähler term. The sum of volume and Kähler singularities vanish by field equations. This gives rise to the interaction between volume and Kähler term at the loci of non-determinism.

4. H-picture suggests that the frames as singularities correspond to 1-D core for the deformations of CP_2 type extremals with light-like geodesic as M^4 projection, at partonic 2-surfaces and string world sheets, and at 3-D $t = t_n$ balls of CD as "very special moments in the life of self" which integrate to an analog of catastrophe. T

   Deformations of Euclidean CP_2 type extremals, the light-like 3-surfaces as partonic orbits at which the signature of the induced metric changes, string world sheets, and partonic 2-surfaces at $r = t_n$ balls taking the role of vertices give rise to an analog of Feynman (or twistor -) diagram. The external particles arriving the vertex correspond to different roots of the polynomial in M^8 picture co-inciding at the vertex.

The proposed picture at the level of $H = M^4 \times CP_2$ has dual at the level of (complexified) M^8 identifiable as complexified octonions. The parts of frame correspond to loci at which the space-time as a covering space with sheet defined by the roots of a polynomial becomes degenerate, i.e. touch each other.

Concerning the physical interpretation, a crucial step of progress was the interpretation of M^8 as analog of momentum space allowing to interpret $M^8 - H$ duality as an analog of momentum-position duality and of complementarity principle of wave mechanics [L159]. This forced to modify $M^8 - H$ duality in M^4 degrees of freedom to satify the constraints posed by UP.

There is a nice analogy with the catastrophe theory of Thom [A41, A21]. The catastrophe graph for cusp catastrophe serves as an intuitive guide line. embedding space coordinates serve as behaviour variables and space-time coordinates as control variables. One obtains a decomposition of space-time surface to regions of various dimension characterized by the degeneracy of the root.

Progress in the understanding of TGD inspired theory of consciousness

The improved view about ZEO makes it possible to define the basic notions like self, sub-self, BSFR and SSFR at the level of WCW. Also the WCW correlates for various aspects of consciousness

like attention, volition, memory, memory recall, anticipation are proposed. Attention is the basic process: attention creates sub-CD and subself by a localization in WCW and projects WCW spinor field to a subset of WCW. This process is completely analogous to position measurement at the level of H. At the level of M^8 it is analogous to momentum measurement.

One can distinguish between the Boolean aspects of cognition assignable to WCW spinors as fermionic Fock states (WCW spinor field restricted to given 3-surface). Fermionic consciousness is present even in absence of non-determinism. The non-determinism makes possible sensory perceptions and spatial consciousness.

A precise definition of sub-CD as a correlate of perceptive field at WCW level implies that the space-time surfaces associated with sub-CDs continue outside it. This gives powerful boundary conditions on the dynamics. For the largest CD in the hierarchy of CDs of a given self, this constraint is absent, and it is a God-like entity in ZEO. This leads to a connection between the western and eastern views about consciousness.

A connection with the minimal surface dynamics emerges [L162]. The sub-CDs to which mental image as subselves are assigned would be naturally associated with portions of dynamically generated frames as loci of non-determinism. If one identifies partonic 2-surfaces as vertices, one can interpret the collection of possible space-time surfaces for a fixed 3-surface at PB as a tree. All paths along the tree are possible time-evolutions of subself. The dynamics of consciousness for fixed 3-surface at PB becomes discrete and provides discrete correlate for a volitional action as selection of a path or a subset of paths in the tree. The reduction of dynamics of mental imagines to discrete dynamics would mean a huge simplification and conforms with the discreteness of cognitive representations.

Challenges

There are many challenges to be faced. The discrete dynamics of sub-self consciousness certainly correlates with the notion of cognitive representation based on adelic physics [L69, L70] and implying a discretization at both space-time level and WCW level. The Galois group for the extension of rationals acting on the roots of the polynomial plays a key role in this dynamics [L134, L150].

One teaser question remains. Localization requires energy quite generally and this conforms with the fact that mental images demand metabolic energy feed. It is possible to redirect attention and it remains unclear whether the mental image disappears totally or suffers BSFR.

This relates directly to the question whether consciousness continues after the physical death. If mental images (and corresponding sub-CDs) can disappear, the same can happen to us since we are mental images of some higher level self. If this cannot happen, BSFR means death and reincarnation with an opposite arrow of time in a completely universal sense. For instance, sleep period could correspond to a kind of death at some level of the personal self hierarchy generalizing the Id-ego-superego hierarchy of Freud. This would explain why we have no memories of the sleep period.

15.6.6 Appendix: M^8- and H views about classical non-determinism and particle reactions

M^8 picture and $M^8 - H$ duality

In M^8 picture, space-time surfaces correspond to real projections of 4-D complex "roots" of octonionic polynomials obtained from real polynomials with rational coefficients by algebraic continuation, i.e. by replacing real coordinate by complexified octonion coordinate [L62, L63, L64] [L127, L128]. The interested reader finds a rather detailed summary of $M^8 - H$ duality in Appendix 15.6.6.

$M^8 - H$ duality maps the point of $M^4 \times E^4$ to a point of $M^4 \times CP_2$ such that the point of $M^4 \subset M^4 \times E^4$ is mapped to some point of $M^4 \subset M^4 \times CP_2$. $M^8 - H$ duality is not a local map. Rather, the normal space of a $x \in X^4 \subset M^8$ goes to a point of CP_2 characterizing its quaternionic normal space.

1. To be a 4-D "root" in the complex sense means that the real part of a complexified octonionic polynomial determining the space-time surfaces vanishes. The number theoretic content of this condition is that the normal space of the space-time surface is quaternionic and therefore

associative. The second option would be that the tangent space is associative but this gives only M^4 as a solution.

2. At a given point there are n roots and some of them can coincide in some regions of the space-time surface. These regions correspond to the branchings of the space-time surface at which particle-like entities identified as space-time surfaces meet and interact.

   The quaternionic normal plane at this intersection is not unique so that several CP_2 points of $X^4 \subset H$ correspond to a single point of $X^4 \subset M^8$. The extreme situation is encountered in a point-like singularity when the normal plane at a given point of M^4 is a sub-manifold of CP_2.

   The interpretation is as particle vertices. The intuitive expectation is that they correspond to partonic 2-surfaces and perhaps also string world sheets. These surfaces are mapped to those in $M^4 \times CP_2$ by $M^8 - H$ correspondence.

3. Also 6-D brane like entities are predicted as universal "roots" they correspond to 6-spheres in M^8 with M^4 projection which is a 3-ball with constant value $E = E_n$ of energy as counterpart of the Minkowski time coordinate such that E_n is the root of the real polynomial defining the octonionic polynomial. The momenta $(E_n, p = 0)$ are mapped to points $t_n = (\hbar_{eff}/E_n, 0)$ and define "very special moments of time in the life of self".

   The points with $p \neq 0$, in particular the points corresponding to quark momentum, however correspond to $t < t_n$ at the boundary of cd with size $L(p) = \hbar_{ef}/\sqrt{E_n^2 - p^2}$. To these moments the failure of classical determinism giving rise to one particular kind of quantum non-determinism is concentrated. Note that points of double hyperboloid of M^4 with opposite energies are mapped to opposite boundaries of cd.

4. The intersections of 4-D "roots" with 6-D brane-like entities are 2-D and it might be possible to interpret them as analogs of either partonic 2-surfaces or string world sheets at which several roots become degenerate of octonionic polynomial coincide. Outside the singularity, the roots do not coincide and define separate space-time sheets and it is natural to interpret them as external particles of a particle reaction.

5. At the light-like orbits of partonic 2-surfaces the induced metric for the H-image of the space-time surface becomes degenerate since its signature changes. Could one say that the Minkowskian and Euclidean roots coincide at the partonic orbits?

   One can also wonder what the M^8 interpretation of wormhole contacts having two throats could be. Do the two throats correspond to two coincing roots at the level of M^8 having different normal spaces and mapped to separate 2-surfaces in H?

Catastrophe theoretic analogy

Consider the analogy with the catastrophe theory of Thom [A41] in more detail.

1. Catastrophe map is the graph of solutions for the vanishing of the gradient of a potential function as a function of control parameters. One considers only real roots as function of variable control parameters and the number of real roots varies as a function of parameters and one obtains lower-dimensional regions at which the number of roots to catastrophe polynomial changes as roots become degenerate [A41, A21]. Cusp catastrophe serves as the school example.

2. In the recent case, space-time surfaces correspond to roots of complexified octonionic polynomials and the coefficients of the polynomial appear as control parameters. Also complex roots are allowed and real 4-D space-time surface is obtained as a real projection and mapped to H by $M^8 - H$ duality and conjectured to correspond to a preferred extremal of an action determined by the twistor lift of TGD.

3. The basic motivations for this assumption are quantum criticality requiring preferred extremal property, which requires at the level of H the independence of the dynamics on coupling parameters of the twistor lift of Kähler action outside the loci of non-determinism demanded by M^8 level.

Connection between singularities and preferred extremals of various types

The above picture suggests the characterization of the space-time surfaces in terms of their singularities as surfaces of M^8.

At the level of H one can consider 4 kinds of very simple preferred extremals, which give rise to prototype singularities.

1. Einsteinian spacetime $X^4 \subset M^8$ with a 4-D M^4 projection and a unique normal space as a point of CP_2. $X^4 = M^4$ defines a prototype.

2. Cosmic string extremal $X^2 \times Y^2$ with Y^2 a complex surface in CP_2 and defining a set of normal spaces assignable to a point of X^2. $M^2 \times S^2$, S^2 a geodesic sphere defines a proto type. S^2 can be either homological trivial or non-trivial.

3. $X^3 \times S^1 \subset M^4 \times CP_2$, where S^1 is a geodesic circle of CP_2, is a candidate for a preferred extremal and singular surface. Both $M^3 \times S^1$ and $E^3 \times S^1$ are minimal surfaces and vacuum extremals of Kähler action.

   For the Euclidean signature, X^3 could be space-like and define a 3-ball compactifying to S^3 as a sub-manifold of the S^6 brane. The very special moments t_n would be singular in the sense that the normal space at a given point of $X^3 \subset M^4 \subset M^8$ would not be unique and would give rise S^1 singularity.

4. CP_2 type extremal with light-like geodesic as $M^4 \subset H$ projection and corresponding to a light-like geodesic in M^8 with normal spaces forming a 3-D surface in CP_2. Also $M^1 \times Y^3 \subset M^4 \times CP_2$ can be considered but is probably not a preferred extremal.

The intuitive picture is that these 4 types of preferred extremals correspond to singularities of the normal space of $X^4 \subset M^8$ of dimension $d = 0, 1, 2, 4$ and codimension $d_c = 4 - d$.

Analogy with knot theory

In knot theory a knot in 3-D space is projected to 2-plane where one obtains a diagram containing crossings. Knot invariants can be constructed in terms of this diagram. A knot theory inspired intuition is that space-time surfaces near to these special cases are projected to these special surfaces to get the toy model.

1. Canonically embedded $M^4 \subset M^8$ (or $M^4 \subset M^4 \times CP_2$) is an analog of the plane to which the knot is projected. One can project the space-time regions with 4-D $M4$ projection to M^4. In particular, those with a Minkowskian signature of the induced metric.

2. The M^4 projection of CP_2 type extremal is 1-D light-like geodesic. One must project the deformations of CP_2 type extermals to CP_2 type extremal at the level of H. At the level of H, CP_2 type extremal could correspond to a light-like geodesic of M^8 such that each point of the geodesic is singular point such that the union of quaternionic normal spaces defines a 3-D quaternionic surface in CP_2.

   A puncture in E^3 as an infinitesimal hole serves as an analogy. At the puncture, one can say that all normal spaces labelled by points of S^2 are realized.

   At the given point of the light-like geodesic, the quaternionic normal space of point is not unique but a 3-D union of normal spaces and defines a 3-D subset CP_2.

3. For the $X^2 \times Y^2 \subset M^4 \times CP_2$ type cosmic string extremals and their small deformations, one must project to $M^2 \times S^2 \subset CP_2$. For a point of X^2 the normal spaces define $Y^2 \subset CP_2$ so that the singularity is milder.

   For $X^3 \times S^1 \subset M^4 \times CP_2$ the normal spaces at a point of X^3 would define $S^1 \subset CP_2$. If X^3 is Euclidean, these 3-D singularities could correspond to the $t = t_n$ planes associated with the branes. The small deformations of these surfaces would project to $M^3 \times S^1$. This picture would integrate all 3 kinds of singularities and various types of preferred extremals to a single unified picture.

A toy model for the singularities

The following toy model for the singularities in the case of CP_2 type extremals generalizes also to other singularities.

1. A rather general class of CP_2 type extremals can be represented as a map $M^4 \to CP_2$ given by

$$m^k = p^k f(r) \ ,$$

   where p^k is light-like momentum and r is radial $U(2)$ invariant CP_2 coordinate labelling 3-spheres of CP_2 such that $r = \infty$ gives homologically non-trivial geodesic 2-sphere instead of 3-sphere.

   If $f(r)$ approaches constant value for $r \to \infty$, one can say that M^4 time stops at this limit, and one obtains a homologically non-trivial geodesic sphere instead of 3-D surface identifiable as an intersection with 6-D brane. Various external particles of the vertex would correspond to $m^k = p_k f_i(r)$ such that their values at $r = \infty$ coincide.

   It is not possible to obtainh omologically trivial 2-sphere in this manner.

2. Outside the vertex, the CP_2 type space-time sheets have distinct light-like geodesics as M^4 projections and they can be continued to distinct regions of M^4 in the toy model.

   The analog of the knot diagram would be a set of M^4:s with different constant values of CP_2 coordinates. The CP_2 type extremals would be glued along light-like geodesics to various M^4s.

   The CP_2 points of M^4:s meeting at the same geodesic sphere must belong to the same geodesic sphere S^2. The S^2:s associated with different vertices are different. Note that any two geodesic spheres must have common points.

3. In the toy model for the string world sheets $X^2 \times Y^2$ would be projected to a piece of $M^2 \times S^2$ connecting two partonic vertices with the same S^2. S^2:s would be at the ends of the string, whose orbit is a piece of M^2.

   $B^3 \times S^1$ could be interpreted as a subset of 6-D brane with B^3 identified as the $t = t_n$ cross section of M^4 light-cone.

This picture would suggest that the singularities could be indeed located to $t = t_n$ planes and integrated together to form a rough analog of catastrophe map.

Some examples of minimal surfaces with 1-D CP_2 projection

This subsection is not directly relevant to the basic topic and is added to give ideas about the possible role of volume term.

The original proposal was that preferred extremals are extremals of Kähler action but the twistor lift introduced the volume term as an additional term. This removed the huge vacuum degeneracy of Kähler action meaning that any 4-surface for which CP_2 projection was so called Lagrange manifold with the property that induced Kähler form vanishes, was a solution of field equations. For these surface induced Kähler potential is pure gauge.

The addition of the volume term removes this degeneracy and only minimal surfaces of this kind are possible as extremals. It is however not clear whether they are preferred extremals (are they analogs of complex surfaces?).

These solutions have not been studied previously [K11]. Space-time surfaces representing a warped embedding of M^4 with a flat metric represent the simplest example.

1. Denoting the angle coordinate of the geodesic sphere S^1 byΦ and the metric of S^1 by $ds^2 = -R^2 d\Phi^2$ the ansatz reads in linear Minkowski coordinates as $\Phi = k \cdot m$, where k is analog of four-momentum. The induced metric is flat and the second fundamental form vanishes by the linearity of Φ in m so that the field equations are satisfied.

Boundary conditions require the vanishing of the normal components of momentum currents and give $(\eta^{\alpha\beta} - R^2 p^\alpha p^\beta)n_\beta = 0$ .This condition cannot be satisfied so that these solutions should have infinite size, which looks unphysical.

The presence of the volume term in the action implies that the induced metric appears in the boundary conditions and this represents a problem quite generally. The only way to overcome the problem is that there are no boundaries. The many-sheetedness indeed makes this possible.

The warped extremals could represent a reasonable approximation of the space-time surface in the regions which are almost empty.

2. The light velocity defined in terms of time taken to get from the M^4 position A to B, is reduced to $c_1 = \sqrt{1 - |k \cdot k|}$. If k is light-like this does not happen.

   Although the analog of gravitational force is vanishing in warped metric, the deviation the flat metric from M^4 metric given by $|k \cdot k|$ in flat case could it be interpreted as gravitational potential and the gravitational potential energy of test mass would be given by by $E_{gr} = -m|k \cdot k|$.

   Could Nature provide a kind of cognitive representation or toy model of a gravitational field as a piecewise constant function in terms of CDs with which warped vacuum extremals would be associated? The representation would contain length scale dependent Λ as second parameter assigning momentum 4-momentum proportional to $\Lambda\, p^k$ to the CD. The volume energy would include its gravitational potential energy represented in terms of warping?

   For warped solutions the space-time light cone - to be distinguished from its embedding space counterpart - would be defined by $c_1^2 t^2 - r^2 = 0$ and space-time CD would be modified accordingly.

Only single extremal - canonically embedded M^4 - remains from the spectrum of cosmological vacuum extremals for Kähler action having 1-D CP_2 projection and defined by $\Phi = f(a)$, where f is an arbitrary function of light-cone proper time coordinate $a = \sqrt{t^2 - r_M^2}$.

At QFT-GRT limit, the many-sheeted space-time is approximated with Einsteinian cosmology with the deviation of the induced metric from M^4 metric defined by the sum of the corresponding deviations for the sheets. Since the value of Λ becomes large in short p-adic length scales, a cosmology resembling GRT type cosmology could emerge and Einstein's equations would be a remnant of Poincare symmetry.

The induced metric for the solutions has very little to do with the metric appearing at the Einsteininian limit. The models of cosmology as space-time surfaces based on Kähler action with vanishing Λ could however make sense in very long scales for which Λ approaches zero.

For string dominated cosmology, the comoving mass is proportional to a [K113, K11, K70]. One has a silent whisper amplified to a Big bang in GRT sense. Also critical cosmology [K11] as an analog of inflationary cosmology for which curvature scalar as dimensional quantity vanishes can be regarded as a silent whisper amplified to a Big Bang and also it becomes Euclidean for a critical value $a = a_0$ of cosmic time.

15.7 Still about quantum measurement theory in ZEO

The relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision could be much clearer. The following considerations suggest a more precise picture about cognitive representations and formulation of quantum measurement theory for them.

In the sequel ZEO based theory of consciousness [L72, L108] as quantum measurement theory is discussed first by starting with a criticism of physicalism and after that introducing ZEO based view about consciousness as quantum measurement theory as a solution to the problems of physicalism.

After this the relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision [L69, L70] is discussed. The considerations suggest a more precise picture about cognitive representations and formulation of quantum measurement theory for them. One can generalize classical cognitive representations as number theoretical discretizations of space-time

surfaces in the extension of rationals considered to their quantum counterparts as wave functions in the Galois group of the extension and introduce also fermions as spinors in the group algebra of Galois group. The strongest option is purely number theoretical representations of spinors as spinors in this group algebra. Presumably however M^8 spinors are required and have interpretation in terms of octonion structure.

An attractive vision is that number theoretical quantum measurements reduce to measurement cascades involving a sequence of state function reductions reducing the entanglement between wave functions in sub-Galois group H and group G/H and ends up to a prime Galois group for group algebra has prime dimension and represents Hilbert space prime not decomposable to tensor product.

Also time measurement is considered from the number theoretic perspective assuming $M^8 - H$ duality [L102]. Clock readings are realized as roots of the rational polynomial determining the space-time surface in M^8. Time measurement would involve a localization to a definite extension of rationals, whose dimension n must be proportional to the temporal distance T between the tips of causal diamond (CD) to guarantee fixed time and energy resolution.

15.7.1 ZEO based theory of consciousness as quantum measurement theory

Consider first zero energy ontology (ZEO) based quantum measurement theory as a theory of consciousness.

Criticism of physicalism

It is good to start with a criticism of physicalism.

1. In physicalism consciousness would reduce to a physical property, like energy, momentum or charge and one would have the hard problem. There would be absolutely no idea why for instance sensory qualia emerge and how they correspond to sensory input. For instance, the assignment of sensory qualia to brain regions leads to a mystery: auditory, visual, etc. areas look exactly the same. How they can give rise to so different qualia?

   Remark: The answer to the question is that this is not possible. I n TGD framework macroscopic quantum coherence and ZEO allow to assume that sensory qualia are seated at sensory organs [L60].

2. This is not the only problem: free will is not possible and we must stop talking about ethics and moral as we have indeed done in modern free market economy, which threatens to destroy our civilization.

3. The third problem of physicalism and also idealism is that conscious experience is about something: it carries information about something, external world, my body, even about my thoughts. It is associated with a pair of systems- me and the rest of the world - rather than single system as consciousness as a physical property implies. This "aboutness", kills the physicalistis view and actually idealism and under reasonable assumptions also dualism. Standard ontologies of consciousness fail.

Physicalistic approach has also problems with quantum measurement theory. The basic problems are basically due to the fact that observer as a conscious entity remains an outsider: observations affect the measured system but theory cannot say anything about observer as subjective entity. In ZEO the situation is different [L108] (`http://tinyurl.com/wd7sszo`) .

1. Quantum jump defines the basic building brick of conscious experience. It is something between two different quantum worlds, not in the world as a physical property of quantum system. Consciousness is a moment of re-creation. This a solves the hard problem and problem of free will.

2. Also the paradox of state function reduction can be solved if one can understand the problems related to the notion of time. There are two times: experienced time and geometric time,

or the clock time. They are very different. Experienced time irreversible and has preferred moment "Now". Geometric time reversible and without preferred "Now". For some reason these times have been however identified.

ZEO based quantum measurement theory

In ZEO physical states as time= constant snapshots are replaced by pairs of "initial" and "final" states A and B or - by holography - with superpositions of deterministic time evolutions from A to B with respect to geometric time - note the analogy with computer program in computer science, behavior pattern in neuroscience, and function in biology.

1. In "small" state function reductions (SFRs) -"weak" measurements - the superposition of time evolutions from A to B is replaced with a new one such that states A at passive end - "initial state" - are not changed. Classical determinism is respected although one has quantum jump and generalization of quantum measurement theory. Two times - two causalities. The temporal distance T between A and B increases in statistical sense and this gives the correspondence between experienced time as sequence of state function reductions and geometric time is identified as T. These measurements changing B correspond to "weak" measurements analogous to classical measurements and to sensory input. A represents permanent part of selfness, "soul" one might say.

2. In "big" (ordinary) state function reductions (BSFRs) the roles of "initial" and "final" states change and the arrow of geometric time changes. Self dies and reincarnates with an opposite arrow of geometric time.

3. In more precise view the pairs of time=constant snapshots are replaced with what I call causal diamonds (CDs). The assumption that the size of CD is preserved In BSFR as assumed originally leads to some paradoxical looking implications. For instance, the size of CDs assignable to our sub-selves identifiable as mental images would increase without bound. $M^8 - H$ duality suggests strongly that the sizes of CDs can decrease in BSFR: the formerly active boundary would be frozen but the temporal distance of formerly passive boundary would be reduced so that the size of CD would decrease. One could say that self has childhood and starts from scratch with all sins of previous life forgiven.

This picture about state function reduction finds considerable empirical support.

1. The paradoxical experimental findings of Minev *et al* in atomic systems challenging standard quantum measurement theory give strong support for the reversal of the arrow of time in BSFR [L99] [L99] (`http://tinyurl.com/yj9prkho`).

2. Also Libet's finding that experience of free will [J44] seems to be preceded - caused - by neural activity, can be understood. It is not anymore support for the claim that free will is an illusion. State function reduction changing time order happens, and free will causes neural activity in the geometric past.

3. There is are lot of support for the new view about time from biology. For instance, self-organization - not only biological - could be understood as involving time reversal meaning that the time reversed reduction of order implied by generalization of second law looks from standard observer's viewpoint like increase of order. Self-assembly and generation of structures in long scales would involve increase of time order. Evolution is second aspect of self-organization and reduces to the unavoidable increase of h_{eff} as dimension for extension of rationals. Also the need for energy feed - metabolic energy feed in living matter - can be understood because the increase of h_{eff} keeping other parameters constant, increases energy scale. Dark matter would be visible everywhere in sharp contrast with standard prejudices.

4. There is support even from cosmology and astrophysics, where TGD predicts quantum jumps in macroscopic scales. For instance, stars older than Universe can be understood in more detailed picture about ZEO [L100, L101] (`http://tinyurl.com/tf38xnx`).

One can of course criticize the view about the role of clock time as the distance T between the tips of CD as over-simplified [L108].

1. The state function reductions preceding SSFRs are preceded by unitary processes U. What one can say about "time evolution" U. First of all, U is assumed to produce a zero energy state de-localized in the space of CDs - in particular with respect to the distance T between the tips of CD.

   The simplest guess is that in SSFR a complete localization in T - measurement of T - and other moduli of CD (say boost with respect to the lower tip of CD) occurs. Can one reduce the localization in T to a SSFR reducing quantum entanglement or is time measurement something different? What entanglement of CD sizes with different values of T with the measurement apparatus could mean? What the presence of a measurement apparatus for time T - the clock at fundamental level, could mean mathematically? Later also the question whether one could reduce this measurement to pure number theory emerges?

2. The notion of completely localized state is over-idealization and also mathematically poorly defined. Gaussian wave packet over classical states with well-defined classical conserved energy (by Poincare invariance) with respect to T localized around some value T_0 is a more realistic notion and time measurement would mean localization to a wave packet around T_0.

   In [L108] the proposal that the time evolution of self could be seen an analog of cooling process analogous to cosmic cooling is considered. This would correspond to an adiabatic time evolution happening for a particle in box whose size increases slowly. In this process the coefficients in a superposition of states with given classical energy remain unaffected but the classical energies of the states themselves decrease. This would conform with Uncertainty Principle stating that the classical energies scale as $1/T$.

A more detailed view about quantum measurement in ZEO

Consider next in more detail what state function as quantum measurement means in TGD.

1. In standard quantum measurement theory quantum measurements are often thought to be performed by humans only. In TGD one assumes that state function reduction as analog of quantum measurement is universal and can take place for any pair of mutually entangled systems unentangled from its complement.

2. Density matrix for the entangled pair of systems is the fundamental observable. This applies to both BSFRs and SSFRs at active boundary of CD, which correspond to "weak" measurements commuting with the observables diagonalized at the passive boundary of CD and thus leaving the states at it invariant.

3. Quantum measurement involves typically measurement of several observables. This is realized as a measurement cascade. First the quantum measurement of density matrix occurs for some pair formed sub-system S_1 and its complement S_2 forming together system S. After the same occurs for S_1 and S_2. Observables correspond to density matrices in this cascade. One proceeds as along as new decompositions are found. If the final state belongs to a sub-space with prime dimension the cascade stops since there is no further decomposition to tensor product.

4. The density matrix for subsystem in general case decomposes to a sum of projectors t subspaces and the state function reduction takes to one of them. The outcome of the measurement can be sub-space rather than ray.

   Number theoretic vision suggests also a second possibility. The SSFR would take place only if the eigenvalue of density matrix having probability interpretation associated with the subspace or ray is in the extension of rationals associated with the matrix elements of the density matrix and space-time surfaces considered (defining the cognitive representation). If one assumes frequency interpretation of probability theory, this probability must be rationals. Entanglement can be number theoretically stable. This would that one can have stable entanglement.

It is natural to assume that BSFR can can increase the extension of rationals associated with the eigenvalues of density matrix in the extension of the extension associated with its matrix elements.

5. Stable entanglement could be crucial for quantum computation as also the possibility of large values of h_{eff} and of time reversal. One can also assign to entanglement with coefficients in an extension of rationals p-adic variant of entanglement entropy by replacing logarithms of probabilities with the logarithms of their p-adic norms. These p-adic entanglement negentropies can be positive so that the entanglement carries information. This negentropy is different from the real negative entropy due to the loss of precise knowledge about entangled states. Quite generally, the sum of p-adic negentropies can be larger than real entropy. This would explain the paradoxical looking fact that highly evolved biological systems are highly entropic [I59] [L35]. england

15.7.2 The relationship between adelic physics and ZEO based quantum theory

The challenge is to formulate quantum measurement theory taking into account the constraints from adelic physics [L69, L70]. One can consider the possibility is that the quantum physics could reduces at the level of cognitive representations to purely number theoretic physics. This would mean huge simplification. I have considered quantum theory at the level of cognitive representations from the point of view of number theory in [L106] and from the perspective of scattering amplitudes in [L105].

Two kinds of cognitive representations

One can consider two kinds of cognitive representations. The cognitive representations considered hitherto correspond to number theoretical discretization of space-time surface determined by an extension of rationals, they are "classical". The bosonic wave functions in Galois group of extension acting on cognitive representations and their fermionic counterparts based on fermionic dynamics in the group algebra of Galois group and its normal subgroups (Galois groups too) would define quantal cognitive representations.

1. There are cognitive representations both at the classical level in terms number theoretical discretizations of space-time surfaces defined by the extension of rationals and at the quantum level based on spinorial wave functions in Galois group of the representation. Also the spinorial wave functions in factor sub-groups and normal subgroups of Galois group are involved.

2. One can assign preferred primes p_{pref} to the classical space-time dynamics as ramified primes p_{ram} of the extension. For these the polynomial defining extension has double root in $O(p) = 0$ approximation. This would be the realization of quantum criticality for cognition: criticality is typically in potential models a situation in which two or more extrema of the potential function coincide - catastrophe theory of Thom is classical example.

3. At the level of state (spinorial) space wave functions in Galois group acting on cognitive representations are natural candidate for a bosonic state space. Quantum states would be wave functions in Galois group G with normal subgroup H acting as a Galois group of lower-D extension.

   G/H is group itself and one can express wave functions in G as superpositions of products wave functions in G/H and H. The wave functions in G/H and H define naturally a tensor product and an attractive idea is that state function reduction can be regarded as measurement in G/H or equivalently in H. When H has prime order further reduction is not possible since Hilbert spaces with prime dimension are primes of tensor product.

   A natural candidate for preferred primes p_{pref} is as orders of smallest possible normal subgroups of Galois group, kind of primitive generating Galois groups.

Remark: One must consider also the possibility that quark and possibly also leptonic degrees of freedom are present as additional spinor indices. The fact that M^8 has octonionic structure could require also M^8 spinor structure.

4. In TGD dark matter is identified as $h_{eff} = n \times h_0$ phases of ordinary manner. n is identified as the order of Galois group of Galois extensions and thus of the extension itself. For ordinary value of Planck constant empirical inputs suggests the identification $h = 6h_0$ [L46, L83].

   Quite interestingly, one has $6 = 2 \times 3$ so that there is factorization to 2-D and 3-D subspaces assignable to massless particles, and massive gauge bosons. This indeed suggests that number theoretical vision could allows to represent all many-particle states in terms of wave functions (spinor fields) in the group algebra of Galois group.

5. How to construct cognitive representations for fermions? A natural generalization of the bosonic dynamics in n-D group algebra of Galois group is introduction of spinor structure in terms of 2^k-dimensional spinors in the group algebra. For $k = n$ both chiralities are present and for $k = n-1$ only second chirality. In fact, one could pose even more chirality conditions giving $2^{n/2}$-D ($[n+1]/2$-D) spinors for even (odd) n. Indeed, the recent view about SUSY in TGD framework suggests that only quarks - second embedding space chirality - appear as fundamental fermions and that leptons are local composites of 3 quarks - spartners of quarks in well-defined sense [L109] (`http://tinyurl.com/y4pdb2xz`).

   The simplest option is that at the level of cognitive representations the fermionic oscillator operator algebra corresponds to the oscillator operator algebra creating fermions states having at most $k = n$, $k = n-1$,...$n/2$ ($[n+1]/2$) fermions assignable to these spinors in finite measurement resolution. Entire quantum dynamics at the level of cognitive representations would reduce to the dynamics of fermions in the group algebra of Galois group and its Galois sub-groups.

6. There is also question about the Galois groups of the extensions of various p-adic number fields Q_p induced by the extension of rationals with dimension n. For p-adic numbers in approximation the extension reduces to a finite field $G(p,k)$, $k \leq n$, and one has k-dimensional extension. Galois group G_p is smaller than the Galois group G for rationals. G_p would act naturally in the p-adic counterparts of cognitive representations and the representations of G would reduce to direct sums of representations of G_p. Note that the distinction between sensory and cognitive (real and p-adic) would emerge only at the quantum level.

   For $p < n+1$ the fact that one has $x^{p-1} = 1$ for $G(p)$ implies that the irreducible polynomial P defining the extension Q reduces to a polynomial with degree $nmodp-1 \leq p-1$. Information is lost for $p < n+1$. For $p \geq n+1$ situation is different but also in this case the reduction occurs for ramified primes since polynomial P as in this case multiple roots. This would be the counterpart of quantum criticality at the level of cognitive representations.

7. Could the primes appearing as factors of n be preferred p-adic primes? Since these primes as p-adic primes mean a loss of information, they are distinguished but hardly preferred in p-adic evolution. Ramified primes larger than n are more plausible candidates and can be assigned even with polynomials of order 2. The preferred p-adic primes assignable to elementary particles are indeed large: electron would correspond to $M_{127} = 2^{127} - 1 \sim 10^{38}$ [K66].

Quantum measurement theory for cognitive representations

What can one say about quantum measurement theory for cognitive representations? The basic questions concern the tensor products. How many tensor factorizations there are and can one pose some conditions on them? Assume that fermionic Fock states for second quantized spinor fields in n-D group algebra are enough for quantum physics at the level of cognitive representations.

1. Tensor product decomposition for n-D group algebra corresponds to the factorization $n = k \times l$. All factorizations of n define a possible quantum measurement situation and state function reduction can take place in bosonic sector to k or equivalently l-dimensional space. These factorizations would be highly unique since they correspond to pairs of Galois group G and its Galois subgroup H. They are defined modulo discrete automorphism of G. It is

not clear whether the choice of this automorphism has physical content: one might consider a discrete variant of gauge invariance.

For the fermionic oscillator algebra analogous statement holds true. Now the decompositions are induced by $n = k \times l$ decompositions.

2. State function reduction cascades would correspond to sequences of Galois subgroups $G \supset G_1 \supset ....G_k$ such that G_k corresponds to either trivial group of group with prime order. In this case the final state would be reached by a factorization in which the density matrix for G_k does not allow eigenvalues in the extension considered. This extension could be G, G_1 or perhaps rationals (frequency interpretation for probabilities).

$M^8 - H$ duality and measurement cascade

$M^8 - H$ duality [L102] suggests much more concrete picture about the measurement cascade.

1. $M^8 - H$ duality predicts that the roots r_n of a rational polynomial defining the space-time surfaces at the level of M^8 correspond "very special moments in the life of self" $t = r_n$ for the M^4 linear time in the rest system of CD, and that once these moments have been experienced, BSFR can take place. This is possible but not the only possible interpretation.

2. $M^8 - H$ duality and the view about evolution as analog of genetic evolution in which genes are conserved suggests that the polynomials can be regarded as functional composites of simple polynomials $P = P_{n_1} \circ P_{n_2} \circ ...P_{n_k}$ satisfying $P_{n_r} = 0$ (n_i refers to the degree of the polynomial). P possesses the roots of P_i and the corresponding Galois groups as normal subgroups as the counterpart for the conservation of genes in evolution.

   One can distinguish also primitive polynomials as those defining extensions which do not decompose further. Galois groups with prime number of elements corresponds to such extensions. Note that the same extension can appear at several levels in hierarchy and would correspond to a realization of extension at different hierarchy level defining a kind of abstraction level.

3. Intuitively the measurement cascade should correspond to a cascade proceeding to shorter time and length scales by increasing the resolution and also to a process in which abstraction is gradually concretized.

   Could the measurement cascade for a state localized to a given extension of rationals start with the measurement of the root set $X_1 = \{r_{1,1}\}$ of P_{n_1} corresponding to the lowest time resolution. After than P_2 and the root set $X_2 = \{r_{2,i}\}$ would be measured meaning a refined of time resolution replacing $r_{1,i}$ with as subset of X_2 around it.

   Here one must be however very cautious: one could also consider a hierarchy of CDs with decreasing size scales as the counterpart of the measurement cascade. I do not understand well enough the scale hierarchy to answer the question whether these two views might relate.

Measurement of time number theoretically

Could the measurement of clock time T as (average) distance between the tips of CD [L108] be understood as number theoretical measurement?

1. What about the measurement of time as the distance T between tips of CD or more generally as the center of mass value T_0 of T in the case that one has Gaussian wave packets localized around varying T_0? How could one realize the measurement apparatus - the clock - in terms of entanglement?

   Suppose that the superposition over CDs with different values of T corresponds at the level of space-time surfaces in M^8 to that for space-time surfaces determined by polynomials P_n with varying degrees and rational coefficients. The measurement fixing the extension and Galois group would not fix P_n since there is a large number of polynomials with rational coefficients but same Galois group. The measurement fixing the extension leads to a partial (at least) localization in T or T_0 but this is not expected to be enough.

2. A stronger localization in the state function reduction measuring n would require that T or T_0 correlates with the degree n. How could this be achieved in a natural manner? Intuitively the requirement of some fixed time resolution based on the preferred moments $t = r_n$ interpreted as clock readings has fixed resolution as the average time lapse $\Delta T = \langle \Delta T_{i,i+1} = r_{i+1} - r_i \rangle$ would require $n \propto T$ or $n \propto T_0$. How could this be achieved concretely? Could one specify the zero energy states by giving the time resolution as ΔT and being equivalent to energy resolution. This would also dictate the resolution of the cognitive representation as the set of space-time points in the extension.

15.8 The dynamics of SSFRs as quantum measurement cascades in the group algebra of Galois group

Adelic physics [L68, L69] is a proposal for the physics of both sensory experience having real physics as correlate and cognition having various p-adic physics as correlates. Adele is a book-like structure formed by real numbers and the extensions of p-adic number fields induced by a given extension of rationals with the pages of the book glued together along its back consisting of numbers belonging to the extension of rationals. This picture generalizes to space-time level. Adelic physics relies on the notion of cognitive representation as unique number theoretic discretization of the space-time surface. This discretization has also fermionic analog in terms of spinor structure associated with the group algebra of the Galois group of extension.

Adelic physics, $M^8 - H$ duality, and zero energy ontology lead (ZEO) to a proposal that the dynamics involved with "small" state function reductions (SSFRs) as counterparts of weak measurements could be basically number theoretical dynamics with SSFRs identified as reduction cascades leading to completely un-entangled state in the space of wave functions in Galois group of extension of rationals identifiable as wave functions in the space of cognitive representations. As a side product a prime factorization of the order of Galois group is obtained.

The result looks even more fascinating if the cognitive dynamics is a representation for the dynamics in real degrees of freedom in finite resolution characterized by the extension of rationals. If cognitive representations represent reality approximately, this indeed looks very natural and would provide an analog for adele formula expressing the norm of a rational as the inverse of the product of is p-adic norms.

15.8.1 Adelic physics very briefly

Number theoretic vision leading to adelic physics [L68] provides a general formulation of TGD complementary to the vision [K104] (`http://tinyurl.com/sh42dc2`) about physics as geometry of "world of classical words" (WCW).

1. p-Adic number fields and p-adic space-time sheets serve as correlates of cognition. Adele is a Cartesian product of reals and extensions of all p-adic number fields induced by given extension of rationals. Adeles are thus labelled by extensions of rationals, and one has an evolutionary hierarchy labelled by these extensions. The large the extension, the more complex the extension which can be regarded as $n-D$ space in K sense, that is with K-valued coordinates.

2. Evolution is assigned with the increase of algebraic complexity occurring in statistical sense in BSFRs, and possibly also during the time evolution by unitary evolutions and SSFRs following them. Indeed, in [L130] (`http://tinyurl.com/quofttl`) I considered the possibility that the time evolution of self in this manner could be induced by an iteration of polynomials - at least in approximate sense. Iteration is a universal manner to produce fractals as Julia sets and this would lead to the emergence of Mandelbrot and Julia fractals and their 4-D generalizations. In the sequel will represent and argument that the evolution as iterations could hold true in exact sense.

   Cognitive representations are identified as intersection of reality and various p-adicities (cognition). At space-time level they consist of points of embedding space $H = M^4 \times CP_2$ or M^8

($M^8 - H$ duality [L62, L63, L64] allows to consider both as embedding space) having preferred coordinates - M^8 indeed has almost unique linear M^8 coordinates for a given octonion structure.

3. Given extension of given number field K (rationals or extension of rationals) is characterized by its Galois group leaving K - say rationals - invariant and mapping products to products and sums to sums. Given extension E of rationals decomposes to extension E_N of extension E_{N-1} of ... of extension E_1 - denote it by $E \equiv H_N = E_N \circ E_{N-1} ... \circ E_1$. It is represented at the level of classical space-time dynamics in M^8 (`http://tinyurl.com/quofttl`) by a polynomial P which is functional composite $P = P_N \circ P_{N-1} \circ ... \circ P_1$. with $P_i(0) = 0$. The Galois group of $G(E)$ has the Galois group $H_{N-1} = G(E_{N-1} \circ ... \circ E_1)$ as a normal subgroup so that $G(E)/H_{N-1}$ is group.

   The elements of $G(E)$ allow a decomposition to a product $g = h_{N-1} \times h_{N-1} \times ...$ and the order of $G(E)$ is given as the product of orders of H_k: $n = n_0 \times .. \times n_{N-1}$. This factorization of prime importance also from quantum point of view. Galois groups with prime order do not allow this decomposition and the maximal decomposition and are actually cyclic groups Z_p of prime order so that primes appear also in this manner.

   Second manner for primes to appear is as ramified primes p_{ram} of extension for which the p-adic dynamics is critical in a well-defined sense since the irreducible polynomial with rational coefficients defining the extension becomes reducible (decomposes into a product) in order $O(p) = 0$. The p-adic primes assigned to elementary particles in p-adic calculation have been identified as ramified primes but also the primes labelling prime extensions possess properties making them candidates for p-adic primes.

   Iterations correspond to the sequence $H_k = G_0^{\circ k}$ of powers of generating Galois groups for the extension of K serving as a starting point. The order of H_k is the power n_0^k of integer $n_0 = \prod p_{0i}^{k_i}$. Now new primes emerges in the decomposition of n_0. Evolution by iteration is analogous to a unitary evolution as ex^{iHt} power of Hamiltonian, where t parameter takes the role of k .

4. The complexity of extension is characterized by the orders n and the orders n_k as also the number N of the factors. In the case of iterations of extension the limit of large N gives fractal.

5. Galois group acts in the space of cognitive representations and for Galois extensions for which Galois group has same order as extensions, it is natural do consider quantum states as wave functions in $G(E)$ forming n-D group algebra. One can assign to the group algebra also spinor structure giving rise to $D = 2^{M/2}$ fermionic states where one has $N = 2M$ or $N = 2M + 1$). One can also consider chirality constraints reducing D by a power of 2. An attractive idea is that this spinor structure represents many-fermion states consisting of $M/2$ fermion modes and providing representation of the fermionic Fock space in finite measurement resolution.

15.8.2 Number theoretical state function reductions as symmetry breaking cascades and prime factorizations

The proposed picture has very important quantal implications and allows to interpret number theoretic quantum measurement as a number theoretic analog for symmetric breaking cascade and also as a factorization of an integer into primes.

1. The wave functions in $G(E)$ - elements of group algebra of $G(E)$ can be decomposed to tensor products of wave functions in $G(E)/H_{N-1}$ and H_{N-1}: these wave functions in general represent entangled states. One can decompose the wave functions in H_{N-1} in similar manner and the process can be continued so that one obtains a maximal decomposition allowing no further decomposition for any factor. These non-decomposable Galois groups have prime order since its group algebra as Hilbert space of prime dimension has no decomposition into tensor product.

2. In state function reduction of wave function $G(E)$ the density matrices associated with pairs $G(E)/H_{N-1}$ and H_{N-1} are measured. The outcome is an eigenstate or eigen-space and gives

rise to symmetry breaking from $G(E) \equiv H_N$ to $E_N \times H_{N-1}$. The sequence of state function reductions should lead to a maximal symmetry breaking corresponding to a wave function as a produce of those associaetd with Galois groups of prime order. This define a prime factorization of the dimension n of Galois group/extension to $n = \prod_{i=1}^{N} p_i^k!$ The moments of consciousness for self would correspond to prime factorizations! Self would be number theoretician quite universally!

Also also the fermionic cognitive representation based on finite-D Fock states defined by spinor components of $G(E)$ is involved. The interpretation of Fock state basis as a a basis of Boolean algebra in TGD: the spinor structure of WCW could be representation for Boolean logic as a "square root" of Kähler geometry of WCW. Cognition indeed involves also Boolean logic.

15.8.3 SSFR as number theoretic state function reduction cascade and factorization of integer

A highly interesting unanswered question is following. "Small" state function reductions (SSFRs) define the life cycle of self as their sequence. What are the degrees of freedom where SSFRs occur?

1. SSFRs take place at the active boundary of CD which shifts in statistical sense towards future in the sequence of state function reductions. State at the passive boundary is not changed.

2. The idea that quantum randomness could correspond to classical chaos (or complexity) associated with the iteration of polynomials (Mandelbrot and Julia fractals) [L130] led to reconsider the hypothesis that the polynomial representing space-time decomposes to a product $P = P_2(T - r) \times P_1(r)$. T corresponds to the distance between the tips of CD and $r = t$ to the radial coordinate of M^4 assignable to the passive boundary of CD and equal to time coordinate t. $P_i(0) = 0$ is assumed to hold true.

   P_2 would change in SSFRs whereas P_1 and state at passive boundary would not. SSFRs (analogous to so called weak measurements) at active boundary would give rise to sensory input and various associations - Maya in Eastern terminology. P_1 would correspond to the unchanging part of self - "soul" or real self as one might say.

   I was also led to consider a simplified hypothesis that P_2 is obtained as iteration $P_2 = Q_1^{\circ n}$ in n:th n unitary evolution preceding SSFR. One would start from some iterate $Q_1^{\circ k}$. This would reduce quantum dynamics to iteration of polynomials and to a deep connection with Mandelbrot and Julia fractals but it was quite clear why this would be true.

3. The mere factorization $P = P_2 \times P_1$ implies that the Galois groups associated with active and passive boundary of CD commute and number theoretic state function reduction cascade for the wave functions in $G(E)$ for the extension determined by P_2 at active boundary could correspond to SSFR. Or course, also other commuting degrees of freedom are possible but number theoretic degrees of freedom could be the most important degrees of freedom involved with SSFRs.

15.8.4 The quantum dynamics of dark genes as factorization of primes

Gene level provides a fascinating application of this picture.

This contribution was inspired by discussion with Bruno Marchal about his with title "Do the laws of physics apply to the mind?" (`https://tinyurl.com/ycls2bpt`). Bruno Marchal is a representative of computationalism, which might be called idealistic and Bruno believes that physics follows from computationalism. The somewhat mystical notion of self-reference is believed to lead to consciousness . I do not share this view. The gist of the posting comes towards end where I describe how computationalism generalizes to quantum computationalism in TGD generalizing also the notion of quantum computation. What conscious problem solving is? This is the question to be discussed.

1. As found, dark photons and dark protons forming DNA codons as triplets could correspond to triplet representations for prime factor Z_3 of Galois group of Z_6. Codon and conjugate codon could in turn correspond to the prime factor Z_2 of Galois group Z_6 so that double

strand would correspond to Z_6 suggested by findings of Mills [L46] and TGD inspired model color vision [L83].

2. DNA codons could correspond to extension with Galois group Z_3, and one can consider an entire hierarchy of extensions of extensions of .. .extensions with dimensions n_i satisfying thus $n = \prod_{i=1}^{N} n_i$ and having Z_6 as subgroup at the lowest level of the hierarchy. The number N of factors would be the number of polynomials in the functional composition and thus define a kind of abstraction levels (abstractions are thoughts about thoughts about..., maps of maps of ...). N is expected to increase in evolution.

3. Could this abstraction hierarchy be realized at gene level? Genes decompose into transcribed regions - exons - and introns. Could different decomposition of genes to exons and introns correspond to different values of N and n_i and to different Galois groups. Could genes themselves form larger composites?

   Could genomes form even large structures such as chromosomes with larger Galois groups. Years ago I considered the possibility of a collective gene expression based on the collective MB of organelle, organ, or even population: could this correspond to an extension associated with several genomes?

4. Could SSFR correspond to a sequence of symmetry breakings for the Galois groups of these structures decomposing them to sub-groups? Number theoretic interpretation would in terms of decompositions of integers to primes! Genome would be a quantum computer performing number theory!

5. Metabolic energy feed would increasing h_{eff} would also increase the orders $n_i = h_{eff}/h_0$ of the extensions appearing in the composition of extensions and thus the orders of polynomial factors P_i in the functional composite defining the extensions. Therefore the decompositions would be dynamical.

   Metabolic energy feed requires BSFR changing the arrow of time if metabolic energy feed is actually feed of negative energy to environment. The emergence of a new prime factorization would require BSFR. That the time evolution by iterations would not require BSFR would support the proposal that time evolution by BSFRs could be induced by iteration dynamics for the polynomial P_2 assignable to the active boundary of CD.

15.8.5 The relationship of TGD view about consciousness to computationalism

This text was inspired by discussion with Bruno Marchal about his with title "Do the laws of physics apply to the mind?" (`https://tinyurl.com/ycls2bpt`). Bruno Marchal is a representative of computationalism, which might be called idealistic and Bruno believes that physics follows from computationalism. The somewhat mystical notion of self-reference is believed to lead to consciousness.

I do not share this view. The gist of the posting comes towards end where I describe how computationalism generalizes to quantum computationalism in TGD generalizing also the notion of quantum computation. What conscious problem solving is? This is the question to be discussed.

To my view computationalism is one of the failed approaches to consciousness - it cannot cope with free will for instance. It however contains an essential aspect which is correct: the idea of deterministic program leading from A to B. Problem solving be can regarded as attempt to find this program. You fix A as initial data and try to find a program leading from A to a final state characterized by data B. The program has duration T and can be very long and it is not clear whether it exists at all. You try again and again and eventually you might find it. In the real conscious problem solving this process means making guesses so that the process cannot be deterministic.

What does this view about problem solving correspond to in ZEO? We have states A and B represented as quantum states and we try to find quantum analog of classical program leading from A to B in some time T which can be varied.

1. A and B are realized as superpositions of 3-surfaces and fermionic states at them - located at time values t=0 and t=T. T can vary. Can we find by varying T a (superposition of) deterministic time evolution(s) - preferred extremal(s) (PE) - connecting A and B?

   In ZEO and for fixed A and T PE in general does not exist. In ideal situation (infinite measurement resolution) and for given A and T, B is unique if it exists at all. One has analog of Bohr orbit and the quantum analog of classical program as the superposition of Bohr orbits starting from A and hopefully leading to B as a solution of the problem.

   Remark: These superpositions can be regarded as counterparts of functions in biology and behaviors in neuroscience. The big difference to standard physics is that time=constant snapshot in time evolution of say bio-system is replaced with quantum superposition of very special time evolutions - PEs. Darwinian selection of also behaviors in biology correlates strongly with this.

2. So: given A and B, we try to find a value of T for which superposition of PEs from A to B exists. This would be the quantum program leading from A to B, and solving our problem.

   Actually, not only ours, universe is full of conscious entities solving problems at various levels of self hierarchy. This takes place by a sequences of "small" SFRs (SSFRs, weak measurements) increasing T in statistical sense and replacing the state at B with a new one determined by state A for given value of T. At the level of conscious experience this is sensory perception and all that which is associated with it.

   Finding the solution is analogous to the halting of quantum Turing machine by ordinary state function reduction, which corresponds in ZEO to a "big" (ordinary) SFR (BSFR). This would mean death in universal sense and reincarnation with reversed arrow of time in ZEO? Or is BSFR and death failure to solve the problem? I cannot answer.

   Remark: The notion of self-reference is replaced with much more concrete notion of becoming conscious of what one was conscious of before SSFR. SSFR indeed gives rise to conscious eperience and one avoids the infinite regress associated with genuine self-reference. As an additional bonus one obtains evolution since the extension of rationals characterizing space-time surfaces can increase meaning higher level of consciousness. At the limit algebraic numbers the cognitive representation is dense subset of space-time surface.

3. Also finite measurement resolution and discreteness characterizing computation emerge from number theory.

   To be a solution classically means that the 3-surface(s) representing B to have fixed discrete cognitive representation given by finite number of embedding space points in the extension of rationals defining the adele. Quantally, quantum superpositions of these points with fixed quantum numbers represent the desired final state.

   Also Boolean logic emerges at fundamental level as square root of Kähler geometry one might say. Many-fermion state basis defines a Boolean algebra and time evolution for induced spinors is analogous to truth preserving Boolean map in which truths code for infinite number of conservation laws associated with symmetries of WCW.

4. How to find the possibly existing solution at given step (unitary evolution plus SSFR) with t=T? One performs cognitive quantum measurements at each step represented by SSFR. They reduce to cascades of quantum measurements for the states in the group algebra of Galois group - call it Gal - of Galois extension considered.

   Gal has hierarchical decomposition to inclusion hierarchy of normal subgroups implying the representation of states in group algebra of Gal as entangled states in the tensor product of the group algebras of normal sub-groups of Gal. The hope is that this Galois cascade of SFRs produces desired state as an outcome and one can shout "Eureka!".

15.9 Questions related to the notion of self and time

The notion of self and the relation between subjective and geometric time involves unclear aspects. In the following I try to articulate the problematic issues as clearly as possible.

1. The precise nature of the hierarchy of causal diamonds (CDs) as correlate of self hierarchy should be characterized. The basic prediction that sub-selves have also time reversed variants should be interpreted and one can ask whether sensory-motor dichotomy is a sensible interpretation.

2. Are sub-selves always experienced as mental images and whether after images really represent re-incarnations of sub-selves.

3. Can the rather dramatic prediction of re-incarnations be transformed to an experimentally testable predictions. If one takes seriously the notion of self hierarchy and identifies the EEG correlates of self in a way proposed by Fingelkurts brothers [J79], this kind of prediction is possible.

15.9.1 Hierarchies of causal diamonds and space-time surfaces as geometric correlates for self hierarchy

CDs are obtained from the intersections of future and past directed light-ones by replacing their points with CP_2: as a matter fact, CP_2 plays no active role in the definition. I have not been able to nail down the precise definition for the hierarchy of causal diamonds. Self hierarchy demands that CDs serving as embedding space correlates for selves have sub-CDs identifiable as mental images of self. The basic question is whether CDs can also overlap. If so then finite unions of CDs could be allowed.

Selves as conscious entities are assumed to have space-time surfaces within CDs as space-time correlates. These CDs are dynamical: the other boundary remains unaffected during sequence of repeated state function reductions as also the states at it. Second boundary shifts so that the distance between the tips of CD increases and defines the experienced flow of time. These space-time surfaces form also a hierarchy. One could consider also a more precise identification of self. By SH string world sheets and/or partonic 2-surfaces or their light-like orbits could serve as space-time correlates of selves. The orbit of partonic 2-surface is indeed analogous to nervous system residing at the boundary between internal (Euclidian) and external (Minkowskian) worlds.

Given space-time surface has both Minkowskian and Euclidian regions - wormhole contacts - separated by wormhole throats at which the signature of the induced metric changes. Minkowskian space-time sheets are connected by extremely short CP_2 sized Euclidian wormhole contacts and in GRT-standard model approximation are approximated by single GRT space-time. If the magnetic flux through wormhole contact is monopole flux, the wormhole contact connecting two Minkowskian space-time sheets has interpretation as a building brick of elementary particles. Minkowskian space-time sheets at different levels of hierarchy are disjoint and separated by Euclidian wormhole contacts. This forces to modify the notion of quantum mechanical subsystem as a tensor factor of the state space.

What is new that two Minkowskian space-time sheets glued to larger disjoint Minkowskian space-time sheets can be connected by magnetic flux tube serving as a correlate for (negentropic) entanglement just as wormholes in ER-EPR proposal of Maldacena and Susskind [B19, B20] (see `http://tinyurl.com/y7za98cn`) serve as correlates for maximal entanglement between blackholes. Two unentangled systems can therefore have subsystems, which are entangled and correspond to two space-time sheets connected by magnetic flux tubes! This is possible only in many-sheeted space-time and the hypothesis has been that two selves, which have no entanglement at their own level of self-hierarchy, can have entangled subselves and that this negentropic entanglement (NE) means sharing of mental images giving rise to a kind of stereo consciousness. The fusion of right and left visual fields would be example of stereo consciousness. Stereo consciousness would make also possible to communicate besides bits also their meaning: during conscious communication the mental images of two selves would fuse temporarily to single mental image by the reconnection of magnetic flux tubes. This reconnection would make possible also directed attention.

What does this situation mean at the level of CDs? It would seem that the CDs associated with selves sharing mental images overlap and that the space-time surfaces assignable to fused mental images/subselves belong to the intersection of CDs. Thus it seems that one must allow unions of also overlapping CDs.

15.9.2 Are time reversed sub-selves always experienced as mental images?

In the proposed vision about self as generalized Zeno effect self dies as the first state function reduction to the opposite boundary of CD takes place. This implies the re-incarnation of self with the property that the geometric time flows in opposite direction since the opposite boundary of CD shifts such that the temporal distance between it and the opposite static boundary increases in repeated state function reductions leaving the states at static boundary un-affected.

Subselves correspond to mental images. The question is whether self really experiences the time reversed sub-selves as a mental image and if this is the case, what can one conclude about this. For sub-sub...-selves this problem is not acute if sub-sub-selves are experienced as kind of statistical averages.

A possible interpretation for self and its time reversal is in terms of sensory input and motor action. I have indeed proposed that motor action is essentially sensory experience in reversed time direction and Libet's discovery [J44] that conscious decision is preceded by neural activity (with respect to geometric time) provides a support for this interpretation. The time reversal of sensory mental image would represent motor action and at the level next below our level of hierarchy would be directly experienced as volitional act.

I have considered also other interpretations. One is suggested by visual illusion in which the picture of dancer is experienced to make either right or left pirouette. The direction of rotation would distinguish between mental images and its time reversal. It however seems that the sensory-motor dichotomy provides the most plausible and economical interpretation.

One can also wonder what happens, when mental the image is associated with a boundary of CD_1, which overlaps with CD in such a way that the opposite boundary is outside of CD. Does self experience the mental image associated with CD but not its time reversal?

15.9.3 Re-incarnation and EEG

It is amusing how fast the attitudes change as ideas evolve and experimental data emerge. Only few years ago I could not say anything definite about reincarnation in the framework of TGD inspired theory of consciousness. Now it has become an unavoidable prediction of ZEO, which itself is a "must" in TGD framework.

The prediction related to re-incarnation is however not quite what one might have expected. In death of self a reincarnation as time reversed conscious entity takes place. For time reversed self subjective time evolution corresponds to evolution in a reverse direction of geometric time. The next death/reincarnation after this re-incarnation gives rise to a self for which the arrow of geometric time is the original one.

Can one test this prediction? If one accepts the predicted fractal self hierarchy in which sub-selves correspond to mental images of self, this is possible. I am too lazy to retype basics about ZEO, CDs, and about how self as generalized Zeno effect emerges and just assume that reader knows the basic concepts or sees to trouble to refresh her knowledge about them.

1. Self hierarchy predicts that also our mental images are conscious entities. Motor-sensory dichotomy naturally corresponds to sub-self and time reversed sub-self. That is sensory mental image and that associated with motor action induced by sensory input. Motor action initiated in the geometric past at the opposite boundary of CD (this explains Libet's finding that conscious decision is preceded by neural activity in geometric time). Note that motor action does not proceed from brain to muscles but in reversed time direction from muscles to brain! This conforms with the vision in which magnetic body is intentional agent.

2. To proceed one must identify EEG correlates for the sub-selves (mental images) and their time reversed re-incarnates. Here the work of Fingelkurts brothers (see `http://tinyurl.com/jpszfpy`) working in Finland helps [J79]. They postulate what they call operational architecture of brain (OA) having operations (O) and operational modules (OM) as building bricks. Quasi-stationary EEG segments are assumed to serve as correlates for operations and synchrony of these segments associated with various locations in brain tells that they belong to the same OM.

Synchrony means spatio-temporal coherence - not only spatial - and is very natural concept in ZEO, where 4-D CDs and space-time surfaces inside them serve as geometric correlates of selves. Synchrony implies that these EEG segments at different spatial locations begin and end at the same time. Between EEG segments there is rapid transition period (RTP) allowing to distinguish segments from each other. Quasi-stationary segments of EEG have average duration is about .3 seconds.

The translation of this picture to TGD framework is rather straighforward. Operations correspond to sub-selves and OMs to collections of them forming sub-selves of self. CDs (sub-CDs) in turn serve as geometric correlates for selves (sub-selves). The quasi-stationary segments of EEG become correlates for sub-selves/mental images. Operational module corresponds to a self/CD having sub-selves/sub-CDs with synchronous EEG segments. The average duration of mental image would be about .3 seconds.

Two sub-sequent quasi-stationary segments separated by RTP would correspond to sub-self and its re-incarnation in the original time direction. Note that a very brief period of geometric time defined by the duration of RTP identifiable as the duration of a unitary time evolution between two sub-sequent state function reductions at the same boundary of CD corresponds to a finite duration of experienced time - the lifetime of the time reversed mental image!

The testable prediction is that the segment corresponding to time-reversed sub-self is located in geometric past and runs in opposite direction of geometric time. This EEG segment should be assignable to motor response accompanying sensory mental image. This is a highly non-trivial prediction testing the new view about time.

3. One can check whether these EEG segments appear as pairs with first member assignable to sensory mental image and second one to motor mental image. Time reversal implies that second law is obeyed in "wrong" time direction for EEG segment assignable to the motor output and this can be tested. Already Fantappie [J121] discovered that both directions of (geometric) time appear in living matter and introduced the notion of syntropy as time reversal of entropy. Spontaneous molecular self-assembly is a basic example of a syntropic process and identifiable as a decay process in reverse direction of geometric time. Phase conjugation is known to occur for phase conjugate laser light and sound. Does a process analogous to self-assembly occur for segments of EEG associated with motor actions: is the motor part of EEG time reversed? To answer this question one needs phase information about EEG besides power spectrum. In principle this information is contained in EEG.

15.9.4 After images as reincarnations of mental images?

After images (see `http://tinyurl.com/kevnzgq`) appear periodically as one can easily find by looking and lamp and closing eyes. They also change colors. Could these after images be interpreted as re-incarnations? This sounds attractive but one must be very careful. A sub-self S, which dies and transforms to its time reversal S_1 reincarnates eventually as sub-self S_2 with the original arrow of time. According to the assumption about first reduction to opposite boundary made S_2 emerges at time later than S died and this conforms with what is known. The time interval between two subsequence after images would give information about the average value of Δt. The after images need not be identical copies of the original and their color indeed changes.

An alternative interpretation is that after images are not re-incarnations but belong to a 4-D population of sub-selves. Our geometric past is alive and changes all the subjective time. This is not so confusing when one realize that ZEO means that conscious existence is essentially 4-dimensional. Also our memories are dynamical and change all the subjective time. Negative energy signals to geometric past which correspond to time reversed sub-selves indeed affect the geometric past and memory representations. In principle this kind of signalling could be carried out artificially to manipulate geometric past.

15.9.5 Re-incarnation and time reversed selves as basic predictions of TGD inspired theory of consciousness

Life has been hard for skeptics during last two decades. A typical skeptic has as building bricks of his ego the items in the list of notions that they regard as pseudoscientific. This allows to attack

the people who have the gift of imagination and passion for genuine understanding, which skeptics unfortunately do not possess. What makes attacks easy that no arguments based on contents are needed and the skeptic need not waste his time by trying to understand the arguments of the person to be labelled as pseudoscientist or crackpot.

The typical rhetoric tricks used begin from replacement of Dr X with Mr X and end up with the "conclusion" that the work of Mr X is totally incomprehensible. I have learned that rather often skeptic of this kind is an academic dropout who never managed to do his MsC. Obviously, the role of skeptic became a way to survive socially and retain the illusion "I am a scientist". During last decades the list of pseudoscientific notions has shortened item by item as quantum biology and quantum consciousness have emerged as respected branches of science. The notion of re-incarnation (see `http://tinyurl.com/jfpowqg`) has been certainly regarded as one of safest pillars supporting the ego of skeptic but even this pillar is in danger to fall down. Poor skeptics.

It is indeed amusing how fast the attitudes change as ideas evolve and experimental data emerge. Only few years ago I could not say anything definite about reincarnation in the framework of TGD inspired theory of consciousness. Now it has become an unavoidable prediction of zero energy ontology (ZEO), which itself is a "must" in TGD framework.

Reincarnation: a testable prediction?

The prediction related to re-incarnation is however not quite what one might have expected. In death of self a reincarnation as time reversed conscious entity takes place. For time reversed self subjective time evolution corresponds to evolution in a reverse direction of geometric time. The next death/reincarnation after this re-incarnation gives rise a mental image for which the arrow of geometric time is the original one.

Can one test this prediction? If one accepts the predicted fractal self hierarchy in which sub-selves correspond to mental images of self, this is possible. I am too lazy to retype basics about ZEO, CDs, and about how self as generalized Zeno effect emerges and just assume that reader knows the basic concepts or sees to trouble to refresh her knowledge about them.

1. Self hierarchy predicts that also our mental images are conscious entities. Motor-sensory dichotomy naturally corresponds to sub-self and time reversed sub-self. That is sensory mental image and that associated with motor action induced by sensory input. Motor action initiated in the geometric past at the opposite boundary of causal diamond (CD) (this explains Libet's finding that conscious decision is preceded by neural activity in geometric time). Note that motor action does not proceed from brain to muscles but in reversed time direction from muscles to brain! This conforms with the vision in which magnetic body is intentional agent.

2. To proceed one must identify EEG correlates for the sub-selves (mental images) and their time reversed re-incarnates. Here the work of Fingelkurts brothers (see `http://tinyurl.com/jpszfpy`) working in Finland helps [J79]. They postulate what they call operational architecture of brain (OA) having operations (O) and operational modules (OM) as building bricks. Quasi-stationary EEG segments are assumed to serve as correlates for operations and synchrony of these segments associated with various locations in brain tells that they belong to the same OM.

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Two sub-sequent quasi-stationary segments separated by RTP would correspond to sub-self and its re-incarnation in the original time direction. Note that a very brief period of geometric time defined by the duration of RTP identifiable as the duration of a unitary time evolution between two sub-sequent state function reductions at the same boundary of CD corresponds to a finite duration of experienced time - the lifetime of the time reversed mental image!

The testable prediction is that the segment corresponding to time-reversed sub-self is located in geometric past and runs in opposite direction of geometric time. This EEG segment should be assignable to motor response accompanying sensory mental image. This is a highly non-trivial prediction testing the new view about time.

3. One can check whether these EEG segments appear as pairs with first member assignable to sensory mental image and second one to motor mental image. Time reversal implies that second law is obeyed in "wrong" time direction for EEG segment assignable to the motor output and this can be tested. Already Fantappie [J121] discovered that both directions of (geometric) time appear in living matter and introduced the notion of syntropy as time reversal of entropy. Spontaneous molecular self-assembly is a basic example of a syntropic process and identifiable as a decay process in reverse direction of geometric time. Phase conjugation is known to occur for phase conjugate laser light and sound. Does a process analogous to self-assembly occur for segments of EEG associated with motor actions: is the motor part of EEG time reversed? To answer this question one needs phase information about EEG besides power spectrum. In principle this information is contained in EEG.

Do conscious entities with different time arrows interact?

Zero Energy Ontology (ZEO) predicts conscious entities with both arrows of geometric time. I find that forcing myself to think and write about this is difficult. The fear is that the whole nice scenario falls down by predicting something totally absurd. The questions that I try to avoid are following. What could these ghostly time-reversed entities be? Do they interact with those with standard time orientation? How could they do so?

Let us first briefly recall what ZEO based theory of consciousness says.

1. In ZEO self corresponds to a generalized Zeno effect that is sequence of state function reductions leaving the passive boundary of CD unaffected as also the members of state pairs associated with 3-surfaces at it. At active boundary the members of state pairs change and the active boundary drifts reduction by reduction farther away from passive boundary. The temporal distance between the tips of CD increases gradually and corresponds to the experience about flow of time.

2. Negentropy Maximization Principle (NMP) [K73] forces eventually self to die by making the first reduction to the passive boundary of its causal diamond (CD), which now becomes the active boundary: a new time reversed self is born. This option is forced because it produces more negentropy. For this self the arrow of geometric time would be opposite since now the formerly passive boundary would be active and shift in opposite direction of time: in this manner CD would steadily increase in size.

   Also the time-reversed self would eventually die and make the first reduction to the opposite - the original - boundary of CD. The position of the boundary of active boundary in first reduction would be shifted to the geometric future from the original position. The first and - as will be found - probably wrong guess for the size of shift towards geometric future from the position at the moment of previous death would be as the average increase of the temporal distance between tips of CD during Zeno period. This increment could be rather small as compared to the size of CD itself.

This picture raises questions.

1. Do we make this kind jump to time-reverse life at some level of our personal self hierarchy as we fall sleep? If wake-up period corresponds to re-incarnation in the original time direction, time increment of CD from its previous value would be the duration of sleeping period as seen

by a larger conscious system. This is much longer than the subjective chronon for sensory mental images about .1 seconds.

Remark: Note that EEG splits to pieces of duration about 300 ms and it might be possible to identify in EEG periods, which correspond to mental images and their time reversals. These periods could differ by a phase conjugation although the power spectrum would have the same typical behavior (sound wave and its phase conjugate have same power spectrum but we can distinguish sound and its time-reversal from each other).

Could the first big reduction correspond to a time increment, which is of the same order of magnitude as the total time duration of life-cycle of the time-reversed self? The size of 3-surfaces at the boundary of time-reversed CD has increased by about life-time. Could the first reduction to the opposite boundary increase the size of the 3-surface at this boundary by the same amount? If so, the re-incarnations for human life cycles would take roughly life-time after the death.

Could one identify negative energy time reversed signal as time-reversed self at some level of hierarchy? If so then the selves associated with CDs could gradually increase their energy by dying and re-incarnating repeatedly since the opposite boundary would increase also the magnitude of the negative energy at the opposite boundary. This is in principle possible since conservation laws hold true by the very definition of zero energy states as well as for classical time evolutions appearing in their quantum superposition. The average energy for a given member of pair defining zero energy state would increase gradually. The size of the CD associated with re-incarnating self could become arbitrary large and gain an arbitrary high total energy: the wildest speculation is that cosmologies correspond to very large selves [L45].

2. Could selves/systems living in opposite directions of time have direct interactions? If the vision that motor actions are realized as negative energy signals travelling to brain of the geometric past and induce neural activity fraction of second earlier than the conscious decision was made (Libet's finding), this could be the case. Motor action could correspond to a death of sensory self, reincarnation as time-reversed motor-self, and a re-incarnation as sensory self in time scale of .1 seconds. Sensory-motor cycle would correspond to a sequence of re-incarnations as time reversed sub-self.

3. How the time reversed selves could reveal themselves? If their presence can be indeed detected, a key signature would be the opposite direction of the thermodynamical arrow of time for them. Heat would be apparently transferred in wrong direction: from cold to hot. This kind of apparent breakings of second law have been observed: phase conjugate laser waves and acoustic signals represent examples of this. Fantappie suggested that they occur routinely in living matter and introduce the notion of syntropy as time reverse counterpart of entropy [J121]. The strange cooling of the air at magnetic walls associated with the rotating magnetic systems [L52] provides second example.

4. Good music is claimed to send cold shivers in spine and sensations of cold are assigned also with the perception of ghosts. Could the claims about encounters of ghosts be due to a perception of time reversed selves? I remember that in my personal great experience for three decades ago the entire body went into a state analogous to that created by a good music. Did I interact with a time reversed conscious entity? My experience indeed was that I was in contact with what I called Great Mind. This is of course just a subjective experience and the skeptic scientist knows that I was in a psychotic state since it is completely obvious from my scientific work even without reading it that I am a madman.

15.10 Appendix: TGD and quantum biology

The ontology behind the applications involves the notion of many-sheeted space-time, ZEO, hierarchy of Planck constants identified in terms of dark matter, and p-adic physics as physics of cognition. Also magnetic body (MB) carrying dark matter and energy having non-standard value of Planck constant $h_{eff} = n \times h$ identified as intentional agent represents new ontology. The additional assumption $h_{eff} = h_{gr}$ identifying h_{eff} with gravitational Planck constant is rather

powerful. Also p-adic length scale hypothesis is also central in applications. NMP is the basic variational principle of consciousness and means that living systems must do their best to build negentropy resources to avoid the first reduction to the opposite boundary of personal CD. This strong suggests that metabolic energy necessary for survival is needed to transfer NE from the nutrients and the ADP-ATP cycle is essentially transfer of NE in molecular scale.

15.10.1 The notion of magnetic body (MB)

MB is assumed to be carrier of dark matter.

1. The flux tubes of MB can suffer h_{eff} changing phase transitions inducing the change of the length of flux tube. This leads to a view about living matter as a network of bio-molecules connected by magnetic flux tubes. The ability of biomolecules to find each other in the dense molecular soup would rely on the reduction of h_{eff} bringing molecules near each other. The reconnections of flux tubes possible if the field strengths are same and therefore also cyclotron frequencies are identical are also expected to central element in bio-communications since they change the topology of the network and make possible analogs of relays.

   The receptors to which information molecules attach could be seen as plugs to which magnetic flux tubes having information molecule at its end attach and give rise to a fusion of two flux tubes to a longer flux tube connection. For instance, nerve pulse transmission would be more like building quantum connections than communication.

2. Flux tubes with large h_{eff} make possible high T_c superconductivity [K94, K95]. Superconducting structures would be pairs of flux tubes carrying magnetic fluxes which have same or opposite directions. Cooper pairs would have members at separate flux tubes.

MB as intentional agent

Magnetic field associated with a given system decomposes to flux tubes and sheets to that system has MB (MB). The physics of MBs could be a new chapter in physics and MB could define the basic space-time correlate for non-locality.

1. Flux tubes of MB would serve as correlates for quantum entanglement, which in TGD framework can be negentropic and for this reason rather stable under state function reductions. In GRT context the idea about wormholes as correlates of entanglement between blackholes is highly analogous. The problem with wormholes is that they are highly unstable. Magnetic flux tubes carrying monopole flux are stable since flux conservation prevents their pinching. The pairs of flux tubes wit opposite fluxes can however split to two U-shaped flux tubes by reconnection. It is important to notice that magnetic flux tubes are necessarily closed and can be regarded as flux running along different space-time sheets in opposite direction and from sheet to another through the wormhole contacts at ends.

   One can of course ask whether the braiding of flux tubes could be the correlate for entanglement. To my opinion entanglement without braiding is possible.

2. MB and dark matter at it would serve as intentional agent in biological systems [K31, K32, K33, K34]. The organism-environment duality would be replaced by the trinity MB-organism-environment. For instance, EEG and its strong correlation with brain state and consciousness could be understood in terms of communication of sensory data from cell membranes to MB and control and coordination signals from MB to biological body [K37]. Signals would consist of dark photons with with energies $E = h_{eff}f = n \times hf$ in bio-photon energy range and thus above thermal energies. For instance, the recently observed synchrony between hemispheres in absence of corpus callosum [J95] could be understood in terms of MB serving as "boss".

3. The formation of flux tube reconnections would serve as a correlate for directed attention - attention could be directed to objects of external world or to their representations in brain. The reconnection would take place for U-shaped flux tubes serving as kind of magnetic tentacles and lead to a formation of pairs of flux tubes connecting the two systems. If flux

tubes carry monopole flux as one has reasons to expect, the flux tubes would be actually closed two-sheeted structures (also elementary particles would be this kind of structures) and flux tube pair would be pair of these. The flux tubes of MBs would serve as analogs of wave guides along with precisely targeted communications of dark photon signals ("massless extremals" (MEs)) would be possible. Also supra currents would be possible and the TGD based model of high T_c superconductivity relies on the same mechanism [K94]. These communications would be essential in living matter.

4. The formation of reconnections and phases transitions $n \to m$ changing $h_{eff} = n \times h$ would be a basic mechanism behind biocohemistry. U-shaped flux tubes would act like tentacles emerging from the system and reconnection of the tentacles would build a connection between two systems. The reduction of Planck constant would shorten the connecting flux tubes and could force the systems in the vicinity of each other after which bio-catalysis could take place. Braiding and its 2-braid variant for string world sheets and partonic 2-surfaces in 4-D space-time instead of strings in 3-D space would make possible realization of quantum computer program like structures.

MB is 4-dimensional

MB as preferred extremal represents in terms of space-time topology and geometry 4-D self-organization patterns, behaviors, functions, and skills. What is new that self-organization occurs for 4-D patterns rather than 3-D ones. The entire process is replaced with a new one. Sequence of state function reductions leads from a 4-D self-organization pattern to an asymptotic 4-D self-organization pattern [K93].

Morphogenesis provides examples of this kind of phenomena [I52, I53, I67]. The first key idea is that DNA and cell replication is induced by the replication of MBs serving as information carriers (see `http://tinyurl.com/ydg6okkk`) [K93]. The second key idea is that in ZEO MB is 4-dimensional and represents behavioral patterns rather than only 3-dimensional patterns.

According to Michael Levin, concerning morphogenesis and morphostasis the basic challenge is to understand how the shape of the organism is generated and how it is preserved. The standard local approach based on belief on genetic determinism does not allow one to answer these questions satisfactorily.

1. The first approach to this problem relies on a self-organization paradigm in which the local dynamics of cells leads to large scale structures as self-organization patterns. In TGD framework 3-D self-organization is replaced with 4-D self-organization (the failure of strict determinism of the classical dynamics is essential motivating zero energy ontology (ZEO)). One can speak about 4-D healing: expressing it in somewhat sloppy manner, the space-time surface serving as a classical correlate for the patient is as a whole replaced with the healed one: after the 4-D healing process the organism was never ill in geometrical sense! Note that in quantal formulation one must speak of quantum superposition of space-time surfaces.

2. Second approach could be seen as computational. The basic idea is that the process is guided by a template of the target state and morphogenesis and healing are computational processes. What Levin calls morphogenetic fields would define this template. It is known that organisms display a kind of coordinate grid providing positional information that allows cells to "decide" about the profile of genetic expression (for references see [I53]). In TGD framework MB forming coordinate grid formed from flux tubes is a natural candidate for this structure. They would also realize topological quantum computation (TQC) with basic computational operations realized at the nodes of flux tubes to which it is natural to associate some biological sub-structures.

The assumption about final goal defining a template can be argued to be too strong: much weaker principle defining a local direction of dynamics and leading automatically to the final state as something analogous to free energy minimum in thermodynamics might be enough. Unfortunately, second law is the only principle that standard physics can offer. Negentropy Maximization Principle (NMP) provides the desired principle in TGD framework. Also the approach of WCW spinor field to the maximum of vacuum functional (or equivalently that of Kähler function) gives a goal for the

dynamics after the perturbation of the organism causing "trauma". If Kähler function is classical space-time correlate for entanglement negentropy, these two views are equivalent.

TGD thus suggests an approach, which could be seen as a hybrid of approaches based on self-organization and computationalism. The MB becomes the key notion and codes also for learned behaviors as TQC programs coded by the braiding of flux tubes. The replication of the MB means also the replication of the programs behind behavioral patterns (often somewhat misleadingly regarded as synonymous with long term memories): both structure and function are replicated. This hypothesis survives the killer tests provided by the strange findings about planaria cut into two and developing new head or tail while retaining its learned behaviors: the findings indicate that behavioral programs are preserved although planaria develops a new brain.

$h_{gr} = h_{eff}$ hypothesis

Nottale [E1] introduced originally the notion of gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where M is large mass such as that of Earth or Sun and m the mass of quantum coherent object and v_0 is a parameter with dimensions of velocity [E1]. Nottale did not propose macroscopic quantum coherence in astrophysical scales but in TGD framework this is a natural option [K112, K87].

The obvious question is whether the gravitational Planck constant deduced from the Nottale's considerations and the effective Planck constant $h_{eff} = n \times h$ deduced from ELF effects on vertebrate brain and explained in terms of non-determinism of Kähler action could be identical. At first this seems to be non-sensical idea since $\hbar_{gr} = GMm/v_0$ has a gigantic value. The hypothesis $h_{eff} = h_{gr}$ leads to much stronger predictions [K90, K31, K32, K33, K34] than either hypothesis alone. One can also introduce analogs of h_{gr} for other interactions: the idea is that when the coupling strength between two charges becomes so large that perturbation theory does not exist, a phase transition increasing the Planck constant happens and guarantees the convergence.

The essential point is that h_{eff} and h_{gr} would characterized body parts of MB: this allows to understand the dependent on masses of two particles. The flux tubes with a given value of h_{eff} would carry only particles of particular mass m so that the random soup of biomolecules would become a highly ordered structure analogous to library in which each book type is its own shelf. Furthermore, the cyclotron energies $E_c \propto h_{eff}/m$ would be same irrespective of particle mass m although cyclotron frequencies are different.

The proposed identification of the energy range of dark photon cyclotron energies in living matter is as visible and UV range assigned to bio-photons which would therefore result in the transformation of dark photons to ordinary photons. Further important point, is that the energy spectrum would be in the range of molecular excitation energies (visible and UV range) so that dark photons transformed to ordinary ones would allow MBs to control biochemistry.

By Equivalence Principle one can describe gravitational interaction by reducing it to elementary particle level. For instance, gravitational Compton lengths do not depend at all on the masses of particles. Also the radii of the planetary orbits are independent of the mass of particle mass in accordance with Equivalence Principle. For elementary particles the values of h_{gr} are in the same range as in quantum biological applications. Typically 10 Hz ELF radiation should correspond to energy $E = h_{eff}f$ of UV photon if one assumes that dark ELF photons have energies of biophotons and transform to them. The order of magnitude for n would be therefore $n \simeq 10^{14}$.

The experiments of M. Tajmar *et al* [E4, E5] discussed in [K117] provide a support for this picture. The value of gravimagnetic field needed to explain the findings is 28 orders of magnitude higher than theoretical value if one extrapolates the model of Meissner effect to gravimagnetic context. The amazing finding is that if one replaces Planck constant in the formula of gravimagnetic field with h_{gr} associated with Earth-Cooper pair system and assumes that the velocity parameter v_0 appearing in it corresponds to the Earth's rotation velocity around its axis, one obtains correct order of magnitude for the effect requiring $r \simeq 3.6 \times 10^{14}$.

The most important implications are in quantum biology and Penrose's vision about importance of quantum gravitation in biology might be correct.

1. This result allows by Equivalence Principle the identification $h_{gr} = h_{eff}$ at elementary particle level at least so that the two views about hierarchy of Planck constants would be equivalent. If the identification holds true for larger units it requires that space-time sheet identifiable as quantum correlates for physical systems are macroscopically quantum coherent

and gravitation causes this. If the values of Planck constant are really additive, the number of parallel space-time sheets corresponding to non-determinism evolution for the flux tube connecting systems with masses M and m is proportional to the masses M and m using Planck mass as unit. Information theoretic interpretation is suggestive since hierarchy of Planck constants is assumed to relate to negentropic entanglement very closely in turn providing physical correlate for the notions of rule and concept.

2. That gravity would be fundamental for macroscopic quantum coherence would not be surprising since by EP all particles experience same acceleration in constant gravitational field, which therefore has tendency to create coherence unlike other basic interactions. This in principle allows to consider hierarchy in which the integers $h_{gr,i}$ are additive but give rise to the same universal dark Compton length.

3. An interesting question is how large systems can behave as coherent units with $\hbar_{gr} = GMm/v_0$. In living matter one might consider the possibility that entire organism might be this kind of system. Interestingly, for larger masses the gravitational quantum coherence would be easier. For particle with mass m $h_{gr}/h > 1$ requires larger mass to satisfy $M > M_P^2/m_e$. The first guess that life has evolved from long to shorter scales and reached elementary particle last. Planck mass is the critical mass corresponds to the mass of water blog with volume of size scale of 10^{-4} m (big neuron) is the limit.

The general proposal discussed above is testable. In particular, a detailed study of molecular energies with those associated with resonances of EEG could be highly rewarding and reveal the speculated spectroscopy of consciousness.

EEG as communications between MB and BB

Models of EEG and nerve pulse are basic applications of the notion of MB in neuroscience. The basis idea is that EEG and its fractal counterparts are communications to the various layers of MB having onion-like structure with cyclotron frequency correlating with the size of the layer. Josephson junctions about which basic example is cell membrane would communicate sensory information to MB as dark photons.

The general model for EEG follows neatly from this picture combined with the general model of high T_c superconductivity [K94, K95]. A fractal hierarchy of EEGs and its generalizations identified in terms of generalized Josephson radiation is predicted with levels labeled by p-adic length scales and the value of $\hbar$ at various levels of dark matter hierarchy [K37]. At macrolevel one can approximate neuronal and axonal (and also cell-) membrane as Josephson junction formed by the two lipid layers of the membrane. At microscopic level ionic pumps and channels defined by Josephson junctions involving magnetic flux tubes connecting interior and exterior of the cell.

"Generalized" means that Josephson frequency as energy difference $E = ZeV/h_{eff}$ of Cooper pair for membrane potential is replaced with the sum of difference of cyclotron energies and E. This implies that the variations of membrane potential by oscillations and nerve pulses induced frequency modulation of the frequency of dark photons sent to the MB. This defines a coding of the information carried by nerve pulses do dark photons. Whale's song represents a good analogy for the coding. Besides EEG one would have its counterparts for various organs, organelles and even cell.

Experimental evidence for MB

The team led by Michael Tyszka, associate director of Caltech Brain Imaging Center, has however discovered that the resting state network seems to work normally in people born without corpus callosum [J95] (see `http://tinyurl.com/3gjhtgb`)! As if brain hemispheres were communicating by some other means than neural signalling! This finding challenges not only the views about the origin of brain synchrony as being created by neural circuits but also the models of autism and schizophrenia explaining them in terms of impaired communications between hemispheres.

The MB of entire brain controls it and could naturally do this via the intermediate control of brain hemispheres forcing them to operate in the same rhythm. Brain synchrony and resting network would not be produced by resonant neuro-circuits as usually believed but by the spatiotemporal coherence of the EEG radiation from the MB of entire brain forcing brain hemisphere

MBs to oscillate in the same rhythm and in turning synchronizing the brain hemispheres [K92]. This would be like forcing soldiers to march in the same pace and brain hemispheres could cooperate without any neural communication between hemispheres. The communication between hemispheres would be needed for more refined collaboration involving "discussion" between hemispheres: hemispheres of a person without corpus callosum would be like soldiers obeying blindly the orders. This might be also an essential element of autism and schizophrenia.

15.10.2 MB and biology

MB could play a key role in biology as intentional agent using biological body as motor instrument. MB could even serve as a template for biomolecules and even that fundamental bio-chemical processes are induced by those for MB. Dark cyclotron photons transformed to ordinary photons would be the fundamental control tool of MB. Also reconnection of flux tubes, change of length of flux tubes induced by the change of the value of $h_{eff} = h_{gr}$, superconductivity associated with a pair of flux tubes could be fundamental control mechanisms.

MB, biophotons, and biochemistry

The model for quantum biology relying on the notions of MB and dark matter as hierarchy of phases with $h_{eff} = nh$, and biophotons [K25, K15] identified as decay produces of dark photons. The assumption $h_{gr} \propto m$ becomes highly predictable since cyclotron frequencies would be independent of the mass of the ion.

1. If dark photons with cyclotron frequencies decay to biophotons, one can conclude that biophoton spectrum reflects the spectrum of endogenous magnetic field strengths. In the model of EEG [K37] it has been indeed assumed that this kind spectrum is there: the inspiration came from music metaphors suggesting that musical scales are realized in terms of values of magnetic field strength. The new quantum physics associated with gravitation would also become key part of quantum biophysics in TGD Universe.

2. For the proposed value of h_{gr} 1 Hz cyclotron frequency associated to DNA sequences would correspond to ordinary photon frequency $f = 3.6 \times 10^{14}$ Hz and energy 1.2 eV just at the lower limit of visible frequencies. For 10 Hz alpha band the energy would be 12 eV in UV. This plus the fact that molecular energies are in eV range suggests very simple realization of biochemical control by MB. Each ion has its own cyclotron frequency but same energy for the corresponding biophoton.

3. Biophoton with a given energy would activate transitions in specific bio-molecules or atoms: ionization energies for atoms except hydrogen have lower bound about 5 eV (`http://tinyurl.com/233vcad`). The energies of molecular bonds are in the range 2-10 eV (`http://tinyurl.com/yccmm7mm`). If one replaces v_0 with $2v_0$ in the estimate, DNA corresponds to.62 eV photon with energy of order metabolic energy currency and alpha band corresponds to 6 eV energy in the molecular region and also in the region of ionization energies.

   Each ion at its specific magnetic flux tubes with characteristic palette of magnetic field strengths would resonantly excite some set of biomolecules.This conforms with the earlier vision about dark photon frequencies as passwords.

   It could be also that biologically important ions take care of their ionization self. This would be achieved if the magnetic field strength associated with their flux tubes is such that dark cyclotron energy equals to ionization energy. EEG bands labelled by magnetic field strengths could reflect ionization energies for these ions.

It must be made clear that TGD has had an interpretational problem related to the identification of biophotons as decay product of dark protons [K31, K32, K33, K34, K90]. The resolution of this problem leads to conclusion that both Earth's and galactic MBs control living matter with EEG related by scaling. This would be rather dramatic realization of non-locality.

The problem is following. If one wants bio-photon spectrum to be in visible-UV range assuming that bio-photons correspond to cyclotron photons, one must reduce the value of $r = h_{gr}B_{end}/mv_0$ for Earth particle system by a factor of order $k = 2 \times 10^{-4}$. r does not depend on

the mass of the charged particle. One can replace B_{end} with some other magnetic field having value which is considerably smaller. One can also increase the value of v_0.

1. For h_{gr} determined by Earth's mass and $v_0 = v_{rot}$, where $v_{rot} \simeq 1.55 \times 10^{-6} c$ is the rotation velocity of Earth around its axis and for $B_{end} \to B_{gal} = 1$ nT, where B_{gal} is typical strength of galactic magnetic field, the energy of dark cyclotron energy is 45 eV (UV extends to 124 eV). This is roughly by a factor 50 higher than the lower bound for the range of bio-photon energies. One possibility is that B_{gal} defines the upper limit of the dark photon energies and has variation range of at least 7 octaves with lower limit roughly 1/50 nT.

   One can also consider the possibility B_{gal} defines lower bound for the magnetic field strengths involved and one has $v_0 > v_{rot}$. For sun the rotation velocity at Equator is $v_{rot} = 2 \times 10^{-5}$ m/s and v_0 is $v_0 \simeq 5.8 \times 10^{-4} c$. One has $v_0/v_{rot} \simeq 29.0$. If same is true in case of Earth, the value of the energy comes down from 25 eV to 1.6 eV which corresponds to visible wave length.

   The assignment of B_{gal} to gravitational flux tubes is very natural. Now however the frequencies of dark variants of bio-photons would not be in EEG range: 10 Hz frequency would correspond to $5 \times 10{-}4$ Hz with period of 42 min. The time scale of 42 min is however very natural concerning consciousness and could be involved with longer bio-rhythms. Scaled EEG spectrum with alpha band around 46 min naturally assignable to diurnal sub-rhythms could be a testable prediction. Natural time would be sidereal (galactic) time with slightly different length of day and this allows a clear test. Recall the mysterious looking finding of Spottiswoode that precognition seems to be enhanced at certain time of sidereal day [J114]. Cyclotron frequency 1 Hz would correspond to 7 hours. One can ask whether 12 hours (25) is the natural counterpart for the cyclotron frequency 1 Hz assignable to DNA. This would correspond to lower bound $B_{gal} \to 7B_{gal}/12 \simeq .58$ nT or to $v_0 \to 1.7 v_0$.

2. The idea has been that it is dark EEG photons, which correspond to bio-photons. Could one assign bio-photons also to dark EEG so that magnetic fields of Earth and galaxy would correspond to two different control levels? If $B_{end} = .2$ Gauss is assumed to determine the scale of the magnetic field associated with the flux tubes carrying gravitational flux tubes, one must reduce h_{gr}. The reduction could be due to $M \to M_D = kM$ and due to the change of v_0. k could characterize the dark matter portion of Earth but this assumption is not necessary.

   This would require $k = M_{dark,E}/M_E \simeq 5 \times 10^{-5}$ if one does not change the value of v_0. This value of k equals to the ratio of B_{gal}/B_{end} and would be 1/4:th of $k = 2 \times 10^{-4}$. One might argue that it is indeed dark matter to which the gravitational flux tubes with large value of Planck constant connect biomatter.

3. Suppose that one does not give up the idea that also Earth mass gives rise to h_{gr} and scaled analog of EEG. Then M_D must correspond to some mass distinguishable from and thus outside Earth. The simplest hypothesis is that a spherical layer around Earth is in question. TGD based model for spherical objects indeed predict layered structures [K132]. There are two separate anomalies in the solar system supporting the existence of a spherical layer consisting of dark mass and with radius equal to the distance of Moon from Earth equal to 60.3 Earth radii [K112]. The first anomaly is so called Flyby anomaly and second one involves a periodic variation of both the value of the measured Newton's constant at the surface of Earth and of the length of the day. The period is about 6 years and TGD predicts it correctly.

   One can imagine that dark particles reside at the flux tubes connecting diametrically opposite points of the spherical layer. Particles would experience the sum of gravitational forces summing up to zero in the center of Earth. Although the layer would be almost invisible (or completely invisible by argument utilizing the analogy with conducting shell) gravitationally in its interior, $h_{gr} = M_D m/v_0$ would make itself visible in the dynamics of dark particles! This layer could represent magnetic Mother Gaia and EEG would take care of communications to this layer.

   The rotation velocity $v_{rot,M} \simeq 2.1 \times v_{rot,E}$ of Moon around its axis is the first guess for the parameter v_0 identifiable perhaps as rotation velocity of the spherical layer. A better guess

is that the ratio $r = v_0/v_{rot,M}$ is the same as for Sun and as assumed above for Earth. This would give for the ratio of cyclotron frequency scales $r = (B_{end}/B_{gal}) \times 2.1$. 66.7 min, which corresponds to $B_{gal} = .63$ nT, would correspond to .1 s. For this choice 1 Hz DNA cyclotron frequency would correspond 11.7 h rather near to 12 h. This encourages the hypothesis that 72 min is the counterpart of .1 s cyclotron time. The cyclotron time of DNA (very weakly dependent on the length of DNA double strand) in B_{gal} (or its minimum value) would be 12 h.

Magnetic body of Earth controlling bio-dynamics would be a dramatic manifestation of non-locality to say nothing about the control performed by galactic magnetic body. M_D would be associated with the magnetic Mother Gaia making life possible at Earth together with magnetic Mother Galactica. Both MBs would be in continual contact with biomolecules like ATP and the molecules for which ATP attaches or provides the phospate. Metabolic energy would be used to this process. These MBs would be Goddesses directing its attention to tiny bio-molecules. If this picture is correct, the ideas about consciousness independent on material substrate and assignable to a running computer program can be safely forgotten.

Model for the flux tube connections between biomolecules

A more concrete TGD based model for the flux tubes connections between molecules relies on the general ideas of TGD inspired quantum biology [K71].

1. Biomolecules containing aromatic rings are known to play a fundamental role. For instance, most neurotransmitters and psychoactive drugs involve aromatic rings). All DNA nucleotides contain them and there are 4 proteins, which also have them. Trp and phe are of special importance and form a pair structurally analogous to a base pair in DNA strand. The rings are assumed to carry the analog of supra current and be in or at least be able to make transition to a state with large $h_{eff} = n \times h$. The delocalization of electron pairs in aromatic ring could be a signature of $h_{eff}/h > 1$.

2. Trp-phe pairing [K71] would be responsible for information molecule-receptor pairing. Information molecule and receptor would be at the ends of flux tubes serving as communication lines, and the attachment of info molecule to receptor would fuse the two flux tubes to longer one. After that communication would become possible as dark photon signals and dark supra currents. Formation of info molecule-receptor complex would be like clicking icon generating a connection between computers in net. Info molecules would generate the communication channels - they would not yet be the signals. This distinguishes TGD view from standard neuroscience.

3. All quantum critical phenomena involve generation of large h_{eff} phases and changes of h_{eff} in the sense that their values are different at different ends of space-time surface at boundaries of CD. Folding emerges or disappears at QC possible in certain temperature range of width about 40 K and depending on pH. The flux tubes associated with phe and trp containing aromatic rings carrying "supra current" would become dark (either $h \to h_{eff}$ or $h_{eff} > h$ increases) and thus much longer and reconnect temporarily and force phe and trp in a close contact after the reverse transition inducing shortening. This is a general mechanism making biomolecules able to find each other in what looks like molecular soup in the eyes of standard biochemist. The contacts between amino-acids phe and trp formed in this manner would be structurally identical with the hydrogen bonding between members of DNA base pairs and they would fix the final folding pattern to high degree.

Pollack's mechanism

The discovery of negatively charged exclusion zone formed in water bounded by gel phase has led Pollack to propose the notion of gel like fourth phase of water [L31, I74, I60] (see `http://tinyurl.com/oyhstc2`). The proposal is that the fourth phase corresponds to negatively charged regions - exclusion zones - with size up to 100-200 microns generated when energy is fed into the water - say as radiation, in particular solar radiation. The stoichiometry of the exclusion zone is

$H_{1.5}O$ and can be understood if every fourth proton is dark proton residing at the flux tubes of the MB assignable to the exclusion zone and outside it [L31] [K71].

This leads to a model for prebiotic cell as exclusion zone. Dark protons are proposed to form dark nuclear strings whose states can be grouped to groups corresponding to DNA, RNA, amino-acids, and tRNA and for which vertebrate genetic code is realized in a natural manner [L3, K53]. The voltage associated with the system defines the analog of membrane potential, and serves as a source of metabolic energy as in the case of ordinary metabolism. The energy is liberated in a reverse phase transition in which dark protons transform to ordinary ones. Dark proton strings serve as analogs of basic biopolymers and one can imagine analog of bio-catalysis with enzymes replaced with their dark analogs.

Pollack's exclusion zones (EZs) might for instance explain why DNA is negatively charged. EZs or their generalization could play fundamental role in metabolism with protons running through mitochondrial membrane being dark as also other biologically important ions involved. EZs could be important even in electrolysis and allow to explain what happens in cold fusion. These hypothesis could be tested.

Why metabolism is needed?

The simplest and at the same time most difficult question that innocent student can make about biology class is simple: "Why we must eat?". Or using more physics oriented language: "Why we must get metabolic energy?". The answer of the teacher might be that we do not eat to get energy but to get order. The stuff that we eat contains ordered energy: we eat order. But order in standard physics is lack of entropy, lack of disorder. Student could get nosy and argue that excretion produces the same outcome as eating but is not enough to survive.

We could go to a deeper level and ask why metabolic energy is needed in biochemistry. Suppose we do this in TGD Universe with dark matter identified as phases characterized by $h_{eff}/h = n$. At deeper level metabolic energy should closely relate to negentropic entanglement (NE) and thus information. Identification of these two is however not possible. I have considered several answers to the question why metabolic energy is needed. Here two answers will be discussed.

1. Conscious information could be the basic currency and the transfer of metabolic energy and metabolites would make possible transfer of NE. Is the transfer of metabolic energy essentially transfer of NE? Could the transfer of NE require metabolic energy? NE transfer could be transfer of systems consisting of negentropically entangled parts or it could be transfer of NE with larger system, even Earth. NMP would force the systems to fight for NE and this would lead to the fight for metabolic resources. The transfer of entanglement is the basic mechanism in quantum computation and would mean in biology stealing of NE, the fundamental crime! The ideas related to metabolism in TGD Universe are discussed in detail in [K59].

2. Could metabolic energy needed to generate NE from scratch? For this option the molecules providing the metabolic energy contain dark atoms. Of course, the nutrients could already contain the negentropic entanglement and photosynthesis could serve as fundamental generator of NE. The following naïve model for dark atoms obtained by replacing h with h_{eff} supports this view.

   (a) The binding energy spectrum of dark hydrogen atom is scaled by $1/n^2$, $n = h_{eff}/h$ (do not confuse this n with the integer n labelling the states of hydrogen atom!) so that generation of dark hydrogen atoms would require energy. Dark atoms have smaller binding energies and their creation by a phase transition increasing the value of n demands a feed of energy - metabolic energy! If the metabolic energy feed stops, n is gradually reduced. System gets tired, loses consciousness, and eventually dies. Also in case of cyclotron energies the positive cyclotron energy is proportional to h_{eff} so that metabolic energy is needed to generate larger h_{eff} and prerequisites for negentropy.

   (b) The analogy of weak form of NMP following from mere adelic physics makes it analogous to second law. Could one consider the purely formal generalization of $dE = TdS - ..$ to $dE = -TdN - ...$, where E refers to metabolic energy and N refers to entanglement negentropy? No: the situation is different. The system is not closed system; N is not

the negative of thermodynamical entropy S; and E is the metabolic energy feeded to the system, not the system's internal energy. $dE = TdN - ...$ might however make sense for a system to which metabolic energy is feeded.

The identification of N is still open: N could be identified either as $N = \sum_p N_p - S$, where one has sum of p-adic entanglement negentropies and real entanglement entropy S or as $N = \sum_p N_p$. For the first option one would have $N = 0$ for rational entanglement and $N \geq 0$ for extensions of rationals. Could rational entanglement be interpreted as that associated with dead matter in this case?

(c) Bio-catalysis and ATP$\leftrightarrow ADP$ process need not require metabolic energy. A transfer of negentropy from nutrients to ATP to acceptor molecule would be in question. Metabolic energy would be needed to reload ADP with negentropy to give ATP by using ATP synthase as a mitochondrial power plant. Metabolites could be carriers of dark atoms of this kind possibly carrying also NE. They could also carry NE associated with the dark cyclotron states as suggested earlier and in this case the value of $h_{eff} = h_{gr}$ would be much larger than in the case of dark atoms.

(d) What is remarkable that the scale of atomic binding energies decreases with n only in dimension $D = 3$. In other dimensions it increases and in $D = 4$ one cannot even speak of bound states! This can be easily found by a study of Schrödinger equation for the analog of hydrogen atom in various dimensions [L46]. Life based on atomic metabolism seems to make sense only in spatial dimension $D = 3$. Note however that there are also other quantum states than atomic states with different dependence of energy on h_{eff}.

Identification of NE possibly transferred in metabolism

I have considered several identifications of NE.

1. NE could be small scale entanglement - say between molecules having dark atoms. The short scale of entanglement does not conform with the large values of h_{gr}. One can however have also $h_{eff}/h = h_{em}/h = Z_1 Z_2 \alpha_{em}$. This would give rise to NE in short scales. The transfer of metabolic energy in ATP $\leftrightarrow$ ADP process could correspond to the transfer of short ranged NE.

2. NE could be between nutrient and larger structure - say Earth, Sun, or some other large enough structure to give a value of $\hbar_{gr} = GMm/v_0$ guaranteeing that dark cyclotron energies (no dependence on mass m) in the range of bio-photon energies (visible and UV) and guarantee that EEG frequencies correspond to these energies. This option discussed in [K90]. Also long range entanglement could be present and correspond to a higher evolutionary level. A possible candidate for the larger structure could be a spherical layer at the distance of Moon from Earth would give correct value for $h_{eff} = h_{gr}$ [K90].

   Nutrients could be carriers of both metabolic energy and of NE - both short and long ranged. Even electrons can provide metabolic energy and in TGD framework therefore also NE for some bacteria (see `http://tinyurl.com/o8xqh6g`): in this case only short range entanglement would be involved.

3. NE could be also between a larger structure and phosphate molecule added to ADP using metabolic energy. This option would predict that phosphates are in unique role as standard entanglers to mass M. Any source of metabolic energy is in principle possible since metabolic energy is only needed to transfer the flux tube connecting phosphate to mass M to ADP so that ATP is obtained. The flux tube would represent the "high energy phosphate bond". ATP in turn attaches the flux tube to biomolecule, which becomes negentropically entangled. Metabolism would be make the transfer of NE possible. Metabolites would not contain information but it would be assignable to the flux tube between phosphate and mass M. Magnetic Mother Gaia would have very concrete meaning.

What happens in bio-catalysis?

Bio-catalysis is key mechanism of biology and its extreme efficacy remains to be understood. Enzymes are proteins and ribozymes RNA sequences acting as biocatalysts.

1. Conditions on bio-catalysis

What catalysis demands?

1. Catalyst and reactants must find each other. How this could happen is very difficult to understand in standard biochemistry in which living matter is seen as soup of biomolecules. I have already already considered the mechanisms making it possible for the reactants to find each other. For instance, in the translation of mRNA to protein tRNA molecules must find their way to mRNA at ribosome. The proposal is that reconnection allowing U-shaped magnetic flux tubes to reconnect to a pair of flux tube connecting mRNA and tRNA molecule and reduction of the value of $h_{eff} = n \times h$ inducing reduction of the length of magnetic flux tube takes care of this step. This applies also to DNA transcription and DNA replication and bio-chemical reactions in general.

2. Catalyst must provide energy for the reactants (their number is typically two) to overcome the potential wall making the reaction rate very slow for energies around thermal energy. The TGD based model for the hydrino atom having larger binding energy than hydrogen atom claimed by Randell Mills [D9] suggests a solution [L46]. Some hydrogen atom in catalyst goes from (dark) hydrogen atom state to hydrino state (state with smaller h_{eff}/h and liberates the excess binding energy kicking the either reactant over the potential wall so that reaction can process. After the reaction the catalyst returns to the normal state and absorbs the binding energy.

3. In the reaction volume catalyst and reactants must be guided to correct places. The simplest model of catalysis relies on lock-and-key mechanism. The generalized Chladni mechanism forcing the reactants to a two-dimensional closed nodal surface is a natural candidate to consider. There are also additional conditions. For instance, the reactants must have correct orientation. For instance, the reactants must have correct orientation and this could be forced by the interaction with the em field of ME involved with Chladni mechanism.

4. One must have also a coherence of chemical reactions meaning that the reaction can occur in a large volume - say in different cell interiors - simultaneously. Here MB would induce the coherence by using MEs. Chladni mechanism might explain this if there is there is interference of forces caused by periodic standing waves themselves represented as pairs of MEs.

2. Phase transition reducing the value of $h_{eff}/h = n$ as a basic step in bio-catalysis

Hydrogen atom allows also large $h_{eff}/h = n$ variants with $n > 6$ with the scale of energy spectrum behaving as $(6/n)^2$ if the $n = 4$ holds true for visible matter. The reduction of n as the flux tube contracts would reduce n and liberate binding energy, which could be used to promote the catalysis.

The notion of high energy phosphate bond is somewhat mysterious concept and manifests as the ability provide energy in ATP to ADP transition. There are claims that there is no such bond. I have spent considerable amount of time to ponder this problem. Could phosphate contain (dark) hydrogen atom able to go to the a state with a smaller value of $h_{eff}/h_{\rm i}$ and liberate the excess binding energy? Could the phosphorylation of acceptor molecule transfer this dark atom associated with the phosphate of ATP to the acceptor molecule? Could the mysterious high energy phosphate bond correspond to the dark atom state. Metabolic energy would be needed to transform ADP to ATP and would generate dark atom.

Could solar light kick atoms into dark states and in this manner store metabolic energy? Could nutrients carry these dark atoms? Could this energy be liberated as the dark atoms return to ordinary states and be used to drive protons against potential gradient through ATP synthase analogous to a turbine of a power plant transforming ADP to ATP and reproducing the dark atom and thus the "high energy phosphate bond" in ATP? Can one see metabolism as transfer of dark atoms? Could possible negentropic entanglement disappear and emerge again after ADP$\rightarrow$ ATP.

Here it is essential that the energies of the hydrogen atom depend on $\hbar_{eff} = n \times h$ in as $\hbar_{eff}^m$, $m = -2 < 0$. Hydrogen atoms in dimension D have Coulomb potential behaving as $1/r^{D-2}$ from Gauss law and the Schrödinger equation predicts for $D \neq 4$ that the energies satisfy $E_n \propto (h_{eff}/h)^m$, $m = 2+4/(D-4)$. For $D = 4$ the formula breaks since in this case the dependence on $\hbar$ is not given by power law. m is negative only for $D = 3$ and one has $m = -2$. There $D = 3$ would be unique dimension in allowing the hydrino-like states making possible bio-catalysis and life in the proposed scenario.

It is also essential that the flux tubes are radial flux tubes in the Coulomb field of charged particle. This makes sense in many-sheeted space-time: electrons would be associated with a pair formed by flux tube and 3-D atom so that only part of electric flux would interact with the electron touching both space-time sheets. This would give the analog of Schrödinger equation in Coulomb potential restricted to the interior of the flux tube. The dimensional analysis for the 1-D Schrödinger equation with Coulomb potential would give also in this case $1/n^2$ dependence. Same applies to states localized to 2-D sheets with charged ion in the center. This kind of states bring in mind Rydberg states of ordinary atom with large value of n.

The condition that the dark binding energy is above the thermal energy gives a condition on the value of $h_{eff}/h = n$ as $n \leq 32$. The size scale of the dark largest allowed dark atom would be about 100 nm, 10 times the thickness of the cell membrane.

Chapter 16

Does Consciousness Survive Bodily Death?

16.1 Introduction

The questions of this essay is "*What is the best possible evidence for the survival of human consciousness after bodily death?* ". It is very difficult to provide water tight evidence for life after death since near-death experiences (NDEs) are subjective and do not offer objective proof.

By re-framing the question as one that addresses consciousness, the situation changes. That is, a theory of consciousness inspired by Topological Geometrodynamics (TGD) [L133], which derives from a broader proposal for the unification of fundamental interactions, provides a general theory of consciousness in which consciousness, life and death are universal phenomena. The theory makes testable predictions at all scales and supports the view that consciousness survives death albeit not in the way one might expect.

The following represents a broad overview of the theory. A glossary of terms that may be alien to the lay reader is provided at the end of the essay.

1. Zero Energy Ontology (ZEO) [L149] solves the basic problem of quantum measurement theory and extends quantum measurement theory to a theory of consciousness. The observer is repositioned from an outsider to an intrinsic part of the system - the conscious entity or self. The self is born, lives and dies.

   The moments of birth and death correspond to what I describe as "Big" State Function Reductions (BSFRs) as counterparts to the ordinary state function reductions (SFRs). What is new is that in the BSFR the self re-incarnates with an opposite arrow of time (AT). Life corresponds to a sequence of "Small" State Function Reductions (SSFRs) in which AT does not change. SSFRs are analogs of "weak" measurements analogous to classical measurements (`http://tinyurl.com/zt36hpb`).

2. A number theoretic view of cognition generalizes real number based physics to adelic physics [L69, L73] involving not only reals but also p-adic number fields and their extensions. One outcome is the identification of dark matter as phases of ordinary matter labelled by extensions of rationals (EQ). The dimension n of EQ is identifiable in terms of the effective Planck constant $h_{eff} = nh_0$ ($h = 6h_0$ is suggested by the findings of Mills [D9] [L75]).

   EQ induces extensions of p-adic number fields serving as correlates of cognition. [L69, L73]. " n" measures the algebraic complexity of these extensions and therefore a universal measure for the level of cognition not restricted to human brain or even living matter. " n" also serves as a measure for the scale of quantum coherence typically proportional to h_{eff}. For these reasons, " n" serves as a kind of universal "intelligence quotient" (IQ).

   Quantum coherence, consciousness, and life are predicted to be possible in arbitrarily long length - and time scales so that the notions of life and death are universal.

3. TGD provides a new view of space-time, classical gauge fields, and gravitational fields. The identification of space-time as a 4-D surface in certain 8-D space-time fixed by the standard

model (SM) symmetries leads to a geometrization of the classical fields and their elimination as primary dynamic variables: once the space-time surface X^4 is known, all classical fields are also known. The many-sheeted space-time of TGD is locally extremely simple but topologically extremely complex whereas the space-time of General Relativity (GRT) is topologically extremely simple but locally complex.

The notions of a field body (FB) and its special case *magnetic body* (MB) are central. In Maxwellian theory, the fields of different objects superpose and in this superposition information is lost. In TGD, the fields of distinct objects in general correspond to separate space-time sheets and the fields do not superpose so that information is not lost. This distinction is crucial to TGD inspired quantum biology. By its higher "IQ" (algebraic complexity measured by $n = h_{eff}/h_0$), MB carrying dark matter in the TGD sense acts as a master which controls the layers of MB with a smaller value of "n" and also the ordinary biomatter at the bottom of the hierarchy. This makes life in all its variety possible at all scales.

The following describes this theory in more detail and some of the applications that suggest an affirmative answer to the question posed in this essay contest. In the TGD Universe, fractality replaces length scale reductionism as a foundational concept, and the notions of life and death are universal so that the question can be formulated in a much wider framework.

The plan of the article is as follows:

1. Section 1: TGD as a solution of the energy problem of GRT by replacing the Einsteinian space-time with 4-surface or as a generalization of string models by replacing string world sheets with 4-surfaces; the dual views of TGD reducing physics to geometry or to number theory; examples of applications.

2. Section 2: TGD inspired theory of consciousness as a generalization of quantum measurement theory based on ZEO and negentropy maximization principle (NMP).

3. Section 3: TGD inspired quantum biology relying on the notions of MB and dark matter as a hierarchy of phases with effective Planck constant $h_{eff}/h_0 = n$.

4. Section 4: TGD view of the brain.

5. Section 5: Aging and death understood in ZEO as universal phenomena.

6. Section 6: Evidence for life after death in the TGD Universe.

7. Section 7: A model for biological death and near death experiences (NDEs).

List of abbreviations:

TGD: Topological Geometrodynamics
QFT: Quantum field theory
GCI: General Coordinate Invariance
SH: Strong form of holography
EP: Equivalence Principle
EQ: Extension of rationals
ZEO: Zero energy ontology
CD: Causal diamond
AB: active boundary of CD PB: passive bounddary of CD SFR: State function reduction
BSFR: "Big" (ordinary) SFR
SSFR: "Small" SFR
NMP: Negentropy Maximization Principle
SL: Second Law of thermodynamics
AT: Arrow of time
NE: Negentropic entanglement
FB: Field body
MB: Magnetic body
BB: Biological body

RMS: Rotating magnetic system
NDE: Near-death experience
OBE: Out-of-body experience

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16.2 Brief summary of TGD

Topological Geometrodynamics is a proposal for a unification of fundamental interactions on which I have worked for the past 43 years. The books "Topological Geometrodynamics"(2006) [K134] and "Topological Geometrodynamics: Revised Edition" [K5] provide summaries of the theory of TGD. The book "Life and Consciousness: TGD based vision" (2014) [K2] describes a TGD inspired theory of consciousness. The article "Philosophy of adelic physics" (2017) [L69, L73] describes a number theory based vision of TGD and extends real number based physics to p-adic number fields to describe physical correlates of cognition. The most recent mathematical progress concerning the construction of scattering amplitudes in TGD is discussed in the articles [L140, L141, L142].

The article "Summary of Topological Geometrodynamics" (2020) [L146] provides the most recent summary of TGD with illustrations. My CV (`https://cutt.ly/3bJ2aSm`) contains a list of published articles, books, and online books about TGD. A list of online articles can be found at `https://cutt.ly/ZbJ2s75`.

16.2.1 The basic problem and idea behind TGD

TGD relies on a new view of space-time inspired by the problem of GRT due to the loss classical conservation laws (the "energy problem"). Matter makes the flat Minkowski space M^4 of Special Relativity (SRT) curved so that it loses Poincare transformations as its symmetries. Poincare invariance implies the conservation laws of energy, momentum, and angular momentum via Noether's theorem so that they are lost in GRT.

The following is a short summary of the solution of this problem provided by TGD (see **Fig. 16.1**.

1. If space-times are 4-surfaces in a space of form $H = M^4 \times S$, S some compact space with a very small size, space-time isometries (Poincare transformations) are lifted to those of H. If these isometries act as symmetries of a general coordinate invariant action determining the space-time surface as an orbit of a 3-surface, Poincare symmetries are not lost and Noether's theorem guarantees the existence of conserved charges and gives explicit expressions for them.

   The geometry of $S = S = CP_2$ codes for the symmetries of SM: color symmetries correspond to the isometry group $SU(3)$ and electroweak symmetries to the holonomies of CP_2 being broken by CP_2 geometry. CP_2 does not allow spinor structure in the standard sense [L21] but - as already observed by Hawking and others [A29, A17] - it allows a modified spinor structure obtained by coupling spinors to an odd multiple of the Kähler gauge potential: this coupling is essential to obtain correct electromagnetic charges for fermions. For quarks and leptons the couplings would correspond to $n = 1$ and $n = 3$.

   However, the TGD view of color makes it possible to identify leptons as local 3-quark composites [L123, L122, L113, L140, L151] so that only quarks are needed as fundamental fermions. The mystery of matter-antimatter symmetry would thus be solved: leptons correspond to antimatter and baryons to matter.

2. Besides sub-manifold geometry, topology also becomes important (hence the term "**TGD**") since the many-sheeted space-time of TGD is topologically non-trivial at all scales and the physical objects that we see around us correspond directly to space-time sheets, topologically condensed at ever larger space-time sheet. Length scale hierarchies form.

16.2.2 Physics as geometry and physics as number theory

TGD decomposes to two basic threads: physics as geometry [L23, L22, L38, L126] and physics as number theory [L77, L78, L73] (see **Fig. 16.2**).

1. In the geometric approach space-time surfaces X^4 correspond to extremals for both volume action and the so called Kähler action as an analog of Maxwell action. This action is predicted by the twistor lift of TGD [L57] (see **Fig. 16.6**).

   The essential distinction between this approach and the standard quantization is that classical physics is an exact part of quantum physics rather than its long length scale limit: quantum states are superpositions of preferred extremals of t action, analogous to Bohr orbits (see **Fig. 16.3**) .

2. In the approach based on number theory, X^4 corresponds to an algebraic surface in a complexified 8-dimensional Minkowski space M^8, having an interpretation as complexified octonions O_c. This surface is obtained as a "root" for the complexified quaternion-valued "real" part of an octonionic polynomial obtained from a real polynomial with rational coefficients by algebraically continuing it to O_c. This is done by replacing the real argument with a complexified octonion [L141, L142] (see **Fig. 16.7**).

These approaches are related by the $M^8 - H$ duality [L141, L142] (see **Fig. 16.7**) for which weak and strong forms can be considered.

1. The identification of M^8 as an analog of 8-D momentum space as cotangent space of $M^4 \times CP_2$ represents the most recent step in this progress [L141, L142, L155].

2. One can realize both weak and strong forms of $M^8 - H$ duality in M^4 degrees of freedom by an inversion map $p^k \in M^4 \to m^k = \hbar_{eff} p^k/p^2$ [L141]. This conforms with the Uncertainty Principle (UP) but does not however the full UP. An even stronger form of $M^8 - H$ duality states that momentum p^k is mapped to a union of points $m^k + \delta m^k$, such that $\delta m^k \cdot p_k = n2\pi$ belong to the interior of causal diamond (CD), and would satisfy full UP [L155].

3. The weak form of $M^8 - H$ duality relies on the strong form of holography (SH) which makes it possible to deduce $X^4 \subset H$ from the images of *2-D surfaces* $X^2 \subset X^4 \subset M^8$ (and possibly also of light-like 3-surfaces) under $M^8 - H$ duality [L120].

4. Recent work strongly suggests that SH may not be necessary: the strong form of $M^8 - H$ duality maps the *entirety* of space-time surfaces from M^8 to H. This provides a major simplification [L141, L142].

The identification of M^8 as an analog of momentum space generated a breakthrough but also resulted in an objection. Periodic functions and Fourier analysis characteristic for dynamics are absent at the level of M^8. Could they emerge at the level of H? The conjecture is that the non-locality of the map of the tangent planes of $X^4 \subset M^8$ to CP_2 points brings in dynamics and implies that CP_2 points are represented as Fourier expansions of M^4 coordinates [L127, L155].

Quantum TGD leads to a generalization of the geometrization of the physics program of Einstein. The entirity of quantum theory is geometrized in terms of the notion of a "world of classical worlds" (WCW) consisting of space-time surfaces identifiable as preferred extremals (PEs) analogous to Bohr orbits (see **Fig. 16.8**). General Coordinate Invariance (GCI) implies 3-D holography and probably also effectively 2-D holography (strong holography (SH)).

The mere existence of WCW Kähler geometry requires a maximal isometry group. This was shown by Freed [A19] to be the case for loop spaces. This leads to the vision that physics is unique from its existence. Indeed, the twistor lift of TGD [L124, L125] works only for $H = M^4 \times CP_2$ [A30] since only M^4, E^4, and CP_2 have twistor spaces with the Kähler structure required by the existence of the twistor lift based on 6-D Kähler action. At the number theory side, the octonionic M_c^8 is the unique choice.

The number theory based vision is a completely new element and leads to adelic physics [L69, L73] involving both real physics and various p-adic physics (where $p = 2, 3, ...$ are primes). p-Adic physics are identified as correlates of cognition and imagination in a universal sense predicted

to be present at all scales (see **Fig. 30**) and not restricted to human brain or even living systems as usually understood.

The polynomials defining the $X^4 \subset M_c^8$ give rise to an infinite hierarchy of extensions of rationals (EQs) inducing those of p-adic number fields. This predicts an infinite hierarchy of adeles. The adele for a given EQ is defined essentially as the Cartesian product of real numbers and extensions of various p-adic number fields induced by EQ.

This hierarchy is identified as an evolutionary hierarchy (see **Fig. 16.9**). The dimension n of EQ has an interpretation as an effective Planck constant $h_{eff} = nh_0$ ($h = 6h_0$). Quantum coherence is predicted to be possible in arbitrarily long scales and the values of " n" define a length scale hierarchy as quantum coherence scales. The phases with a non-standard value of h_{eff} behave like dark matter.

16.2.3 About the applications of TGD

TGD has non-trivial applications at all scales.

1. Space-time topology is non-trivial at all scales. "Einsteinian" space-time surfaces have an M^4 projection of dimension $D_P = 4$, and look like small deformations of M^4. Also 4-D space-time surfaces with $D_P < 4$ are possible and correspond to non-perturbative gravity. In particular, the so-called CP_2 type extremals with $D_P = 1$ and cosmic strings with $D_P = 2$, are possible. These deviations from GRT are crucial for an understanding of elementary particles and galactic dark matter and energy [L121, L117].

   All space-time surfaces - including "Einsteinian" ones - have a finite size. In the "Einsteinian" case, CP_2 coordinates can be many-valued functions of M^4 coordinates, and it is convenient to talk about a many-sheeted space-time.

   A quantum field theory (QFT) limit for "Einsteinian" space-time surfaces is obtained by replacing the space-time sheets with a single, slightly metrically deformed, region of M^4. The counterparts of the SM gauge potentials are identified as the sums of induced spinor connections of space-time sheets. The counterpart of the GRT metric corresponds to the sum of the deviations of the induced metric from the flat M^4 metric. Einstein's equations can be regarded as a remnant of Poincare invariance. Many-sheeted space-time is topologically non-trivial at all scales and this hidden many-sheetedness leads to non-trivial predictions at all scales, in particular, biology.

2. For a given EQ fixed by a polynomial defining space-time surface $X^4 \subset M^8$ there is a unique discretization of X^4 - cognitive representation - as points, whose coordinates are common to the real and p-adic variants of X^4 and therefore in the EQ. This intersection of reality (i.e. real space-time surfaces) and p-adicities implies a strong correlation between cognition and sensory reality. The p-adic length scale hypothesis that emerged from p-adic thermodynamics as a model for particle massivation [L24] and p-adic fractality are very powerful quantitative tools, which lead to highly non-trivial predictions.

For more detailed representations, one can consult the books [K134, K2, K5], the article [L69] about adelic physics, and the articles [L74, L94]. The latest mathematical progress is described in the articles [L140, L141, L142, L155]. The homepage dedicated to TGD (`http://tgdtheory.fi`) contains online books and articles - also updated versions of published articles.

16.3 TGD inspired theory of consciousness

TGD inspired theory of consciousness can be regarded as an extension of quantum measurement theory to a theory of consciousness that relies on Zero Energy Ontology (ZEO) [L149]. When I wrote the first version of this chapter, the view about ZEO, in particular about what happens to the causal diamonds (CDs) in state function reductions, involved many uncertainties. In [L180] the recent, much more precise view is represented.

16.3.1 Conditions satisfied by the theory of consciousness

Any quantum theory of consciousness must be consistent with existing physics. Since existing physics cannot explain biological phenomena and consciousness, a theory explaining them is bound to predict some new physics.

The new theory must solve the basic problems intractable to current theoretical physics. Many of these problems are philosophical. This theory should also be applicable to quantum biology and neuroscience and answer at least the following questions.

1. In everyday life everyone, even a strict physicalist, will in their subjective experience, regard free will as real, but in the role of natural scientist, deny it since it is inconsistent with the determinism of classical physics. Could the underlying view of time be wrong? Could free will be consistent with deterministic field equations after all?

   It seems that behavior is built from deterministic time evolutions connecting initial and final states. Biological functions, behaviors, and computer programs represent good examples of this. Could free will be in the selection between deterministic time evolutions. These questions suggest a new ontology in which a deterministic classical time evolution becomes the basic entity instead of the time=constant snapshot of time evolution central to the standard ontology.

2. A similar problem plagues quantum measurement theory. The state function reduction (SFR) is non-deterministic whereas the Schrödinger equation is deterministic. This has led to myriads of "interpretations". This problem is analogous to the conflict between free will and classical deterministic physics.

   It is easy to trace the origin of the problem. In standard quantum theory the observer can affect the measured system but still remains an outsider. A quantum theory of consciousness would generalize quantum measurement theory. The notion of "self" as part of a system would replace that of "observer".

   Quantum coherence is assumed to be possible only at very short scales. Coherence of biological systems, however, suggests this assumption is wrong. There is also the question whether there is some scale at which quantum behavior transforms to classical behavior. This question has not been answered. Could the quantum world actually prevail at all scales and only appear as classical? Could discontinuous quantum jumps somehow look like deterministic and smooth classical time evolutions?

3. Experienced time and the geometric time of the physicist are very different. Subjective time however correlates with geometric time: contents of sensory experience correspond to a moment of geometric time within an accuracy of .1 second: one can speak of a sensory chronon. How should one distinguish between these two times?

4. Are there physical correlates for cognition and imagination? Could they be realized at the level of space-time?

5. What do life, death, and aging mean? Could they be universal notions applicable at all scales? Does consciousness survive after the cessation of bodily function in some sense? If this were the case, universality might make it possible to provide indirect, and yet convincing, evidence for life after death.

16.3.2 ZEO based quantum measurement theory extends to a theory of consciousness

ZEO based quantum measurement theory [L149] leads to a quantum theory of consciousness (see **Fig. 16.10**). In particular, the theory predicts that the arrow of time (AT) changes in "Big" (ordinary) SFRs (BSFRs) (see **Fig. 16.13**) as opposed to "Small" SFRs (SSFRs) as the counterparts of "weak" measurements (`http://tinyurl.com/zt36hpb`).

BSFR suggests that self-organization (SO) at all scales partially reduces to dissipation with a reversed AT implied by the generalization of the second law of thermo-dynamics (SL).

1. SO always involves an energy feed. The energies of quantum states increase with $h_{eff} = nh_0$ and h_{eff} tends to be reduced spontaneously. The energy feed prevents this and hence the reduction of the universal "Intelligence Quotient" (IQ) as the dimension n of EQ characterizing the algebraic complexity of EQ and of a space-time surface [L141, L142]. This prevents also the reduction of the scale of quantum coherence. In biology this corresponds to the metabolic energy feed.

2. In ZEO, the energy feed necessary for SO could be partially replaced with an extraction of energy from the environment by dissipation in a reversed direction of time. The self-organizing system could effectively send negative energy to the environment.

   The basic signature is a generation of gradients in conflict with SL in its standard form. This conforms with what happens in SO but does not of course prove that SO is based solely on time reversed dissipation. Both the energy feed and the extraction of energy from the environment are involved.

   For time reversed dissipation no specific mechanisms are required and only metabolic energy storages - systems able to receive the negative energy dissipated in a reversed time direction - are enough. Even thermal energy could be used and there is evidence for this [L194]. This inspires a totally new vision, not only of living matter, but also in regards to possible energy technologies.

3. Time reversals occur at very short time scales at the elementary particle level and for ordinary matter with $h_{eff} = h$). For MBs controlling ordinary matter, time reversals would have long lasting effects on ordinary matter as well.

   MB has an onion-like layered structure implied by the p-adic length scale hypothesis [K79] and h_{eff} hierarchy [L104]. Layers have sizes even larger than the size of the Earth. The slaving hierarchy formed by the layers of MB carrying dark matter could control the dynamics by inducing time reversals at the lower levels as BSFRs interpreted as generalized motor actions (master and slave are standard notions in the theory of SO). A given layer of MB is characterized by its size determined by a p-adic length scale characterizing flux tube thickness and by the value of h_{eff}.

ZEO

The TGD based view of consciousness relies on ZEO solving the basic paradox of quantum measurement theory. First, a brief summary of ZEO [L149] is required.

1. The notion of a causal diamond (CD) (see **Fig. 16.11**) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms (3-D balls). The half-cones are mirror images of each other. CD=$cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2. The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics [L68])via the $M^8 - H$ duality [L120, L141, L142].

2. The quantum formulation based on the notion of fini-dimensional moduli space of CDs forming that backbone of WCW [L180]. This formulation makes it possible to get rid of various uncertainties of the earlier formulations. The sequences of "small" state function reductions (SSFRs), or rather a sequence unitary transformations, which in the moduli space of CDs correspond to dispersion analogous to that associated with Schrödinger equation followed by localizations in the moduli space (SSFR) as position measurements. These are the TGD counterparts of sequences of measurements of the same observables. Present are also "big" SFRs (BSFRs) changing the arrow of time and serving as the TGD counterparts of the ordinary SFRs.

3. In the ZEO, quantum states are not 3-dimensional, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. By holography time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving AT that give rise to an analog of the Zeno effect (`https://cutt.ly/yl7oIUy`) [L149].

To avoid confusion, one may emphasize some aspects of ZEO.

1. ZEO does not mean that the physical states identified in standard quantum theory as 3-D time= constant snapshots - and assigned in ZEO to the opposite boundaries of a causal diamond (CD) - would have zero energy. Rather, these 3-D states have the same conserved quantities, such as energy. Conservation laws allow us to adopt the convention that the values of conserved quantities are opposite for these states so that their sum vanishes.

   This is not new: in quantum field theories (QFTs), one speaks, instead of incoming and outgoing particles, external particles arriving from the geometric past and future and having opposite signs of energy. That conserved quantities vanish in the *4-D* sense, expresses only the content of conservation laws. A weaker form of this condition [L155] states that the total conserved Poincare charges are opposite only at the limit of infinitely large CD. CD would be an analog of quantization volume in QFTs, whose finiteness implies a small conservation of momentum.

2. ZEO implies *two* times: subjective time as a sequence of quantum jumps and geometric time as a space-time coordinate: for instance, the proper time of the observer. Since subjective time does not correspond to a real continuum, these times are not identifiable but are strongly correlated. This correlation has led to their identification although they are different.

BSFR as death and reincarnation in universal sense

In BSFRs, AT is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. The BSFRs can occur at all scales since TGD predicts a hierarchy of effective Planck constants h_{eff} with arbitrarily large values. There is empirical support for BSFRs.

1. The findings of Minev *et al* [L99] for atomic systems can be explained by the same mechanism [L115]. BSFR replaces the zero energy state with a new one and changes the roles of the 3-D states (active and passive state) at the boundaries of CD.

   For an observer with a standard AT, the final zero energy state is a superposition of deterministic, smooth time evolutions leading to a fixed 3-D state at the formerly active boundary of CD. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution. The ZEO based interpretation is that a second BSFR as a return back to the initial state occurs.

2. Libet's experiments on the active aspects of consciousness [J44] can be understood from this perspective. For instance, a test subject raises his index finger and neural activity starts *before* the conscious decision to do so. In a physicalistic framework, neural activity leads to the experience of making the decision so that free will would not be real.

   Libet himself proposed what he called a veto option: free will is in the decision to stop the action already initiated. The problem with the veto option [J34] is that the activity beginning .5 seconds earlier looks like dissipation with a reversed AT. In the standard direction of time this looks like self-organization which leads from a chaotic state to an ordered state at around .15 seconds before the raising of the finger. The ZEO explanation is that a macroscopic BSFR occurred and generated a signal proceeding backwards in time which generated neural activity and dissipated to randomness.

3. An example from a different scale comes from earthquakes and supports universality. Earthquakes involve a strange anomaly: they are *preceded* by ELF radiation. One would

expect that ELF radiation would follow the earthquake. In the TGD framework, the identification as BSFR can explain the anomaly [L116, L95].

In biology, the reversals of AT may occur routinely [J121] and indeed are a central element of biological SO in the TGD framework. Time reversal also explains self-organized quantum criticality (SOQC) identifiable as the basic mechanism of homeostasis [L119, L194]. Homeostasis would occur spontaneously rather than being a result of programming.

Sequence of SSFRs as life cycle

SSFRs are counterparts of "weak" measurements, which are much like classical measurements and do not involve any dramatic changes. The sequence of SSFRs gives rise to a conscious entity - self - as a sequence of moments of consciousness. Subjective time as a sequence of SSFRs correlates with the geometric time for which one identification is as the distance T between the tips of CD, whose size increases statistically.

1. In SSFRs [L145] members of states at the "passive" boundary (PB) of the CD are not changed and PB itself is not shifted although it increases in size. The active boundary (AB) recedes from PB and increases in size in a statistical sense. Also, the states at AB change by unitary time evolutions followed by SSFRs that do not affect the states at PB.

   SSFRs correspond to a measurement of observables whose action does not affect the states at PB. Cognitive measurements are excellent candidates for these kind of measurements [L145]. The time T identified as the temporal distance between the tips increases in a statistical sense and correlates with the subjective time identified as a sequence of SSFRs.

2. The identification of a "geometric now" as a correlate of "subjective now" is not unique. The most natural identification of the geometric time is as the linear M^4 time coordinate assignable with the line connecting the tips of CD (see **Fig. 16.11**) . The "geometric now" would correspond to the $T_{now} = T/2$ which corresponds to a 3-D ball (not a 2-D sphere, which is its boundary) at which the expansion of 3-ball with light-velocity changes to contraction - the analogy with the Big Bang followed by the Big Crunch is obvious. T_{now} increases in a statistical sense.

3. $M^8 - H$ duality predicts that the roots r_n of the real polynomial P define special moments $t = r_n$ of M^4 linear time: I have called them "very special moments in the life of self" [L62, L63, L64, L102, L141, L142]. If these moments correspond to the values of T_{now} for SSFRs, the size of CD increases in a step-wise manner.

4. The Lorentz invariant light-cone proper time "a" labeling the hyperboloids inside the lower and upper half-cones of the $CD \subset H = M^4 \times CP_2$ is the second natural candidate for the geometric time coordinate and is completely analogous to cosmic time. It reduces in a good approximation to "t" near the time axis connecting the tips of CD.

   This picture applies at the level of H. $M^8 - H$ duality [L141, L142] forces also consider the M^8 level. M^8 is analogous to momentum space: there is no time and space in the usual sense. Could the claims of timeless and spaceless states of consciousness correspond to the M^8 mode? In momentum space, time and spatial coordinates are replaced with energy and momenta.

$M^8 - H$ duality leads to a more detailed picture of the evolution of self. One may consider first what the evolution of self looks like geometrically.

1. A given space-time surface in M^8 is determined in terms of an octonionic polynomial $P(o)$ obtained by algebraically continuing a real polynomial $P(x)$ with rational coefficients (so that p-adic variants of the space-time surface exist). $P(o)$ is decomposed to quaternion valued "real" and "imaginary" parts and the space-time surface corresponds to a root for the real part of $P(o)$ [L102, L141, L142].

   The associativity of the normal space of the space-time surface is the number theoretical dynamic principle. It implies that space-time surfaces are minimal surfaces. Also their counterparts in $H = M^4 \times CP_2$ - obtained by $M^8 - H$ duality - are minimal surfaces geometrizing the massless wave equation.

2. One can assign to the half-cones of the CD distinct polynomials which must be identical at $t = T/2$. The condition is satisfied if the polynomials are $P(o)$ for the "lower" half-cone and $P(T - o)$ for the "upper" half-cone. The space-time surfaces associated with the half-cones are in well-defined sense mirror images glued together at $T_{geom} = T/2$. This is not however the case for the space-time surfaces assignable to sub-CDs of CD interpreted as correlates of the mental images of the self assignable to CD.

This proposal has strong implications.

1. The evolution by steps consisting of unitary time evolution+SSFR increases the size of CD in a statistical sense (the number of CDs larger than the given CD is infinitely larger than those smaller than it). PB remains unaffected apart from scaling. Hence the size of the region of space-time surface identified as a "root" of the real part of P, increases: more of the surface determined by P becomes visible in each SSFR. This is like opening a packet containing a gift. Each "very special moment" $t = r_n$ brings something new in light.

2. At $T_{now} = T/2$ the sensory input from the geometric past induces sensory mental images drifting to the geometric future and gives rise to memory mental images assignable to sub-CDs. Contrary to a naive expectation, memory mental images indeed drift to the geometric future of T_{now} as the size of CD increases rather than remaining in the geometric past. The emergence of these sub-CDs in shorter scales breaks the mirror symmetry between half-cones.

   This makes it possible to learn from experiences during a given life cycle and utilize that learning during the next life cycle with an opposite AT. In the BSFR, AB becomes passive and these memory mental images become the "silent wisdom" for the time reversed self representing what was learned during the previous life cycle.

ZEO and planned actions

ZEO also provides a model for planned actions. To understand the basic idea, it is good to first describe a strange finding by Armor and Sackett [J39] and its TGD based explanation.

1. Armor and Sackett made a surprising discovery: the prediction of what happens in a future event is more reliable if the person knows that the event will actually occur. The future event was a scavenger hunt and the participant had to predict her performance defined as the number of items to be found. The participants who knew that the event would actually take place, made better predictions.

   Did the participants precognize their performance as passive spectators of themselves in the geometric future so that free will would be an illusion? This need not be the case: the information was about the number of items found and rather abstract. This did not fix the detailed behavior of the participant in the hunt.

2. Reference [L199] shows that the finding actually fits with the vision in which BSFRs occur as cascades which proceed from long to short scales. MBs represent a hierarchy of abstractions about the lowest level. The higher the level, the less detailed the information [L139]. Only this abstract information can be pre-determined.

   The BSFR for MB_2 above MB_1 in the hierarchy - the "boss" - corresponds to a time scale $T_2 > T_1$ and determines the fate of MB_1 in the time scale T_2. MB_1 can apply its free will in the time scale T_1 in the limits posed by its fate. This paradoxical finding makes the distinction between subjective and geometric time very concrete. The fate of the subject person MB_1 is to some degree determined by BSFR of MB_2. With respect subjective (geometric) time, this BSFR occurred *before* (*after*)MB_1 made the prediction.

   This a supports the idea of the organizer of the experiment to perform the experiment was actually communicated by MB_2 to the experimenter. Thus she only actualized her fate.

Could most, if not all, planned actions be like this - induced by BSFR of MB_2 in the geometric future, but in the subjective past (of MB_1)? This would allow for more detailed planning

at the level of MB_1. There would be the experience of planning and a realization induced by the signals from the geometric future sent by a higher level in the hierarchy of conscious entities! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than as agents with completely free will.

1. Ordinary matter is at the bottom of the master slave hierarchy and its coherence is forced by the quantum coherence at higher levels MB layers.

2. The BSFR for a higher level MB gives rise to what is experienced as a planned action at the lower levels of the hierarchy. Planned action at a given level induces a cascade of planned actions in shorter time scales which eventually proceed to the atomic level.

3. Sensory perceptions and motor actions would be universal. Sensory perceptions naturally correspond to SSFRs "weak" measurements (`http://tinyurl.com/zt36hpb`), and both BSFRs and SSFRs can occur with both arrows of time. Motor action is identifiable as a cascade of BSFRs, with each BSFR inducing sensory perceptions as SSFRs at lower levels. These would, in turn, induce motor actions as BSFRs in shorter time and length scales.

16.3.3 Negentropy Maximization Principle (NMP) as variational principle of consciousness

Negentropy Maximization Principle (NMP) defines the variational principle of consciousness in TGD [K73] [L157].

1. NMP replaces the second law (SL) and implies it for ordinary matter. SFR means a reduction of the entanglement for a pair $S_a - S_b$ of sub-system S_a and S_b, its complement in S. Instead of a single measurement, there is a measurement cascade, proceeding from long to short scales. At each step a system decomposes to a pair of unentangled subsystems. NMP states that the negentropy gain in each step is maximized and selects the pair $S_a - S_b$ at each step. This process can be visualized by a tree diagram.

2. In adelic physics [L69, L73] the entropy $N = -S_1 - S_2$ is the sum of real and various p-adic negentropies. p-Adic negentropies can be positive so that for non-trivial EQs one can have $N > 0$. Negentropic entanglement (NE) is stable against NMP so that the process stops. It is natural to assign positively colored emotions to NE. One can also say that NE distinguishes between living and inanimate matter and between dark and ordinary matter.

NMP as a generalization of the second law of thermo-dynamics

On the basis of empirical facts, Jeremy England [I59] has proposed that SL implies evolution. This statement seems to be in conflict with the standard thermodynamic view of biology [L39].

England's view that SL implies evolution, is clearly in error. NMP [L157] explains why England's paradoxical view is apparently true. A generalization of quantum measurement theory to a ZEO based theory of consciousness, and a number theory based view of cognition leading to adelic physics, is required to understand this misinterpretation.

1. SFR decomposes a given system (unentangled from the environment) to 2 subsystems in such a way that the negentropy gain is maximal for the "winning" decomposition. This corresponds to the quantum measurement of a universal observable, identified as the density matrix for the subsystem-complement pair.

2. TGD allows a genuine notion of negentropy assignable to entanglement and thus to the density matrix. The negative of the ordinary entanglement entropy $N = -S$ defines negentropy which at best is $N = 0$ since N is always non-positive.

   A genuine measure of information is needed. Since information is associated with cognition, one must expand the realm of physics to include cognition. One can also assign to the extensions of p-adic number fields an entanglement negentropy by the analog of a Shannon formula replacing logarithms of probabilities with the logarithms of their p-adic norms [K73] [L157].

Remarkably, p-adic entropy can be negative and NMP mandates this. Furthermore, its magnitude is not smaller than that of real entropy. Therefore negentropy identified as the sum $N = -S_1 - S_2$ of real and p-adic entanglement negentropies can be positive for non-trivial EQs. N defines a genuine measure of information and, by NMP, increases during the life span of the conscious entity. This however implies the increase of real entanglement entropy [L39].

p-Adic number fields, combining with real numbers to form an adele, are needed [L69, L73]. The algebraic extensions of p-adic number fields induced by EQs form an infinite hierarchy with increasing complexity which is identifiable as an evolutionary hierarchy. EQs emerge from M^8-H duality [L141, L142]. Space-time regions are determined by polynomials defining the EQs via their roots. Evolution as an increase of the dimension of EQ is unavoidable.

3. Consider now the connection with thermo-dynamics. When SFR occurs, entanglement entropy becomes zero, but ensemble entropy increases. That is, the outcome of measurement is not deterministic and reduction probabilities correspond to the eigenvalues of the density matrix. This means an increased thermo-dynamic entropy and generation of disorder.

   However, if the SFR cannot occur, entanglement is stable. For the negentropic states for which negentropy cannot decrease, NMP prevents SFR! The negentropic states approach cognitive fixed points and replace thermodynamic equilibria for which entanglement negentropy is maximum. The conscious entity maximizes its knowledge during its life-span quite universally: this applies to all systems at all scales, not only humans.

   For $h_{eff} = h_0$, NMP implies standard quantum measurement theory. Entanglement can be also non-negentropic for non-trivial EQs. In this case, NMP does not prevent complete de-entanglement from occurring and SL holds true. For dark matter with $h_{eff} > h$ NMP can, however, stabilize entanglement. This gives rise to a generation of conscious information. In summary, a pessimistic SL transforms to an optimistic NMP and implies SL for ordinary matter.

16.4 TGD and quantum biology

Often, problems have served as starting points for developments in TGD. This also applies to biology. The following list includes some examples. A more detailed discussion is in [L94].

1. How can one understand the coherence of living systems? If bio-chemistry alone explained life, we would be sacks of water with some chemicals added. Sacks of water do not climb in trees or write poems. Could quantum coherence induce ordinary coherence? What entities serve as intentional agents and how could they realize their intentions?

2. Why is metabolism needed? Particles with nonstandard h_{eff}/h_0 have a higher energy as a rule. Is metabolic energy needed to excite particles to dark states and thus to increase their "IQ"? Could evolution be seen as an increase of $h_{eff}/h_0 = n$ as the dimension of EQ forced by the fact that the number of extensions with a dimension higher than a given integer n is infinitely larger than the number of extensions with a dimension smaller than n.

3. Is the genetic code (GC) totally accidental? Could the biochemical realization of the GC mimic a deeper level of the GC?

4. What is morphogenesis? If biology is merely biochemistry, this question remains unresolved. However, if space-time topology is non-trivial at all scales, the situation changes dramatically. All structures - *including bio-molecules, membrane like structures, organelles, organs, etc. - are 4-D space-time surfaces representing dynamic patterns*, and morphogenesis emerges at a classical level in the 4-D sense [L93, L53]. Holography implies that 3-D surfaces are equivalent to corresponding 4-D surfaces as analogs of Bohr orbits. Thus ZEO replaces the ordinary quantum state as a structure with zero energy state as an analog of function, behavior, or program and notions such as 4-D brain emerge. One might even say that structure and function are equivalent.

The model for living matter relies heavily on the notions of MB carrying $h_{eff} > h$ phases behaving like dark matter and ZEO.

16.4.1 MB carrying dark matter as controller of ordinary biomatter

MB contains dark matter identified, as phases of ordinary matter characterized by EQ with a dimension $n = h_{eff}/h_0$ serving as a measure of the algebraic complexity of a given space-time region [L141, L142], and interpreted as a universal IQ. The scales of quantum coherence increase with h_{eff}. The layers of MB characterized by the value of n naturally form a master-slave hierarchy in which ordinary matter with the smallest Planck constant is at the bottom, and controlled by higher levels. The energies of systems increase with h_{eff} and since h_{eff} tends to be spontaneously reduced, an energy feed is needed to preserve the distribution of h_{eff}: the interpretation is as an analog of a metabolic energy feed.

MB acts as a "boss" controlling ordinary matter and induces self-organization [L119].

Anatomy of MB

MB has, as its body parts, magnetic flux quanta: flux tubes and flux sheets. There are two kinds of flux quanta. Flux can be vanishing, which corresponds to a Maxwellian regime. Flux can also be non-vanishing and quantized corresponding to a monopole flux. In the monopole case, the magnetic field requires no current for its creation. This option is not possible in the Maxwellian world. By fractality of the TGD Universe, these flux tubes play a key role at all scales [L117].

Also the Earth's magnetic field with nominal value of $B_E = .5$ Gauss has two parts.

1. The monopole flux part (see **Fig. 16.14**) corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss and explains the strange effects of ELF EM radiation on the physiology and behavior of vertebrates [J57].

   The presence of this part explains the stability of the Earth's magnetic field. This field should have decayed long ago in a Maxwellian world since it is generated by currents which disappear.The contribution of the molten iron in the Earth's core to B_E decays but the changes of the orientation of B_{end} regenerate it [L137]. Also, magnetic fields that penetrate super-conductors as quantized fluxes and even those of permanent magnets (as opposed to electromagnets) may have a monopole part consisting of flux quanta.

2. The interaction of MB with the gravitational field of Earth is discussed in [L161]. Intriguingly, the metabolic energy currency with the nominal value of .5 eV is rather close to the energy for the escape velocity of a proton. Could the transfer of ions from the surface of the Earth to MB be a standard process?

Communications to and control by MB

Communication from the biological body (BB) to MB and its control by MB would rely on dark photons, which can transform to ordinary photons with a large h_{eff} and vice versa. Molecular transitions would represent one form of control.

1. Cell membranes could act as generalized Josephson junctions generating dark Josephson radiation with energies given by the sum $E_J + \Delta E_c$ of ordinary Josephson energy E_J and the difference ΔE_c of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential modulates the Josephson frequency and codes the sensory information at the cell membrane to a dark photon signal sent to MB.

2. The large effects of radiation at ELF frequencies observed by Blackman and others [J57] could be understood in terms of the cyclotron transitions in $B_{end} = .2$ Gauss if "h" in $E = hf$ is replaced with h_{eff}. h_{eff} should be rather large and possibly assignable to the gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. For the simplest model, M represents the Earth's mass coupling to the small mass m, and v_0 is a parameter with dimensions of velocity expected to have discrete spectrum. The energies $E = h_{eff}f$ of dark photons should be in the biophoton energy range (visible and UV) characterizing molecular transitions [K15, K25].

3. For the value $v_0/c \simeq 2^{-11}$, suggested by the Nottale's model for planetary orbits [E1], the predicted cyclotron energy scale is 3 orders of magnitude higher than the energy scale of visible photons. Several solutions of this problem were considered [L160]. The most plausible solution [L160, L153] is $\beta_0 = v_0/c = 1/2$ for living matter so that gravitational Compton length $\Lambda_{gr} = GM/\beta_0$ equals to Schwartschild radius at the surface of Earth. and brings nothing new to the original Nottale hypothesis.

By its higher level of "IQ", MB would naturally be the master controlling BB by cyclotron radiation - possibly via a genome accompanied by dark genome at flux tubes parallel to the DNA strands.

1. Cyclotron Bose-Einstein condensates (BECs) of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear as dark matter in living systems and the $h_{eff} = h_{gr}$ hypothesis predicts a universal cyclotron energy spectrum in the range of bio-photon energies.

2. Dark photons may transform to bio-photons [L28, L27] with energies covering the visible and UV energies associated with the transitions of bio-molecules. This control of biomolecules implies that remote mental interactions are routine in living matter. EEG signals would represent a particular instance of these communications: without the presence of MB it is difficult to understand why the brain would use such large amounts of energy to send signals to outer space.

3. In ZEO, the field body (FB) and MB correspond to 4-D rather than 3-D field patterns and quantum states correspond to quantum counterparts of behaviors and biological functions. Conscious holograms could be generated as a result of interference of a dark photon reference beam from MB and a dark photon beam carrying the sensory information. This hologram would be read by MB using the conjugate of the reference beam.

   In ZEO time reversals of these processes also take place. This makes it possible to understand memory as a result of communications with memory mental images (see section 16.3.2).

Evidence for dark charged particles

The notion of dark matter as a controller of biomatter preceded its justification based on number theory [L68, L69].

1. The values of $h_{eff} = nh_0$ must be so large that the energies $E = h_{eff}f$ of dark photons with EEG frequencies are in the biophoton energy range (visible and UV) assignable to molecular transitions [K15, K25].

2. What makes the large values of h_{eff} possible? Nottale's hypothesis [E1] introduces the notion of the gravitational Planck constant $\hbar_{gr} = GMm/v_0$, whose form is fixed by an Equivalence Principle (EP). In the TGD framework, $h_{eff} = h_{gr}$ is assigned to gravitational flux tubes [L96]. There are non-trivial implications that reflect EP.

   (a) The cyclotron energy spectrum $E_c = n\hbar_{gr}eB/m = nGMeB/v_0$ does not depend on the mass m of the charged particle and is thus universal. The energies involved are proposed to be in the range of biophoton energies (at least) suitable for control of the transitions of the bio-molecule. One cannot exclude lower energies above thermal energy for physiological temperature.

   (b) The gravitational binding energies of a mass m for Bohr orbits around M do not depend on M at all [L161].

   Also relatively small values of h_{eff} are possible.

1. Electrons can also have dark phases, but now the value of h_{eff} would be much smaller and satisfy the generalized Nottale hypothesis $h_{eff} = h_{em}$, where h_{em} is the electromagnetic analogue of h_{gr} assignable to flux tubes accompanying valence bonds. This inspires a model

of valence bonds [L147] (`https://cutt.ly/5f5QrgF`) predicting that the value of $h_{eff}/h_0 = n = h_{em}$ increases along the rows of the Periodic Table.

This picture can explain why molecules such as proteins containing atoms towards the right end of the rows of the Periodic Table are ideal carriers of metabolic energy. It also explains why ions, such as Ca^{++} involved with the control and communications of the cell membrane with the "large" part of MB and having very large $h_{eff} = h_{gr}$, are towards the left end of the rows.

2. The energy scale of dark variants of valence electrons is proportional to $1/h_{eff}^2$ so that the orbital radii are scaled up and the identification as a Rydberg atom provides the only possibility in the standard physics model. Could dark valence electrons be in question? There is empirical evidence, known for decades, for the mysterious disappearance of valence electrons of some rare earth metals in heating. An article by Chatterjee *et al* [L67] discusses this phenomenon for Yb.

   The finding [D7] about "misbehaving" Ruthenium atoms also supports the view that covalent bonds involve dark valence electrons. Pairs of Ru atoms were expected to transform to Ru dimers in thermo-dynamic equilibrium but this did not happen. This suggests that valence electrons associated with the valence bond of Ru dimers are dark in the TGD sense and the valence bonded Ru dimer has a higher energy than a pair of free Ru atoms.

   TGD based explanation [L76] could be justified by a resonant coupling of dark electron with an ordinary Rydberg state of the valence electron. In the lowest approximation, dark valence electrons have energies in the spectrum of ordinary valence electrons so that a resonant coupling with Rydberg states can be considered. The evidence found by Randell Mill [D9] for atoms with an abnormally large scale of binding energy suggests the formula $h = 6h_0$ [L75]. Atomic binding energies are proportional to $1/h_{eff}^2$ and Mills reports that the binding energy scale can be 4 times larger than for ordinary atoms. This would correspond to $h_{eff} = h/2$.

Pollack effect

In the Pollack effect (PE) [I60] negatively charged exclusion zones (EZs) are induced at the boundary between the gel phase and water by an energy feed such as IR radiation. The negative charge of EZ is explained as a formation of flux tubes carrying dark protons, which are interpreted as dark nuclei. Every 4^{th} proton should transform to a dark proton transferred to the flux tubes to explain the observations.

A simple model for linear dark proton triplets predicts their states to be in a 1-1 correspondence with DNA, RNA, tRNA, and amino-acids and the numbers of codons coding for given amino-acid are predicted to be the same as for the vertebrate genetic code [L89, L118]. This suggests deep connections between nuclear physics and condensed matter physics, chemistry, and biology, which, in the reductionistic spirit, are considered separate disciplines.

EZs are able to remove impurities from their interior in conflict with the second law of thermodynamics (SL). The TGD based explanation is that the time reversal by BSFR at the level of MB [L149] also induces an effective time reversal in long time scales at the level of ordinary bio-matter.

PE explains the occurrence of a charge separation in living matter. DNA has one negative charge per nucleotide, microtubules are negatively charged, the cell is negatively charged, and ATP carries 3 units of negative charge. Therefore ZEO suggests that PE plays a key role in bio-control and macroscopic SFRs play a key role in living matter.

Basic differences between organic and in-organic matter

One of the basic differences between organic and in-organic matter would be the presence of dark protons and electrons.

1. The notions of acids and bases would reduce to the presence of dark protons: pH would characterize the fraction of dark protons. Reduction and oxidation (the REDOX reaction) could be understood in terms of a transfer of dark electrons associated with valence bonds [L197] (`https://cutt.ly/5f5QrgF`).

2. In biochemistry the density of dark protons would be much higher in PE [I40, I39, L31, I60, I74]. Dark ions could play a key role in TGD based view of biochemistry as the findings of Blackman and others suggest [J57].

Biocatalysis and water memory

Bio-catalysis and water memory [I70] remain mysteries in the bio-chemical approach. MB carrying dark matter could provide the needed mechanisms. Reconnection of flux tubes would be the basic mechanism of bio-catalysis and also explain water memory, which in the TGD framework forms the basis of the immune system [K53].

1. According to the TGD view of catalysis, tentacle-like U-shaped flux tubes associated with MBs of reactants reconnect to a pair of flux tubes connecting the molecules [L92]. This happens if there is a cyclotron resonance for dark cyclotron radiation assignable to massless extremals (MEs) associated with these "tentacles". This requires that the flux tubes have identical magnetic field strengths and - by flux quantization - the same thickness. The same value of h_{eff} guarantees resonance. The next step is the shortening of the "tentacles" by a reduction of h_{eff} and the liberation of energy which "kicks" the reactants over the potential wall making an otherwise extremely slow process possible.

2. The physics of water is plagued by anomalies [I70]. TGD suggests an explanation [L79] in terms of flux tubes assignable to hydrogen bonds [L79, L91]. These flux tubes could have $h_{eff} > h$ so that these flux tube could be long and give rise to long range quantal correlations. Water could be seen as a many-phase system. MBs assignable to water molecule clusters could mimic the cyclotron frequency spectrum of the invader molecule and make possible water memory and a primitive immune system based on reconnections of the "tentacles" of a water cluster and invader molecule [L138]. In this framework water would represent a primitive life form.

16.4.2 Adelic physics, cognition, and biology

$M^8 - H$ duality [L120, L141, L142] concretizes the number theoretic vision.

1. $M^8 - H$ duality states that space- times are representable as 4-D surfaces in either complexified M^8 (complexified octonions O_c) or $H = M^4 \times CP_2$. $n = h_{eff}/h_0$ has an interpretation as a dimension of EQ identifiable as the degree n of the polynomial determining the space-time surface in M^8. Roots correspond to different sheets of n-sheeted space-time surface, and the Galois group G of EQ permutes the sheets with each other and act as a number theoretic symmetry group. Dark matter states at the flux tubes define representations of G.

2. The wave functions in the set of space-time surfaces obtained by the action of G may be interpreted as functions in G defining the group algebra $L(G)$ of G. They define quantal cognitive representations. Also their fermionic counterparts make sense. Galois group G would thus act as the symmetry group of cognition. The notion of cognitive measurement in $L(G)$ makes sense and leads to a model of cognitive process as a cascade of cognitive SSFRs [L145, L157].

3. Galois confinement [L138] would force n-particle states to behave as coherent units like hadrons do as color-confined states.

4. The model makes rather far-reaching predictions. The decomposition of EQ to an extension of an extension of an extension ... of rationals defines a *finite* hierarchy of normal subgroups which in turn makes it possible to express the element of $L(G)$ as entangled products of states in the group algebras associated with the normal subgroups. Simple groups, whose classification is known, are groups which have no normal subgroups [L157, L155] so that this decomposition is trivial. Cognitive processes such as SSFR cascades are impossible for simple Galois groups - thus thinking as analysis is impossible. Could simple groups classify meditative states (or irreducible ideas as analogs of axioms)?

16.4.3 Genetic code (GC)

The model of bio-harmony [L33, L34, L118, L136, L154] is essential for the TGD based understanding of what might be called emotional intelligence (whose reality is accepted) and its relations with ordinary intelligence. The surprising outcomes are the connection with GC and the key role of bioharmony in quantum information processing in living matter.

1. The notion of bioharmony relies on icosahedral and tetrahedral geometries. The representation of the 12-note scale as a sequence of quints, reduced by an octave equivalence (notes differing by octave are experienced as equvalent) to the basic octave, defines the harmony for a given Hamiltonian cycle: the 20 allowed 3-chords of the icosahedral harmony correspond to the 20 triangular faces. The symmetries of the harmony are defined by some subgroup (Z_6,Z_4, or Z_2) of the icosahedral group.

2. Genetic codons correspond to dark photon triplets (3-chords of light) defined by the triangular faces of an icosahedron and tetrahedron. The counterparts of amino-acids are identified as orbits of 3-chords under the symmetries of a given harmony.

   Any combination of 3 icosahedral harmonies with 20 chords with symmetries Z_6, Z_4 and Z_2 and of the tetrahedral harmony with 4 chords gives a particular bioharmony with 20+20+20+4=64 chords assignable to DNA codons. DNA codons coding for a given amino acid correspond to the chords at the orbit of the symmetry group. Rather remarkably, the numbers of DNA codons coding for a given amino acid come out correctly.

3. Music expresses and creates emotions. Musical harmony codes for moods and emotions as holistic aspects of music. Bio-harmony with 64 3-chords, would assign the binary, local, aspects of information to the 6 bits of the codon and its holistic, emotional aspects to the bio-harmony. A chemical representation of the genetic code can thus correspond to several moods represented by bioharmony. In contrast with physicalism, emotions would appear already at the molecular level, and would have physical effects that are not reducible to bio-chemistry. This understanding is not possible without using the notion of MB.

   The model of bio-harmony requires that the values of B_{end} correspond to those associated with the Pythagorean scale definable by the quint cycle. These frequencies correspond to energies that a molecule must have in order to serve as a basic biomolecule. This criterion could select DNA, RNA, tRNA, and amino-acids.

In the second model of GC [L89], codons are represented as dark proton triplets.

1. The numbers of dark proton triplets turn out to correspond to numbers of DNA, RNA, tRNA codons, and amino acids. The numbers of DNA and RNA codons assignable to a given amino-acid in the vertebrate GC are correctly predicted. Genes would correspond to sequences of dark proton triplets [L118].

2. Dark proton triplet - dark codon - would be analogous to baryon and Galois confinement [L138] behaving like a single quantum unit. The N dark codons of a dark gene would, in turn, bind to Galois confined states of the Galois group of an EQ associated with the sequence of codons. An entire hierarchy of confinements is possible.

3. Galois confinement can be realized also for dark photon triplets and the sequences of N dark-photon triplets representing genes as dark $3N$-photon states. Genes could serve as addresses for communications based on dark $3N$-photon resonances.

   For communications between levels with the same value of h_{eff} there would be both energy and frequency resonance and for levels with different values of h_{eff} only the energy resonance. It is an open question whether dark $3N$-photons transforms to single ordinary photon or $3N$ ordinary photons (biophotons) in dark-ordinary communications.

4. The basic hypothesis is that both DNA, RNA, tRNA, and amino acids are paired with their dark analogs, and that energy resonance mediates the interaction between the members of pairs.

How could the icosahedra and tetrahedra be realized? Why must one glue them together? This looks aesthetically unappealing. However, surprisingly, both icosahedrons and tetrahedrons appear in, perhaps the simplest honeycomb of the hyperbolic 3-space H^3 (cosmic time = constant hyperboloid). H^3 is also central to special relativity and cosmology [L154]. Dark GC can be realized in terms of both dark protons and photons using this particular tessellation and would be universal. This master tessellation would induce sub-tessellations at the space-time surface, in particular representations of GC at magnetic flux tubes. Also 2-D and even 3-D representations of GC can be considered (i.e. cell membrane and microtubules) [L156].

16.5 TGD based view of brain

The TGD based view of the brain differs in several ways from the standard neuro-scientific model relying on materialism and reductionism [K63, K62]. The notion of MB as a controller of BB (biological body) forces us to abandon the idea of the brain as the sole seat of consciousness. Also the view of the role of nerve pulses is radically different.

16.5.1 MB and brain

In the TGD framework, the onion-like hierarchical structures of the MB of the brain would correspond to brain regions and provide an abstract map of the brain. The structure of MB with levels labelled by EQs partially characterized by $n = h_{eff}/h_0$ measuring the scale of quantum coherence, would also reflect the geometric and topological structure of the brain.

MB as a hierarchy of abstractions

There is evidence that functionally similar neurons can be modelled using statistically determined hyperbolic geometry [J76]. Functionally similar neurons not necessarily physically near to each other would be near to each other in the effective hyperbolic geometry.

MB could realize this hyperbolic geometry quite concretely as an abstract representation of the hierarchical functional structure of the brain [L139]. That is, functionally similar neurons and also higher level brain structures not near to each other in the brain would be connected to nearby points at MB by flux tubes. Classification, visualizable as putting similar things in the same box, is a basic cognitive function and the hierarchy of MBs could realize classification geometrically.

An astonishing finding supports this view. In the lab, the neurons of the brain of a salamander were shuffled like a pack of cards. The salamander however recovered and preserved its memories (identified as learned behaviors) [J146]. In [K93, K95] this finding was considered as a support for the view that the brain is analogous to a hologram (The TGD Universe can be seen as a conscious hologram [K18]). It seems, however, clear that a single neuron cannot represent the information content of the entire brain. However, if memories are represented by the images of neurons at the level of the MB, the shuffling of neurons has no effect on memories as the experiment indeed demonstrated. Neurons would be analogous to RAM in computer science.

Dark photons and communications and control

Communications both inside the central nervous system (CNS) and also from ordinary cells, could occur by dark cyclotron photon signals with $h_{eff}/h = n$ and light velocity. The value of h_{eff} could be considerably smaller than for the EEG communications from CNS to the large part of the MB. The value of h_{eff} could be estimated from the scaling up of cell length scale to a typical scale found in CNS. This iteration of back-and-forth communications makes pattern completion and recognition possible.

Dark photons could transform in an energy conserving manner to biophotons with energies in the visible and UV range (at least) and thus above thermal energy and therefore have effects that are not masked by thermal radiation. The brain is known to emit biophotons and they are also associated with axons [K25, K15].

Dark Josephson radiation would make information transfer to MB possible whereas the control signals from the MB would be as dark cyclotron photons. **Fig. 16.15** illustrates the communication of sensory data to the "big" part of MB as dark photons.

1. Nerve pulse patterns modulate generalized Josephson frequencies for the flux tubes associated with the membrane proteins (such as ion channels and pumps) which act as generalized Josephson junctions. The sensory input is encoded by the Josephson radiation sent to the "big" part of MB [K37].

2. The frequency modulated Josephson radiation generated by nerve pulses would give rise to EEG (and perhaps also to its scaled variants) as a communication of information from the brain to MB via Josephson frequency modulation. In sharp contrast with the brain-centered neuroscience orthodoxy, the size scale of this layer of the MB would be rather large (i.e. of the order of c/f_c and given by the circumference of the Earth for the Schumann frequency $f_c \sim 7.8$ Hz). The structure of the Earth's magnetosphere suggests that both EEG bands and regions of BB correspond to regions of the magnetosphere [L153].

3. Nerve pulse patterns would code for information communicated to various layers of MB assignable to the EEG bands as a frequency modulated generalized Josephson radiation. Generalized Josephson frequency would be the sum of the ordinary Josephson frequency $f_J = ZeV/h_{eff}$ and the difference Δf_J of the cyclotron frequencies $f_c = ZeB/2\pi m$ for flux tubes at different sides of the neuronal membrane and transverse to it. The modulation of f_J by the nerve pulse patterns [K97, K37, K100] would code for sensory and cognitive information.

4. The frequency modulated dark photon radiation absorbed in cyclotron transitions at MB would generate a sequence of cyclotron resonances at MB, which code for sensory input.

   Already the modulation of the membrane potential at the basal ganglia of sensory receptors could communicate sensory information in this manner. If so, nerve pulse patterns could be a secondary representation of sensory information induced by the sequence of resonance peaks from MB back to the brain. This picture also applies to other forms of information (there are also basal ganglia inside the brain).

5. The dual representations of sensory information as resonance peaks and continuous Josephson radiation would be analogous to the local representation of a function provided by its values for a discrete sequence of time values, and to the holistic representation provided by its Fourier transform for a discrete set of frequencies.

MB controls BB and the motor output generated by the control signals from MB would act as "negative energy" signals with a reversed AT: two BSFRs are required to re-establish the original AT. The motor output of MB could take place via genes and induce gene expression as proteins.

Also other forms of gene expression such as as dark photon signals to the cell-/neuronal membranes could induce nerve pulse patterns.

The number theoretic vision suggests a considerable generalization of the idea of resonant communications [L197]. The model of Galois confinement (GC) based on the notion of bio-harmony [L33, L34, L136, L154] and the notion of GC [L145] suggests that dark $3N$-photon states, analogous to BECs, function as coherent dynamic units.

This inspires the notion of $3N$-resonance. Genes could be represented as sequences of N dark photon "3-chords" serving as addresses in dark $3N$-photon communications [L136, L154]. This picture leads to a model of human language [L195, L196].

16.5.2 A new view of sensory perception

The identification of sensory organs as seats of sensory qualia and a new view of the role of nerve pulses distinguish between the standard view of neuroscience and the TGD view.

Sensory organs as seats of sensory qualia

According to the TGD view, sensory perception generates sensory mental images at sensory organs rather than in the brain [L90]. This could solve some of the basic problems in neuroscience due to the similarity of neural tissue in various sensory areas. The basic objection is phantom limb

syndrome. The new view of time and memory implied by ZEO would solve this problem: the pain in the phantom limb would be a sensory memory of pain.

This view could solve several mysteries in neuroscience. The stimulation of temporal lobes indeed generates sensory memories, and people with cognitive impairment are known for memory feats such as being able to draw a building, seen in the past, in fine detail, or to learn entire works of music from a single listening.

1. These feats can be understood if the sensory memories and memories in general correspond to "seeing" in time direction.

2. The "obvious" interpretation would be that a beam of dark photons travels to the geometric *past*, is reflected back and produce memories as an analog of ordinary vision. Memories would be in the geometric past. However, on further consideration, the process seems to be more complex.

3. It is possible to build a rather detailed model for sensory memories [L143, L144] based on three ZEO and the notion of CD (see **Figs. 16.11** and **16.12**) as a perceptive field of self at the level of embedding space. A crucial element is the identification of the geometric correlate of the "subjective now" (T_{now}) as the 3-D ball along which the half-cones of CD are glued together.

   Memories as mental images would correspond to sub-selves assigned to sub-CDs residing in the *geometric future* of T_{now} and shifting to the geometric *future* (!) during the sequence of SSFRs defining self and increasing the size of the CD and value of T_{now}. In the BSFR, identified as the death of self in a universal sense, these memories would become "silent wisdom" for the next life cycle with an opposite AT. Computer scientists would refer to this function as construction of log files.

New view of the role of nerve pulse transmission

Since perception is not mere passive reception of sensory input, but involves pattern recognition building standardized mental images, the TGD based view of sensory organs requires back and forth signaling between the brain and sensory organs. There should be a virtual sensory input from the sensory areas of the brain, or from MB via the brain, to sensory organs.

A sensory percept would be an actively constructed work of art, a standardized mental image, which is as near as possible to the sensory input. Pattern recognition would occur when the constructed pattern is sufficiently close to a standardized mental image.

The velocity of nerve pulse conduction is too slow to build a standardized sensory mental image by back and forth signalling. Nerve pulse duration of order of 1 ms defines the lower bound for the duration of the synaptic "bridge" making possible the propagation of dark photon signals. For a 10 cm long neural pathway this duration allows about 10^6 forth and back paths of light for a signal between the sensory cortex and retina.

The TGD view of sensory perception and the function of the nerve pulse transmission differs from the standard view. Nerve pulse conduction would not be communication between parts of the CNS but construction of "waveguides" for dark photons as connected flux tubes from axonal units [L90] [K97]. Nerve pulse patterns at the level of the brain would build standardized cognitive representations by decomposing the sensory input into "named" objects of a perceptive field from which associations could be built.

Sensory organs are seats of sensory qualia and sensory perception. This model explains REM dreams, hallucinations, and psychedelic experiences as experiences involving only the virtual input. Imagination can be understood as an "almost sensory" experience.

More concretely:

1. Sensory mental images at the level of sensory organs are generated by an iteration involving the virtual sensory input from the brain to the sensory organs [L90]. Pattern recognition is realized as a carving of a 4-D work of art representing a standardized mental image as near as possible to the original sensory input. **Fig. 16.15** illustrates the back and forth communications of sensory data between sensory organ and brain using dark photons.

2. Nerve pulses would connect existing flux tubes parallel to axons to form longer flux tubes: neurotransmitters at synaptic contacts would act as relays. There is an obvious analogy with an old fashioned telephone network. It would requiree too energy to keep all connections on all the time.

   The meridians assigned with acupuncture network could correspond to a permanent flux tube network and would not require nerve pulses, transmitters, nor information molecules as relays. For CNS, this flux tube network would be dynamic. Plants would only have the meridian system.

3. The standard view of learning as a strengthening of synaptic connections translates into a gradual build-up of long-lived flux tube connections, which make possible dark photon communications. The sender and receiver neuron groups can also fuse to a single, quantum entangled, system.

4. Actually all information molecules (neural transmitters, hormones, and messenger molecules) could be connection builders. An alternative view is that information molecule such as hormone is attached to the end of a flux tube, which stretches as the molecule travels to the target.

   The same theory applies to water memory [K53], which remains a dismissed concept in mainstream science although the research performed outside the confines of institutional support has revealed much about the involved mechanisms.

Dreams, hallucinations, and imagination

TGD makes it possible to understand sensory imagination as virtual sensory inputs from MB via the brain, which do not reach sensory organs. Imagined motor actions as virtual motor actions would not reach muscles.

Virtual sensory inputs would be received by virtual sensory organs inside the brain. A good candidate is the basal ganglia. Ganglions are also associated with sensory receptors. The input from MB or brain would be represented as dark photons.

The notions of virtual sensory and motor input are central to the understanding of speech comprehension and also inner speech. Hallucinations, psychedelic experiences and REM dreams (motor activities during sleep) could be understood as virtual sensory (motor) inputs reaching the sensory organs (muscles). Memory recall could involve virtual (real in the case of sensory memories) sensory input from MB at which memory mental images are realized [L149, L102].

16.5.3 Memories

To understand what memories and memory recall could be in ZEO one must specify what the geometrical correlate of "subjective now" is.

"Geometric now" corresponds to the $T_{now} = T/2$ slice of CD (see **Fig. 16.11**) with maximal size located in the middle of the CD. If one accepts $M^8 - H$ duality [L120] "geometric now" corresponds to a "special moment in the life of self" [L120, L148] identifiable as intersection of the space-time surface and a 6-sphere which is a brane-like entity (in the sense of branes encountered in M-theory) appearing as a universal special solution to algebraic equations determining the space-time surfaces in M_c^8. The special values of T_{now} would correspond to the roots of the real polynomial defining the space-time surface.

2. During the sequence of SFRs, AB shifts towards the geometric future and the size of CD increases (in the statistical sense). The sub-CDs accompanying sensory and other mental images shift in the direction of the geometric future as CD increases during the SFR sequence and become potential memory mental images experiencing BSFRs in a shorter time scale.

   The time=constant snap-shots at the upper half of CD assignable to the memory mental images are ordered with respect to Minkowski time t but the order is opposite to the order of subjective experiences. This makes possible for the time-reversed re-incarnate to have these memories as "silent wisdom". Snapshots correspond to subselves to which memory recall

builds a connection by entanglement or by sending a signal, reflected back in a BSFR of the memory mental image.

How are episodic memories recalled in ZEO?

1. Spontaneous memory recall could correspond to the death of a memory mental image (sub-self/sub-CD) having the same AT as self (CD) followed by re-incarnation with an opposite AT. This would be accompanied by an emission of a past directed "negative energy" signal received by the self associated with the "geometric now". The interpretation is as an extraction of metabolic energy: memory recall indeed requires metabolic energy.

   Active memory recall could correspond to the receipt of a future directed "positive energy" signal by memory mental image arriving from the "geometric now", and allow interpretation as a metabolic energy feed. Reflection of the signal in opposite time direction requires BSFR. Why should BSFR happen? Could the metabolic energy feed induce (by NMP) rapid evolution and aging of the memory mental images leading to its death by BSFR.

2. The prediction is that in an active memory recall by a "positive energy" signals received by the memory sub-CDs (see **Fig. 16.11**), the order of recalled memories is opposite to that of the original experience. There is evidence for this kind of change [J126] (see also the popular article at `http://tinyurl.com/y7hbqmug`).

16.6 Aging and death from TGD point of view

ZEO based vision is that aging and death are universal phenomena and that death is followed by a reincarnation with a reversed AT.

16.6.1 Aging as approach of MB and BB to thermal equilibrium

The book "Lifespan" by Sinclair and LaPlante [I25] proposes that aging corresponds to an approach to epigenetic chaos. The book also proposes that bio-information is not only associated with DNA and GC but also the conformational degrees of DNA and that these are crucial in epigenesis. This vision serves as the starting point of a TGD inspired view of aging written with Reza Rastmanesh [L198].

In adelic physics, NMP [L157] replaces the second law (SL) but implies SL. MB carries dark matter and controls dynamics. Its quantum coherence induces non-quantum coherence of ordinary biomatter. The dissipation of a subsystem with a reversed AT looks like self-organization (SO) from the point of view of the outsider. Also self-organized quantum criticality (SOQC), which is difficult to understand in ordinary thermodynamics, can be explained.

The basic idea is that at birth the temperatures of the MBs of the information molecules are very low but gradually they approach the physiological temperature near the Hagedorn temperature T_H [B11] defining the maximal temperature of MB. T_H is determined by string tension as the energy density of the flux tube and much lower than T_H in superstring theory or in the hadronic string model.

The thermalization leads to epigenetic chaos implying that the flux tubes carrying dark DNA and therefore also ordinary DNA, become looped. The control of methylation and other modifications and their reversals crucial for epigenesis is lost. In particular, demethylation fails and leads to hyper-methylation of the promoter regions of genes. This leads to the failure of the control of genes coding for housekeeping proteins and eventually the system suffers collapse.

16.6.2 What death as BSFR looks like to an outsider?

One can enote the moment of geometric time associated with BSFR of a dying and reincarnating system by T; the dying system before death as S and its time-reversed reincarnate after death as R. Consider an outsider, labelled O. Refer to the AT of O, opposite to that of R, as standard AT. How does O see the situation before T and after T?

Death as seen by outsider before moment T

T can be larger than the "geometric now" of O so that the death of S, which has taken place with respect to the subjective time of O is located in the geometric future of O.

The time evolution of R allows classical signals to propagate in a non-standard time direction. This could explain the reported strange events preceding the death of a close relative or a friend. In neuroscience, the analog for this is what happens in Libet's experiments involving active aspects of consciousness [J44]. The brain receives a time reversed signal arriving from the geometric future. This signal is interpreted in the standard picture as a readiness potential.

Although BSFR is a discontinuous change with respect to subjective time, ZEO implies that O sees the outcome of BSFR of S as an average over continuous and deterministic time evolutions with the standard AT leading to its death. The outcome for a single time evolution is actually the initial state of a time reversed time evolution of R.

Dissipation with the reversed AT is a conspicious thermo-dynamic anomaly implied by BSFR. For O, this looks like SO, which involves generation of gradients. In particular, the extraction of energy from the environment manifests as a cooling of the environment [L194]. It may be possible to test this prediction.

Death as seen by an outsider after moment T

The life of the R increases its CD in an opposite direction of time (see **Fig. ??**). The CD of R eventually remains in the geometric past of those still alive. What happens in the region of space-time surface in $H = M^4 x CP_2$ in the future of the CD of R?

What O see, is the decaying organism. The interpretation is that the highest layer of the onion-like MB is absent and does not continue its control in the original time direction. The ship has "lost its captain". The layers of MB corresponding to the lower levels of the hierarchy are also expected to disappear. The decay of the organism continues down to the lowest molecular levels.

Note that death can be seen as a cascade of BSFRs proceeding downwards to shorter scales and destroying quantum coherence since the metabolic energy feed keeping the distribution of the values of h_{eff} unaffected is not present or usable.

Geometrically the "loss of a captain" means that the CDs in the personal hierachy of CDs cease to increase in size by SSFRs as they suffer BSFR.

Physically the loss means that dark photon radiation from BB providing metabolic energy to the highest control level of MB is not needed anymore and dark photons leak out as biophotons. The same happens at all levels as death proceeds to smaller scales.

Direct evidence here is the biophoton emission from dying plants, which intensifies and is used to deduce the vegetable age.

16.7 Evidence for life after death in universal sense

In any BSFR, the self, - identified as a sequence of SSFRs -, can be said to die and reincarnate with a reversed AT and continue to live as a conscious entity with a reversed AT. Selves thus live back and forth in geometric time. Experience from the previous life cycle would be represented as "silent wisdom" at the passive boundary of CD (PB), and experienced as mental images which need not be directly conscious or are barely conscious.

16.7.1 General signatures of life with reversed arrow of time

The time reversal at the level of MB occurs over considerably longer spatio-temporal scales than for ordinary matter with $h_{eff} = h$ and induces an effective time reversal at the lower levels. This makes it possible to assign well-defined signatures to the presence of time reversed conscious entities. In the TGD Universe life and death are universal phenomena so that these signatures should appear at all scales. This makes it possible to test the theory if these general assumptions are accepted.

1. Time reversal implies that the thermo-dynamic AT for some layers of MB is non-standard. This can induce thermo-dynamic anomalies at the level of ordinary matter. Already Fantap-

pie [J121] proposed that time reversal is common in living matter and introduced the notion of syntropy as time reversed entropy.

To O, dissipation with a reversed AT looks like a development of various kinds of gradients assignable to temperature, pressure, various chemical concentrations in biochemical systems, and to electric and magnetic fields.

In particular, cooling of the environment of a system, for which some layer of MB has suffered time reversal, is possible. This might explain anecdotal reports of eerie, cool spaces, where ghosts are said to be present.

Ordinary dissipation implies the decay of various structures, such as the decay of biomolecules to simpler building bricks. ATs of these processes can occur and the self-assembly of biomolecules challenging SL in its standard form could, at least in some cases, involve time reversal.

2. SO could be induced, not only by an active energy feed, but by a time reversed dissipation of the ordinary bio-matter induced by MB [L119]. There is evidence that living systems are quantum critical systems [I63]. In TGD, the entire Universe is quantum critical in the sense that the values of the fundamental coupling constant (Kähler coupling strength), are analogous to critical temperatures.

   Self-organized criticality (SOC) is a phenomenon difficult to understand in standard physics. Criticality is, by definition, unstable since the critical degrees of freedom act as repellors of dynamics. Even the smallest perturbation can lead far away from the repelling point. If the arrow of time is reversed, the repeller becomes an attractor and the system tends to stay near criticality. This would give rise to self-organized quantum criticality (SOQC) [L194].

16.7.2 Examples about BSFR and death in various scales

Some examples about BSFR as the death of a conscious entity in various scales are in order.

Pollack effect and time reversal

The generalization of the Pollack effect (PE) [I40, L31, I74, I60] plays a key role in TGD inspired biology.

1. As previously explained, PE occurs in the presence of an energy feed such as IR photons, and means a charge separation in water bounded by gel, forming a negatively charged exclusion zone (EZ).

2. EZ has a strange property of driving out impurities: this is a thermodynamic anomaly (along with charge separation). The interpretation is that AT is changed at MB controlling EZ and induces an effective change of AT at EZ differing from the standard AT of an observer positioned outside.

In the TGD framework, PE also generalizes to other ions than H^+ - at least the positively charged ions inside neuronal (cell) membrane. Negatively charged entities are indeed abundant in biology.

1. DNA nucleotide involves a negatively charged phosphate ion. This suggests that DNA strands are accompanied by parallel magnetic flux tubes which carry dark proton triplets as a representation of genetic codons [L54, L118, L136].

2. The cell interior is negatively charged, which suggests similar charge separation with the positive charge assignable to dark ions at the magnetic flux tubes outside the cell. Bosonic ions such as Ca^{2+}, Mg^{2+}, Fe^{2+} and Cooper pairs of fermionic ions such as K^+, Na^+,.. could form Bose-Einstein condensates (BECs). Also negatively charged ions, such as Cl^-, could form BECs at flux tubes.

3. Microtubules carry a constant negative charge density per unit length realized in terms of GTP molecules suggesting that they are accompanied by parallel flux tubes carrying dark charges, such as dark protons. Microtubules could be partially responsible for the negative charge of the cell and could relate to the control of the membrane potential.

BSFRs and homeostasis as self-organized quantum criticality

The article "*Homeostasis as self-organized quantum criticality*" [L194] represents an attempt to understand the properties of cold shock and heat shock proteins (CSPs and HSPs). Since these proteins are similar, it may be preferential to talk about stress proteins (SPs) as having two different operational modes.

The problem of understanding the behavior of SPs turns out to be only one particular facet of a more general problem: how is self-organized criticality (SOC) or even a quantum variant of SOC (SOQC) possible? Kauffman represented empirical evidence for quantum criticality at the level of bio-chemistry [I63]. As previously explained, ZEO leads to a theory of SO and of SOQC.

In fact, living systems as a whole may be quantum critical and manage to stay near criticality, which means that SOQC could be interpreted as homeostasis central for life. There would be no life without death: homeostasis would be possible only by the temporary death/sleep/hibernation of subsystems. Homeostasis would not be due to extremely complex biological programs but caused by the dissipation with a reversed AT driving the system towards quantum critical configuration.

Bio-rhythms as life-death cycles and living clocks

In the TGD Universe, living matter is a population also in 4-D sense. Periodic biological processes would correspond to sequences of CDs associated with sub-selves living back and forth in geometric time.

In the geometric future of a given CD, the decay process occurs and is followed by a generation of the self corresponding to the next CD in the sequence: this self must be distinguished from time-reversed re-incarnate in its geometric past. The first half-period (lower half-cone of CD) would correspond to life and the second half-period (upper half-cone of CD) to a decay process. The next period would correspond to the next CD in the sequence defining a living and conscious biological clock.

EEG rhythms could be associated with these kinds of life forms. There is indeed evidence that the first half of the EEG period is ordered and the second half is chaotic [J79]. The single EEG half period as a counterpart to a living system would represent mental images shifted towards the geometric future, inside the CD, after its birth.

Perhaps most periodic processes identifiable as bio-rhythms are such processes. The most obvious examples are breathing and heartbeat. At longer time scales the annual cycles represent similar examples.

16.7.3 Direct subjective evidence

NDEs provide subjective evidence for the continuation of conscious experience after death at the level of human conscious experience. The universality of death as BSFR also suggests other evidence.

Sleep,anesthesia, and hibernation as "small" deaths?

Sleep, anesthesia, and hibernation could involve BSFR at some layer of MB. Falling asleep would be a "small" death and waking up a "small" rebirth. No dramatic changes of world view usually occur during sleep. Can one conclude that the layer of MB and the corresponding CD are not changed dramatically in size so that the physical decay processes are avoided? The layer of MB could correspond to a considerably smaller size scale as in the case of biological death: this layer is not the "boss" at the highest level so that ship would still have the captain and the decay processes would not start.

After images as re-incarnations in the usual sense

The phenomenon of after images, discussed from the TGD point of view in [K15], suggests that mental images arise and die. The reincarnation of a mental image as an after image is analogous to "ordinary" reincarnation and is distinguished from re-incarnation with a reversed AT. The mental images would shift to the geometric future of the "geometric now" and repeat their karmic cycle and experience BSFR in memory recall.

The process generating after images would be analogous to the proposed process behind biorhythms. MB could have loops such that the signals circulating around loops serve as a sensory input and generate sequential after images.

16.7.4 Do reincarnations occur?

The idea of reincarnation is gaining a new boost. The Washington post article (see this) describes quite a recent example of a child who remembered experiences of a person who might have been a victim of Holocaust. Since the 1960s, more than 2200 children all round the world have described what looks like memories from a previous life.

What makes this interesting from the point of view of TGD inspired consciousness predicts the possibility of re-incarnation.

1. In TGD, space-time is replaced with a 4-surface in $M^4 x CP_2$. 4-*surface can be regarded as an orbit of a* 3-*surface identifiable as a* 4-*D generalization of a point-like particle. General Coordinate Invariance for holog surfaces are analogous Bohr orbits of these* 3-*surfaces* − *rather than* 3-*surfaces, and quantum states are wave functions in the space of these* 4-*D Bohr orbits. Quantum TGD is a kind of wave mechanics in the space of Bohr*

2. The revolutionary idea is that basic physical entities are almost deterministic time 4-D time-evolutions of 3-D particles rather than particles. At quantum level wave functions as quantum states are replaced by the superpositions of these 4-D Bohr orbits. This forces us to replace the standard ontology of quantum theory with "Zero energy ontology" (ZEO). The outcome is a solution to the measurement problem of quantum theory and one gets rid of myriads of "interpretations".

3. Number theoretic vision of TGD predicts the possibility of quantum coherence in arbitrarily long scales. This would be due to a hierarchy of phases of ordinary matter with non-standard value of effective Planck constant. These phases would reside at field bodies/magnetic bodies. This matter behaves like dark matter. Field bodies replace the Maxwellian view of electromagnetic fields and the analog of dark matter resides at field bodies assignable to systems consisting of ordinary matter. This dark matter would be the "boss" that would control ordinary biomatter.

4. The new quantum measurement theory predicts that in the TGD counterparts of ordinary state function reductions (SFRs) ("big" SFRs or BSFRs) the arrow of time changes. On the other hand, the sequences of repeated measurements of the same observables, which in ordinary quantum measurement theory do not affect the state at all, do change it, and the sequence of these "small" SFRs (SSFRs) gives rise to a conscious entity, self. Subjective time flow corresponds to the sequences of SSFRs and must be distinguished from the geometric time.

   Self dies/falls asleep in BSFR and reincarnates with an opposite arrow of time and lives in the opposite direction of time. One might speak of time travel to the geometric past. Eventually also this self dies and reincarnates with the original arrow of time: this would be a re-incarnation in the "ordinary" sense. A rough estimate based on a concrete view of what happens in BSFRs and SSFRs suggests that this happens roughly a typical lifetime later than the death of the previous re-incarnate. The claimed reincarnation described in the article is consistent with this.

But is it possible to remember anything about the previous life? One must distinguish between two situations since previous life could correspond to the same or opposite arrow of time as the recent. Since BSFR and SSFR and the notion of self are universal and not restricted to living matter only, it is better to speak of system S although it might sound rather formal and bring in mind the spherical cows of physicists.

1. If the arrow of the geometric time is the same, the signals from the previous life of S in geometric past can reach the later reincarnate of S and the memory recall is possible. This could explain the memories of previous lives. Especially so if they are related to a very intense experience since in these kinds of situations the classical signals are expected to be very intense.

2. What about the situation in which the arrows of geometric time are opposite? Also falling asleep as "death" and waking-up as a "reincarnation" corresponds to a pair of BSFRs. That

we remember practically nothing from the period of deep sleep could be understood: the classical signals from the period of sleep travel to our geometric past so that we never receive them.

One could however consider a loophole to this. The reincarnate RS of the S or its subsystem could live a short period with a reversed arrow of time and send signals received by the S, which wakes up next morning. Dreams could correspond to these kinds of short periods when a part of the brain is awake and gives information of the dream period. If this smaller part of the brain corresponds to a lower level in the self hierarchy and the temporary period with opposite arrow of time is short, one could understand the decomposition of dreams to short logical periods and surreal character. That the memories from the period of sleep are soon forgotten could be due to the fact that the classical signal is a finite pulse and does not spend a long time in the required part of the brain. It could however arrive again it if rotates around a close monopole flux tuber loop as one might expect.

Temporary short lasting changes of the arrow of time leading from S to RS are indeed predicted to occur routinely. For instance, homeostasis and the biological self-organization in general, would rely in an essential manner on this. Also learning by trial and error mechanism would involve a pair of BSFRs. In fact, our stream of consciousness is not continuous. We continually fall asleep for short periods of time. Living systems would be dying all the subjective time (to be distinguished from the geometric time) and this might make it possible to have memories of previous lifes with an opposite arrow of time!

16.8 Near-death experiences (NDEs)

The Wikipedia article "Near-death experience" [J21] gives a good overall view of NDE, research on NDE, and theories of NDE.

Raymond Moody, the pioneer of NDE, wrote "Life after Life" (1975) [J153] consisting of interviews with NEDrs. Two accounts by medical professionals about personal NDE convinced them that the standard neuroscience view of NDE was wrong. Books by Mary Neal [J136] and by Eben Alexander [J71] conveyed a similar message.

NDE can be studied scientifically. The article by Lichtfield [J99] summarizes the empirical reseach. Retrospective reseach relies on interviews of NDErs and its scientific soundness may be questioned: memories many years after NDE are not reliable and a documentation about the state of the NDEr during NDE is missing. However, prospective studies can be made in hospitals so that documentation regarding patient status is contemporaneous. Interviews can be made immediately after NDE. It is even possible to test various claims such as autoscopy (seeing oneself from outside).

A book edited by Janice Miner Holden, Bruce Greyson, and Debbie James (2009) [J105] summarizes the results of 30 years of scientific investigation since Moody's book.

Books by Pim van Lommel (2010) [J147], by Sam Parnia [J167] (2013) [**?**]2018), and by Bruce Greyson [J42] are recent important publications.

16.8.1 What are NDEs?

The challenge is to understand the structure of NDE and its often deep effect on the life of NDEr.

NDE experience

The following aspects of NDEs summarized in the Wikipedia article [J21] seem nearly universal. These basic aspects need not occur in the order listed below.

- Out-of-body experience (OBE) characterized as detachment from the body and seeing one's own body from outside; awareness of being dead.
- Sensation of darkness, the tunnel experience, and movement toward/or sudden immersion in a powerful light; unconditional love and acceptance; encountering beings of light; reuniting with deceased loved ones.
- Life review.

- Decision by oneself or others to return back and reluctance to return.
- Suddenly finding oneself in one's own body.

This view is over-simplified.

1. NDE does not always have a positive emotional tone. About 25 % of NDEs involve negative emotions such sensations of anguish and distress.
2. Universality is not complete: the notions used to describe NDE depend on culture, in particular religious background.
3. Charlotte Martial, a neuropsychologist who led a team that investigated 154 NDE cases, concluded that findings challenge the assumption about a fixed sequence of events [J89] (see `https://cutt.ly/ZkPdiBT`).

   However, NDE seems to always begin with OBE and end with a return to one's own body. The most common order of events was OBE; being aware of a tunnel; seeing a bright light; and finally a feeling of peace. This exact sequence was reported in 22 percent of the 27 experiences that had all these 4 basic elements.

   The order of basic elements of NDE may be important if the goal is to build a concrete model for NDE. Neuroscientific models may well identify components of NDE that occur in a "disturbed bodily multisensory integration" but do not provide a holistic view.

After effects of NDE

NDE has often profound after effects. Physiological effects include heightened sensitivity to light at some frequencies, sound, and certain chemicals. Anecdotally, NDErs can also have a strange influence on electrical equipment.

Other effects include changes in behavior and social attitudes. Documented changes include

> a greater appreciation for life, higher self-esteem, greater compassion for others, less concern for acquiring material wealth, a heightened sense of purpose and self-understanding, desire to learn, elevated spirituality, greater ecological sensitivity and planetary concern, and a feeling of being more intuitive.

Physiological correlates of NDE

The following is a list of basic physiological correlates of NDE.

1. EEG is absent during the experience. There is no pulse and breathing has stopped. Oxygen based metabolism is reduced leading to hypoxia or even anoxia. It is highly questionable whether the neural activity can receive the needed energy from oxygen based metabolism.
2. Experiments with rats suggest that NDE follows an intense gamma peak in EEG (around 40 Hz) 30 seconds after death (meditative states begin with a gamma peak followed by an alpha peak). The states involving NDE can last for hours. It is difficult to understand how a clinically dead brain could give rise to NDEs at all. It is not clear how long NDEs can be.
3. Pupils are fixated and dilated so that visual experiences seem impossible. How could visual percepts be produced? It has been proposed that biophotons could produce the visual perceptions during NDE [J52] in the visual cortex. The intensity of biophotons might indeed increase in biological death (decaying vegetables emit biophotons [I46]). Visual sensations of this kind are, howeve, simple dots or light, phosphenes: how could they integrate to form visual perceptions?
4. Meditators can produce NDEs at will and can even control them. Also psychedelics, in particular DMT produced by the body, and present in mammalian pineal gland (PG) [J157] can predictably produce NDE-like experiences. The concentration of DMT in the hippocampus of rats having heart arrest increases.

   Could the function of DMT (`https://cutt.ly/Izq2mEz`) and PG be the creation of a third person perspective (always present at cognitive level) and various aspects of NDEs and altered states of consciousness in general?

16.8.2 Explanations of NDE

The explanations of NDE [J21] can be classified as trancendental/religious, psychological, and physiological.

Many transcendental and religious beliefs about the after-life include descriptions similar to NDEs. According to the dualistic interpretations of NDE, the soul leaves the body temporarily during NDE.

Both dualistic, materialistic, and idealistic theories of consciousness can be criticized. Materialism has problem with free will. By requiring that conscious experiences correlate with the physical reality, it it is difficult to avoid the reduction of dualism to materialism [J59]. The problems of idealistic theories are mirror images of the problems of materialistic theories.

For instance, Susan Blackmore [J160, J161, J159] is materialist and an advocate of physiological explanations. She sees consciousness as an illusion. One wonders what the identification of consciousness as one particular phenomenon of consciousness really means.

According to the neuroscientific hypothesis, NDE is a subjective phenomenon due to a "disturbed bodily multisensory integration" that occurs during life-threatening events. The experience would not reflect reality but the disturbed state of the brain. What "disturbed bodily multisensory integration" means and how it is produced, remains unclear.

There are several objections against the neuroscientific hypothesis.

1. Advanced meditators can generate NDE at will; NDE is universal - even children can have NDEs; NDE is well-organized rather than a bundle of chaotic sensations; the empirical justification of the hypothesis is missing.

2. How could a clinically dead brain produce such complex and structured perceptions and even simulate a sensory third person perspective at the level of sensory experience? We do not even understand how a living brain can produce ordinary perceptions in the first person perspective.

Concerning the explanation of NDEs there are several philosophical guidelines.

1. A cognitive third person perspective is part of the conscious experience, yet it is not easy to understand. A sensory third person perspective is even more difficult to understand from a neuroscience perspective. It is difficult to identify a physical correlate or physiological explanation for the "third person" in the physicalistic approach.

2. Eastern philosophies based on an introspective study of conscious experience emphasize that the identification of the experiencer with the physical body is illusory. Is even the notion of an experiencer only a convenient auxiliary notion? Are experiences alone fundamental as idealists argue?

It is hard to see how NDEs could be understood within a framework of materialistic, idealistic or dualistic theories of consciousness. Something new is mandated.

16.8.3 Psychological and physiological explanations of NDE

The summary of psychological and physiological explanations of NDE follows the Wikipedia article [J21].

Psychological explanations

The depersonalization model, expectation model, dissociation model, and birth model represent the basic psychological explanations.

1. Depersonalization model

According to this model, "persons who face their impending death become detached from the surroundings and their own bodies, and no longer feel emotions, and experience time distortions".

The Wikipedia article mentions the following objections against the model. The model does not explain NDEs for subjects who do not experience OBE; unlike NDEs, the depersonalization

experiences are dreamlike, unpleasant and characterized by "anxiety, panic and emptiness". Also, during NDEs subjects remain very lucid about their identity; their sense of identity does not change.

2. Expectancy model

The expectancy model states that although NDEs appear very real, they are actually mental constructions in response to the stress of an encounter with death, and do not correspond to real events.

Wikipedia mentions the following objections. Subjects' accounts often differ from their own religious and personal expectations regarding death whereas imagined scenarios would rely on their cultural and personal background. The NDEs of meditators do not conform with this proposal.

3. Dissociation model

The dissociation model proposes that NDE is a form of withdrawal to protect an individual from a stressful event. Under extreme circumstances, some people may detach from certain unwanted feelings in order to avoid the associated suffering. Detachment from one's immediate surroundings occurs.

The model explains the OBE aspect of NDE but does not say much about other aspects.

4. Birth model

The birth model suggests that near-death experiences could be reliving the trauma of birth. Since a baby travels from the darkness of the womb to light and is greeted by the love and warmth of the nursing and medical staff, the dying brain could be recreating the passage through a tunnel to light, warmth and affection.

The basic objection is that newborns do not possess "the visual acuity, spatial stability of their visual images, mental alertness, and cortical coding capacity to register memories of the birth experience".

Physiological explanations

A wide range of physiological explanations of NDE have been proposed and can be classified according to whether the disturbance is neuroanatomical (say abnormal activity in the temporal lobes), due to the imbalance of involved molecules, such as neural blood gas models (cerebral hypoxia, anoxia, and hypercapnia) or due to an imbalance associated with information molecules (endorphins and other neurotransmitters). Multifactorial models for NDE include an interplay of endorphins, neurotransmitters of the limbic system, the temporal lobe and other parts of the brain.

1. Neuroanatomical models

Olaf Blanke and Sebastian Dieguez [J51] suggest a neuroanatomical model assigning NDEs with a malfunction of temporal-parietal junction:

> "Type 1 NDEs are due to bilateral frontal and occipital, but predominantly right hemispheric, brain damage affecting the right temporal-parietal junction and characterized by OBEs, an altered sense of time, lightness vection (sensation of bodily motion) and flying.".
>
> Type 2 NDEs are due to bilateral frontal and occipital, but predominantly left hemispheric brain damage affecting the left temporal parietal junction and characterized by the feeling of a presence, meeting and communication with spirits, seeing glowing bodies, as well as hearing voices, sounds, and music without vection..

According to French [J54] " the temporal lobe is almost certainly involved in NDEs, given that both damage to and direct cortical stimulation of this area is known to produce a number of experiences corresponding to those of NDE, including OBEs, hallucinations, and memory flashbacks".

According to Greyson [J41]

Multiple neuroanatomical models have been proposed in which NDEs have been hypothesized to originate from different anatomical areas of the brain, namely: the limbic system, the hippocampus, the left temporal lobe, Reissen's fiber in the central canal of the spinal cord, the prefrontal cortex, the right temporal lobe. Although some of the neuroanatomical models proposed may help to explain NDEs, they remain speculative at this stage since they have not been tested in empirical studies..

2. Neurochemical models

These models suggest imbalances of various neurotransmitters (such as glutamate, noradrenaline, dopamine, endogenous opioids, serotonin). There are indeed similarities between NDEs and the effects of hallucinogens.

According to Parnia [J165, J166], neurochemical models are not based on actual data. Parnia writes that no data has been collected via thorough and careful experimentation to back "a possible causal relationship or even an association" between neurochemical agents and NDE experiences.

3. Altered blood gas levels models

Low oxygen levels characterize life-threatening situations. Anoxia or hypercarbia (abnormally high level of CO_2 in blood) are hypothetized to produce phenomena such as seeing brilliant lights, reliving past memories and OBE.

The visual cortex dysinhibition that accompanies anoxia (severe hypoxia) has been suggested as an interpretation of tunnel-like perception during NDEs.

16.8.4 TGD based view of biological death

This section represents a possible TGD based view of biological death. The model is of course only one particular interpretation, but is defensible by a rationale that it is based on a general vision of consciousness, biology and neuroscience, is internally consistent, and does not have any obvious conflicts with empirical facts.

Biological death as process

The first challenge is to build a model for biological death.

1. Upon death, breathing and heartbeat cease which leads to a loss of oxygen based metabolism. EEG signals also disappear after gamma peak (at least in the case of rats). Pupils are fixated and dilated.

2. Sleep as a "small death", is in many respects, similar to death and could represent an example of a life cycle in an opposite time direction. Falling asleep involves a shift of the EEG frequency scale below the alpha band (around 10 Hz). There are four stages of sleep and the lowest frequency scale is around 3 Hz. Since EEG wavelengths naturally correspond to the size scales of MBs, the size scale of MBs receiving sensory input would increase in the process. Gradually the sizes of MBs receiving information from BB would increase. At least four size scales for MBs corresponding to EEG bands during sleep would be involved [K114, K37, K100, L153].

   This is also expected to happen in biological death. The disappearance of EEG readings could mean a shift of EEG to frequencies so low that EEG effectively disappears.

3. This would suggest that death proceeds from short to long scales in the hierarchy of MBs and CDs as the feed of metabolic energy from lower to higher levels ceases and the values of h_{eff} are reduced. Since the size scale L of CD is expected to be $L = (h_{eff}/h)L(h)$, its size is reduced if $L(h)$ is not changed. This would allow the reincarnated self to experience "childhood".

   $h_{eff} = h$ need not be reduced if $L(h)$ is reduced. One however expects that ontogenesis involves the emergence of levels with an increasing value of h_{eff} in the hierarchy of MBs/CDs.

One can see the process possibly leading to death as an attempt of higher levels MB_n of MB to resuscitate BB by dying and in this manner providing metabolic energy to the lower level. If MB_n fails, MB_{n+1} tries. If all levels fail, death is inevitable.

1. First the level MB_{n+1} immediately above level MB_n performs BSFR (i.e. it dies in order to save MB_n). AT changes and the energy of the 3-D state initiating time reversed evolution increases since dark photons at level $n+1$ transform to those at level n (just like dark photons can transform to bio-photons giving rise to an energy release as a plant dies). Thus MB_n receives metabolic energy. NMP forces BSFR of MB_n if the negentropy gain is larger for BSFR than for SSFR, and MB_n "wakes up" as the original AT is established.

   MB_n in turn performs the same operation for MB_{n-1}. If this process manages to proceed to the level of BB, revival occurs. Breathing, heartbeat, metabolism, EEG and other basic rhythms are re-established and the person experience the return to one's own body.

2. BSFR for MB_{n+1} need not necessarily generate enough metabolic energy by time reversed dissipation to induce the revival of MB_n. In this case, MB_{n+2} tries the same. If all these attempts fail, death is inevitable.

This proposal brings to mind the story of Jesus who died to save mankind. There are also variants of the story where Jesus lived another life before resurrecting: is this time reversed life? Myths may tell us something that our present day science cannot express.

What could the peak in EEG gamma band mean?

The death process begins with a peak of EEG activity (at least in the case of rats) over the entire brain lasting about half a minute.

Consider a summary of the findings concerning the EEG of rats suffering cardiac arrest, as given by Bokkon *et al* [J52]. They proposed a model for the visual sensations of NDE in terms of bio-photons.

1. Borjigin *et al.* (2013) [J75] recorded EEG signals over the frontal, parietal, and occipital cortices bilaterally in rats during wakefulness, anesthesia, and cardiac arrest. Within 30 s after the rats' hearts stopped beating, cardiac arrest produced a transient and global surge of synchronized gamma oscillations of brain activity that exceeded the waking state.

2. High levels of global alpha-gamma coupling were also found. This suggests that the visual cortex can be highly activated in cardiac arrest. Previous studies indicate that alpha-gamma coupling is especially important for visual perception [J92]. In particular increased gamma intensity in an area of the brain that is right on top of the visual cortex is detected. The speculation was that the activation level is high and gives rise to visual aspects of NDE.

3. Could a gamma peak occur for humans? The proposal of Bokkon *et al* [J52] is that a gamma peak is accompanied by biophotons assumed to be created by radicals related to oxygen based metabolism and these give rise to NDE. There is evidence that light induces phosphene like sensations in the brain but it is difficult to understand how this could lead to a highly organized sensory perception. Also the assumption that biophotons originate from molecular transitions is questionable since there is no discrete spectrum characterizing molecular transitions.

What could be the exact function of the EEG peak in the gamma band?

1. The EEG peak could mean communications between BB and MB and control by MB. Gamma peak correlates with vision and gamma activity couples to alpha activity: gamma peak and its coupling to alpha is known to occur in the transition to a meditative state and NDE has basic aspects of the meditative state.

2. Could the gamma peak correspond to dark photons with energies of visible light? Could the gamma peak relate to the first stage of NDE involving the tunnel experience and darkness, which is also a visual experience, rather than a lack of visual consciousness, and theorized to be based on a narrowing of the visual field caused by anoxia?

3. How could the gamma peak relate to the experience of seeing light and light beings? These perceptions are not congruent with the effects of hypoxia or anoxia. Where does the light come from and where is it received? Does the light arrive from personal MB? Retinas cannot serve as receptors since during NDE they are not functional. Hence the proposal that NDE could correspond to virtual sensory input from MB to the eyes is not plausible.

4. Could MB utilize PG - the "third eye" - as a sensory receptor to which dark light would be transferred from MB via visual cortex. This may also provide an understanding of auditory experiences during NDE if dark photons are also the mediators of auditory information, perhaps transferred to ears.

Pineal gland as "third eye" in NDE?

The pineal gland (PG) - colloquially referred to as the "third eye" and the principal seat of the soul by Descartes - carries pigments like the retina in the eye and indeed serves as an eye for some animals. What about us? Could visual imagination utilize PG as an eye? Could PG take the role of the eye during NDEs during which virtual sensory input to the eyes (as in case of REM sleep) is not plausible?

A feedback loop between MB and PG could, in principle, make building of the sensory perceptions by a feedback loop possible. Also auditory inputs from the right and left combine to form a single perception. PG has the unique property that it has no division into left and right parts. Could it act as a central unit integrating both the right and left visual and auditory perceptions?

The presence of DMT in PGs of mammalian brain is documented [J78] (`https://cutt.ly/8k5eQSS`). According to the researchers, the discovery of PG as a source of DMT reinforces the idea of the role of this enigmatic gland in unusual states of consciousness. DMT has been linked to the generation of images in dreams, with the states of consciousness that generate NDEs and various mystical experiences. In rats suffering heart arrest the concentration of DMT in PG increases.

Rick Strassman in his aptly named book "DMT: The Spirit Molecule" has studied the effects of DMT on volunteers [J157]. DMT consistently produced NDEs and mystical experiences. Many reported convincing encounters with intelligent nonhuman presences, aliens, angels, and spirits. Nearly all felt that the sessions were among the most profound experiences of their lives.

A curious finding is that PG becomes visible in the human fetus at 49 days, which in the Tibetan traditions (see Bardo Thodol - the Tibetan Book of the Dead) is the number of days in which a soul takes to reincarnate. These coincidences led Strassman to theorize that the soul incarnates in the body at the seventh week of pregnancy.

Could one establish a connection to MB? Could the third person aspect of consciousness emerge before the first person aspect? Interestingly, small children often talk about themselves in the third person perspective.

These findings compel the question: Could PG act as a third eye - and maybe also third ear - during NDE?

1. In the TGD based model for the brain, neural transmitters and various information molecules serve as relays inducing flux tube connections. The binding to receptors would connect the magnetic flux tubes assignable to pre- and post-synaptic neurons to longer flux tubes, which act as wave guides for dark photons and mediate sensory information from sensory organs to brain, and from brain to MB (see **Fig. 16.15**).

   The EEG frequencies associated with these flux tubes are inversely proportional to their length and EEG wavelengths could correspond to the flux tube lengths. Could an EEG burst also build flux tube connections for frequencies below EEG range so that communications to large layers of MB are present although not visible in EEG.

2. Various information molecules, in particular DMT which induces altered states of consciousness and is endogenous, could connect the flux tubes at the neuronal level to long flux tubes and build connections to the distant layers of MB.

3. Could DMT serve as a relay to build the flux tube connections to higher layers of MB with size scales assignable to the Earth's magnetosphere [**?**] and communicate its third person sensory input to PG as dark photons? The gamma peak suggests that DMT acts as a relay to build flux tube connections to the visual cortex which in turn has pre-existing flux tube connections to MB. Specifically how the "Spirit Molecule" connects to dark photons and flux tubes calls for further laboratory investigations.

   In TGD framework sensory organs are carriers of sensory qualia and sensory perception requires feedback from MB and brain as a virtual sensory input as dark photons to sensory organs to build standardized mental images [L90]. In the case of NDEs virtual sensory input to eyes and ears is also absent in TGD unless REM dream periods and their possible auditory counterparts occur. A feedback loop between MB and PG could, in principle, make the construction of organized sensory percepts and pattern completion possible.

   If PG serves as a kind of organizing center, not only the visual but also the auditory input during the entire NDE including OBE, tunnel experience and darkness would be amplified using PG as a sensory organ. Gamma peak would not give rise to NDE but make NDE possible. This would be analogous to the gamma peak coupled to the alpha peak that precedes the transition to the meditative state.

4. More generally, psychedelics could act as relays inducing these kinds of connections and psychedelic experiences and NDE indeed have some common features. This leads to ask whether the anecdotal reports given by psychedelic experiencers and involving meetings with members of advanced civilizations could be real in the sense that remote sensory experience is involved [L40, L55, L56]. Note that if these experiences are based on sending light signals reflecting back with an opposite AT (BSFR for the flux tube carrying the signal), finite light velocity is not a problem.

Could pineal gland also act as a third ear?

There are indications that PG could also act as a third ear.

1. An article by Baconnier et [J73]) tells about a discovery of calcite microcrystals in PG of the human brain. These studies were carried out using electron diffraction and Raman spectroscopy to view cubic and hexagonal morphologies. The only other known deposits of crystal in the human body occur in the otoconia structure of the inner ear. The suggestion is that this rare crystallographic symmetry has links to piezo-electric properties. Investigations continue to explore the bio-electromagnetic crystalline connection between PG and inner ear.

   If calcites are also present in the ear, they could transform the incoming sound signal to dark photon signals propagating to the brain and MB and also faciliate the receipt of the virtual auditory input as dark photons transformed into acoustic oscillations. Oto-acoustic sounds are sometimes heard even by an outsider. An interesting question is whether REM sleep has an analog at the level of the ears.

   In [L90] it is proposed that PG could serve as a relay station at which the dark photon radiation from MB could generate imagined visual and auditory sensations as almost-sensory experiences or send signals to the sensory organs. NDEs suggest that the sensations could already be created in PG so that in some circumstances it could act as a third ear. At the ears, the calcite crystals would transform sound to dark Josephson radiation transferred to MB, where they would generate a sequence of resonance peaks communicated back to the brain and induce a nerve pulse sequence as a cognitive representation of the sensory input.

2. The action of PG as a third ear could explain several strange subjective experiences, including my own. For instance, when I wake-up partially so that my body continues to sleep, I can hear my own snoring as an outsider and it takes time to realize that it is actually me. The intensity of the sensation is considerably stronger than usual. Does my personal MB directly listen to my breathing and perhaps also pick up sounds from the environment - at least those created signalling the presence of living entities - and communicate the sensory data to my PG to wake me up if needed? In this way MB could act as a "guardian angel".

3. Crystals are not present only in the brain. Bones - and also PG - contain hydroxyapatite, a mineral form of calcium apatite $Ca_{10}(PO_4)_6(OH)_2$. Hydroxyapatite contains Posner molecules $Ca_9(PO_4)_6$ proposed to play crucial role in quantum biology by Mathew Fisher [J138] (`http://tinyurl.com/hd3t6sr`): Posner molecules are discussed from the TGD point view in [L43] and it is proposed that the 6 phosphorus atoms could define the 6 bits of genetic codon playing a fundamental role in the dark photon communications using the GC realized as bio-harmony [L33, L34, L136, L154].

   Could bones also act as transmitters/receivers of sound and dark photon signals to MB and back? Could they make the third person aspect of sensory consciousness possible and perhaps be active during sleep? Note that shivers up the spine - possibly related to quantum coherence - are induced by experiences with a strong negative or positive emotional color, in particular good music.

16.8.5 TGD based model for NDE

Existing data provide the groundwork for experimental tests and help to develop a more detailed picture of what happens in death and NDE.

What happens in OBE?

Consider first a sketch for what might happen in OBE.

1. The experience starts with OBE. The roles of the environment and observer effectively change: the perceiver becomes the perceived one. The third person aspect of experience is actually always present but not at the level of sensory input.

   The following analogy may provide a further clarity. Consider a video stream of a room to a TV monitor watched by a person. The disappearance of the video stream from the monitor serves as an analog for OBE. The video stream having the monitor screen as a blind spot would be analogous to the ordinary sensory input, and the direct visual perception of the room including TV screen would correspond to the third person sensory input.

2. EEG would be flat and would not communicate sensory data about the environment via BB to MB unless it has shifted to frequencies below EEG spectrum. MB acting as the "third person" must receive sensory information about BB as seen from the outside. The sensory information could be communicated as dark photons emitted by the dying BB produced as Josephson radiation from cell membranes and as dark cyclotron BE condensates decay in the absence of a metabolic energy feed.

   Eventually darkness enters: this does not however mean an absence of visual consciousness. The interpretation is that the burst of dark photons resulting from the reduction of the values of h_{eff} is over and MB cannot see BB anymore unless a secondary burst occurs.

3. An interesting challenge to this model are descriptions of NDEs involving memories of the conversations of the hospital personnel performing resuscitation. Could the sound waves in the environment generate the signals sent to MB directly?

   Could the oscillations of flux tubes of MB analogous to Alfwen waves and those of vibrating string provide fundamental representation of sound and the correlates for the auditory qualia: this would mean that auditory qualia are realized at the fundamental level as some easterm philosophies propose.

   The proposal that GC is realized for dark photons [L136, L154] inspires the question whether dark phonons (i.e. quanta of sound) also realize GC and whether musical experiences rely on dark phonons and dark phonon triplets as basic chords coding for harmony?

Tunnel experience, immersion into light

Recall that a physiological explanation of the tunnel experience is as a reduced visual perception due to the metabolic restrictions caused by hypoxia or even anoxia. This model generalizes to the TGD framework.

1. In TGD framework the sudden emergence of light might be interpreted as the start of visual input from MB as sensory input to PG.

2. This does not explain the movement along the tunnel. What is moving and where it is moving? The reconnection of U-shaped flux tubes for two systems creating a pair of flux tubes connecting the systems is a necessary prerequisite for dark photon communications by resonance. Could the motion of the U-shaped flux tube (functioning as a tentacle) reaching out from the brain and eventually meeting the U-shaped flux tube from MB create the sensation of motion along a tunnel and the emergence of light? This would initiate the sensory input from MB.

One can also ask whether tunnel experience and immersion into light could be understood as sensory memories about birth as the psychological explanation of NDE proposes? Sensory memories indeed accompany NDEs.

1. The basic objection is that the memories about this period are not linguistic: the immersion to light instead of having a detailed visual view would conform with this since the infant does not cognize and cannot decompose the visual input into objects (similarly, if congenitally blind people get vision back, they see only diffuse light).

2. Note that if the child entangles with mother negentropically, he/she could share its mother's sensory mental images to perceive and perhaps even interpret the world. The experience of unconditional love and peace during this period of NDE could correspond to a memory about maximum entanglement with the mother before the moment of birth. NEDrs also report meeting light beings, relatives, friends, and beloved ones. Do they correspond to a later part of life review or does the negentropic entanglement with mother make this kind of experience also possible immediately after birth?

3. Memories would be represented essentially as sensory mental images - conscious entities living in the geometric future of the deceased self and inside its CD, which is inside the larger CD of MB. Memory mental images should radiate dark photons with positive energy located in MB and form a representation of memories.

Life review and the decision to return

Life review at death is both an abstraction and a summary. Life review consists of experiences of the reincarnate R during NDE, when the entire brain could be dead. The survivor S remembers them. How can one understand this?

1. Sleep is "small death" and corresponds at some level of MB to a conscious state with non-standard AT. Life review is analogous to remembering conscious experiences during the sleep state. We remember from the sleeping period only our dreams.

   The TGD proposal is that MB for some part of the brain (say the visual cortex) is awake during dreams. This makes communication of memory mental images possible since the signals have the AT of the awake person.

2. Could this also be true for memories in the life review experience associated with NDE. Could the dead brain have regions whose MBs are awake and make possible the communication of life review? Could the MB of PG, which would act as a guardian angel and soul, be the higher level self which communicates the life review?

What does the decision to return to life mean? Return could mean a second BSFR re-establishing the original AT leading to a revival. NMP forces BSFR [L157] so that the effective decision maker would be an abstract principle rather than a conscious entity.

16.8.6 After effects of NDE

The psychological after effects of NDEs could be understood in terms of the two BSFRs which can profoundly affect the "silent wisdom" associated with PB. Also the actual memories located in the half-cone representing the active half of CD are changed.

NDErs are sensitive to light at some wavelengths and their presence has anecdotally been associated with strange effects on electronics.

1. The sensitivity to light at some wavelengths should relate to dark photons having an energy spectrum in the visible and UV range. Flux tubes of MB have cyclotron frequencies (very low) but due to the large value of $h_{eff} = h_{gr}$ the energies are in the biophoton range. The educated guess here is that the connections to some parts of MB (with cyclotron frequencies to certain wavelengths) are strengthened in NDE.

2. The emission of this light changing partially to ordinary photons (biophotons) might also cause effects on electronics. The electronvolt is the natural energy unit for charged particles accelerating along flux tubes in electronic systems. Therefore these dark photons could have effects on MB of electronic systems. Could the poorly understood $1/f$ noise in electronic systems be assigned to MB as an analog for biophotons resulting from dark photons? If this were the case, the distribution of flux tube lengths would be scale invariant and behave like 1/length in accordance with fractality.

16.9 Conclusions

Let us summarize the basic vision of life after death proposed in this essay.

1. The TGD inspired theory of consciousness relies on adelic physics [L68, L69], which fuses the physics of sensory experience, based on reals, with the physics of cognition based on p-adic number fields. Entanglement negentropy is always non-positive in ordinary physics but in adelic physics it contains an additional cognitive contribution and can be positive for EQs.

   NMP was originally proposed as the basic variational principle of consciousness generalizing SL and implying it for ordinary matter. The net increase of negentropy is by NMP however non-vanishing. It however turned out that there is no need to postulate NMP separately. NMP is mathematically analogous to the second law and follows from the fact that the dimension of extension of rationals characterizing algebraic complexity of space-time region and therefore evolutionary level is bound to increase in statistical sense. Furthermore, NMP implies the second law.

2. According to ZEO based quantum measurement theory, consciousness, life and death are universal phenomena. This can be tested in all length scales, varying from sub-atomic to astrophysical scales, by identifying signatures of time reversal. For an observer with standard AT, dissipation with a reversed AT manifests as thermo-dynamic anomalies conflicting SL. Generation of gradients and structures, SO and also SOQC giving rise to homeostasis are the basic signatures.

3. The biological applications include models of quantum biology and of a quantum brain relying on the notion of MB and $h_{eff} = n \times h_0$ hierarchy defining a master-slave hierarchy.

   The basic prediction is the quantum coherence of layers of MB with arbitrarily long size scales. MB induces the coherence of ordinary biomatter at the bottom of the hierarchy.

   This vision inspires a model of aging and biological death. Aging would be due to the approach of MB to a thermal equilibrium with BB. The temperature of MB increases and approaches the Hagedorn temperature [B11] of flux tubes which would be near physiological temperatures. By its large heat capacity, MB could also serve as a metabolic energy storage unit. For instance, MBs of stress proteins would serve this function [L194].

4. The TGD based model of the brain differs from the standard neuroscience view in several respects. MB controls BB and brain and uses them as sensory receptors and motor organs in a general sense. Quantum coherence makes possible the identification of sensory organs

as seats of fundamental qualia - also basal ganglia inside the brain could also play this role. In particular, PG could serve as a sensory organ during NDEs.

5. A model for what happens in biological death is developed using NDEs as input. The proposal is that MB performs a hierarchical resuscitation operation: BSFR at a given level " n" of this hierarchy induces BSFR. This however provides metabolic energy to the level "$n-1$" possibly inducing a revival so that temporary death at level " n" gives to the possibility of rebirth as a second BSFR at level " n" . If not, the level "$n+1$" tries the same. An analogy with the Christian resurrection story is one comparative example. The model explains the basic aspects of NDE such as OBE experience, tunnel experiences and immersion into light, meeting light beings dead beloved ones, life review, and a decision to return. OBE would correspond to a third person sensory perspective with MB in the role of perceiver. The sensory input could be sent by MB to the brain and amplified at PG taking the role of eyes and ears as a central sensory receptor.

   As I wrote the first version of this chapter there were uncertainties related to the details of what precisely happens in BSFRs: for instance, could the size of CD decrease or is there a steady increase of the size. The recent purely quantal formulation of time evolution [L180] is in terms of the finite-dimensional space of CDs with maximal isometries forming the backbone of WCW. The time evolution defined by SFRs and the counterparts of unitary time evolutions preceding them would be essentially dispersion plus localications in the space of CDs. Much like for Schrödinger equation.

16.10 Appendix

16.10.1 Appendix A: Brief glossary of the basic concepts of TGD

The following glossary explains some basic concepts of TGD and TGD inspired biology.

- ***Space-time as surface***. Space-times can be regarded as 4-D surfaces in an 8-D space $M^4 \times CP_2$ obtained from empty Minkowski space (M^4) by adding four small dimensions (CP_2). The study of field equations characterizing space-time surfaces as "orbits" of 3-surfaces (3-D generalization of strings) forces the conclusion that the topology of space-time is non-trivial in all length scales.

- ***Geometrization of classical fields***. Both weak, electromagnetic, gluonic, and gravitational fields are known once the space-time surface in H as a solution of field equations is known.

  Many-sheeted space-time (see **Fig. 16.4**) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by ***wormhole contacts*** (see **Fig. ??**) identified as the building bricks of elementary particles. The sizes of wormhole contacts vary but are at least of CP_2 size (about 10^4 Planck lengths) and thus extremely small.

  Many-sheeted space-time replaces reductionism with ***fractality*** . The existence of scaled variants of physics of strong and weak interactions in various length scales is implied, and biology is especially interesting in this respect.

- ***Topological field quantization (TFQ)*** . TFQ replaces classical fields with space-time quanta. For instance, magnetic fields decompose into space-time surfaces of finite size representing flux tubes or -sheets. Field configurations are like Bohr orbits carrying "archetypal" classical field patterns. Radiation fields correspond to topological light rays or massless extremals (MEs), magnetic fields to magnetic flux quanta (flux tubes and sheets) having as primordial representatives "cosmic strings", electric fields correspond to electric flux quanta (e.g. cell membrane), and fundamental particles to CP_2 type vacuum extremals.

- ***Field body*** (FB) and ***magnetic body*** (MB). Any physical system has field identity - FB or MB - in the sense that a given topological field quantum corresponds to a particular source (or several of them - e.g. in the case of the flux tube connecting two systems).

Maxwellian electrodynamics cannot have this kind of identification since the fields created by different sources superpose. Superposition is replaced with a set theoretic union: only the *effects* of the fields assignable to different sources on test particle superpose. This makes it possible to define the QFT limit of TGD.

- ***p-Adic physics*** [K79] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.
- ***Adelic physics*** [L69, L73] is a fusion of real physics of sensory experience and various p-adic physics of cognition.
- ***p-Adic length scale hypothesis*** states that preferred p-adic length scales correspond to primes p near powers of two: $p \simeq 2^k$, k positive integer.
- A ***Dark matter hierarchy*** realized in terms of a hierarchy of values of effective Planck constant $h_{eff} = nh_0$ as integers using $h_0 = h/6$ as a unit. Large value of h_{eff} makes possible macroscopic quantum coherence which is crucial in living matter.
- ***MB as an intentional agent using biological body (BB) as a sensory receptor and motor instrument*** . The personal MB associated with the living body - as opposed to larger MBs assignable with collective levels of consciousness - has a hierarchical onion-like layered structure and several MBs can use the same BB making possible remote mental interactions such as hypnosis [L26].
- ***Magnetic flux tubes and sheets*** serve as "body parts" of MB (analogous to body parts of BB), and one can speak about magnetic motor actions. Besides concrete motion of flux quanta analogous to ordinary motor activity, basic motor motor actions include the contraction of magnetic flux tubes by a phase transition reducing Planck constant, and the change in thickness of the magnetic flux tube, thus changing the value of the magnetic field, and in turn the cyclotron frequency. Reconnections of the flux tubes allow two MBs to get in contact and temporal variations of magnetic fields inducing motor actions of MBs favor the formation of reconnections. Flux tube connections at the molecular level bring a new element to biochemistry making it possible to understand bio-catalysis. Flux tube connections serve as a space-time correlates for attention in the TGD inspired theory of consciousness.
- ***Cyclotron Bose-Einstein condensates (BECs)*** of various charged particles can accompany MBs. Cyclotron energy $E_c = hZeB/m$ is much below thermal energy at physiological temperatures for magnetic fields possible in living matter. In the transition $h \to h_{eff}$ E_c is scaled up by a fractor $h_{eff}/h = n$. For sufficiently high value of h_{eff} cyclotron energy is above thermal energy $E = h_{eff}\ ZeB/m$. Cyclotron Bose-Einstein condensates at MBs of basic biomolecules and of cell membrane proteins - play a key role in TGD based biology.
- ***Josephson junctions*** exist between two superconductors. In TGD framework, ***generalized Josephson junctions*** accompany membrane proteins such as ion channels and pumps. A voltage between the two super-conductors implies a ***Josephson current***. For a constant voltage the current is oscillating with the ***Josephson frequency*** . The Josephson current emits ***Josephson radiation***. The energies come as multiples of ***Josephson energy***.

  In TGD generalized Josephson radiation consisting of dark photons makes communication of sensory input to MB possible. The signal is coded to the modulation of Josephson frequency depending on the membrane voltage. The cyclotron BEC at MB receives the radiation producing a sequence of resonance peaks.
- ***Negentropy Maximization Principle*** (NMP). NMP [K73] [L157] is the variational principle of consciousness and generalizes SL. NMP states that the negentropy gain in SFR is non-negative and maximal. NMP implies SL for ordinary matter.
- ***Negentropic entanglement*** (NE). NE is possible in adelic physics and NMP does not allow its reduction. NMP implies a connection between NE, the dark matter hierarchy,

p-adic physics, and quantum criticality. NE is a prerequisite for an experience defining abstraction as a rule having as instances the state pairs appearing in the entangled state.

- ***Zero energy ontology (ZEO)*** In ZEO physical states are pairs of positive and negative energy parts having opposite net quantum numbers and identifiable as counterparts of initial and final states of a physical event in the ordinary ontology. Positive and negative energy parts of the zero energy state are at the opposite boundaries of a ***causal diamond*** (CD, see **Fig. 16.11**)) defined as a double-pyramid-like intersection of future and past directed light-cones of Minkowski space.

  CD defines the "spot-light of consciousness": the contents of conscious experience associated with a given CD is determined by the space-time sheets in the embedding space region spanned by CD.

16.10.2 Appendix B: Figures

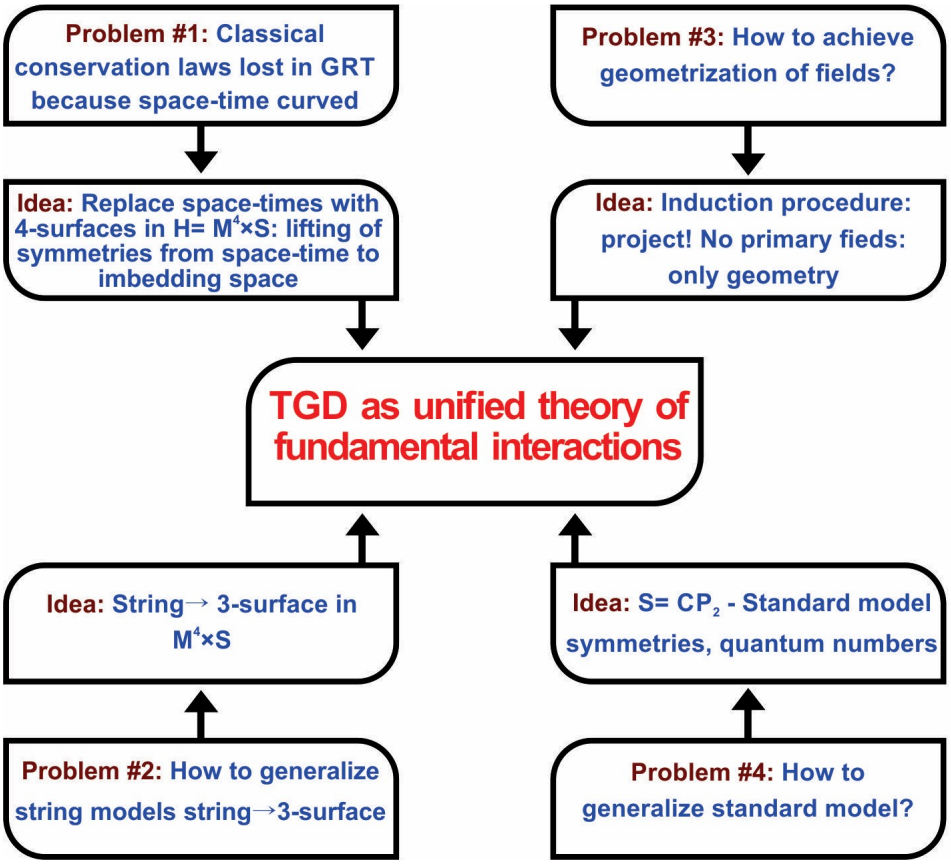

Figure 16.1: The problems leading to TGD as their solution.

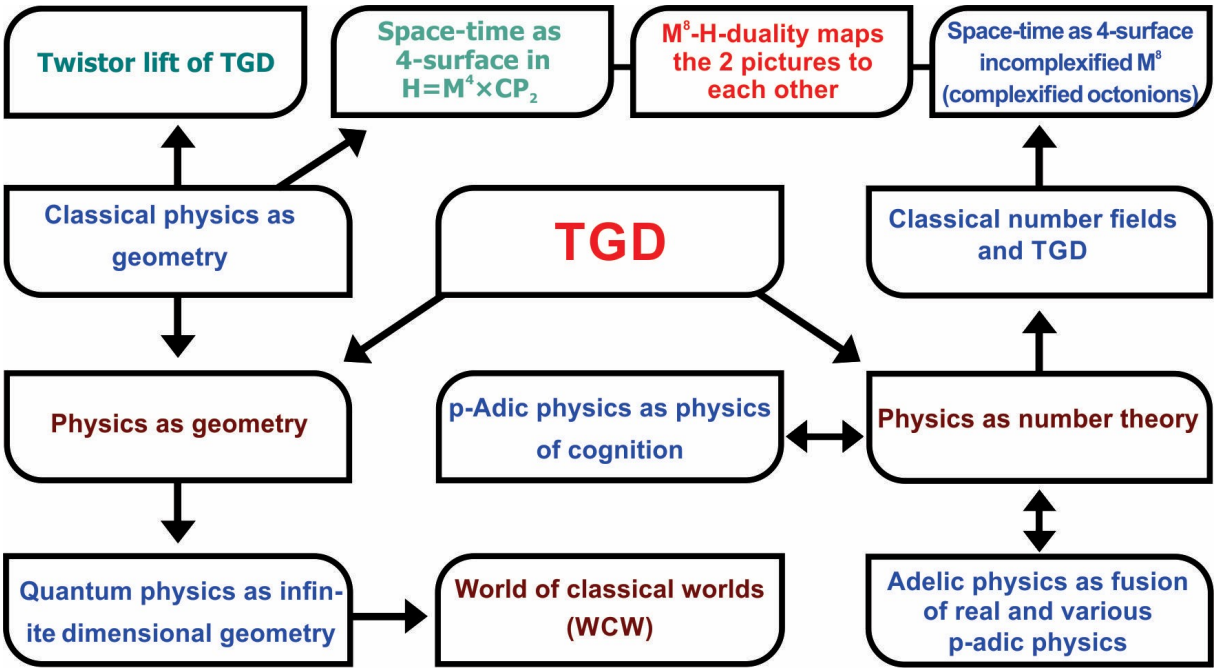

Figure 16.2: TGD is based on two complementary visions: physics as geometry and physics as number theory.

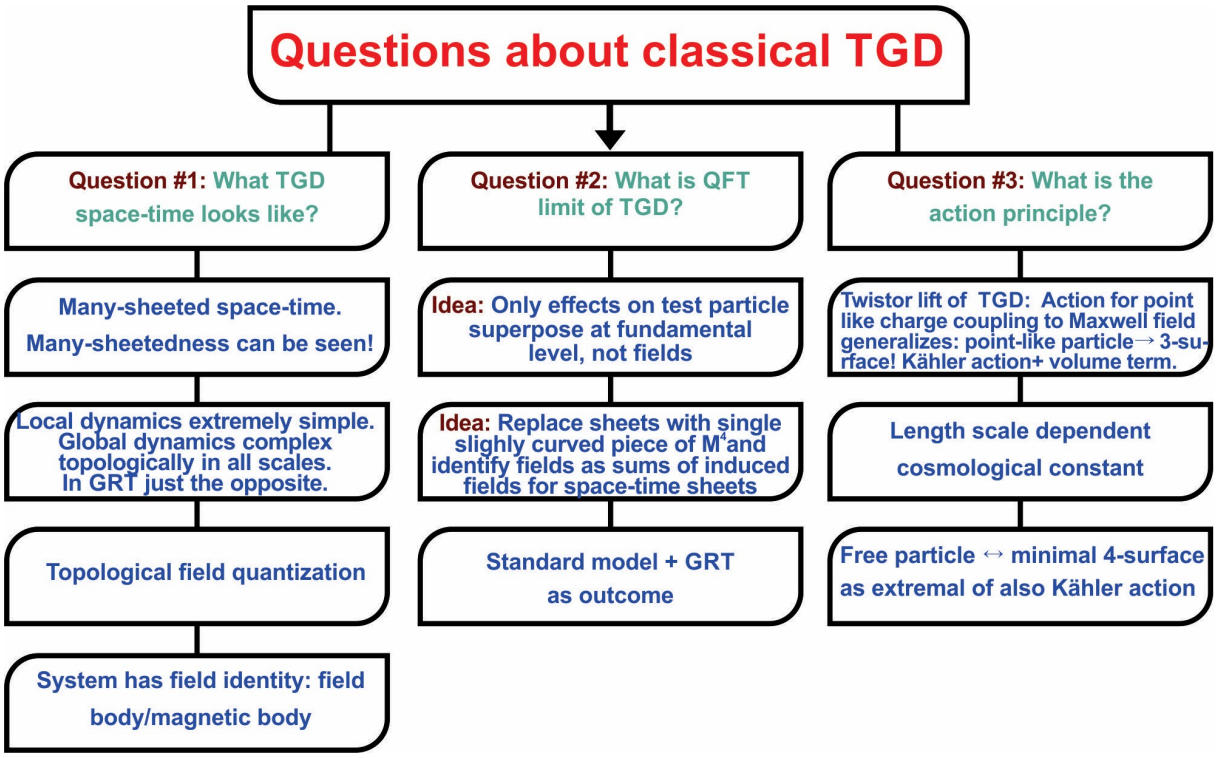

Figure 16.3: Questions about classical TGD.

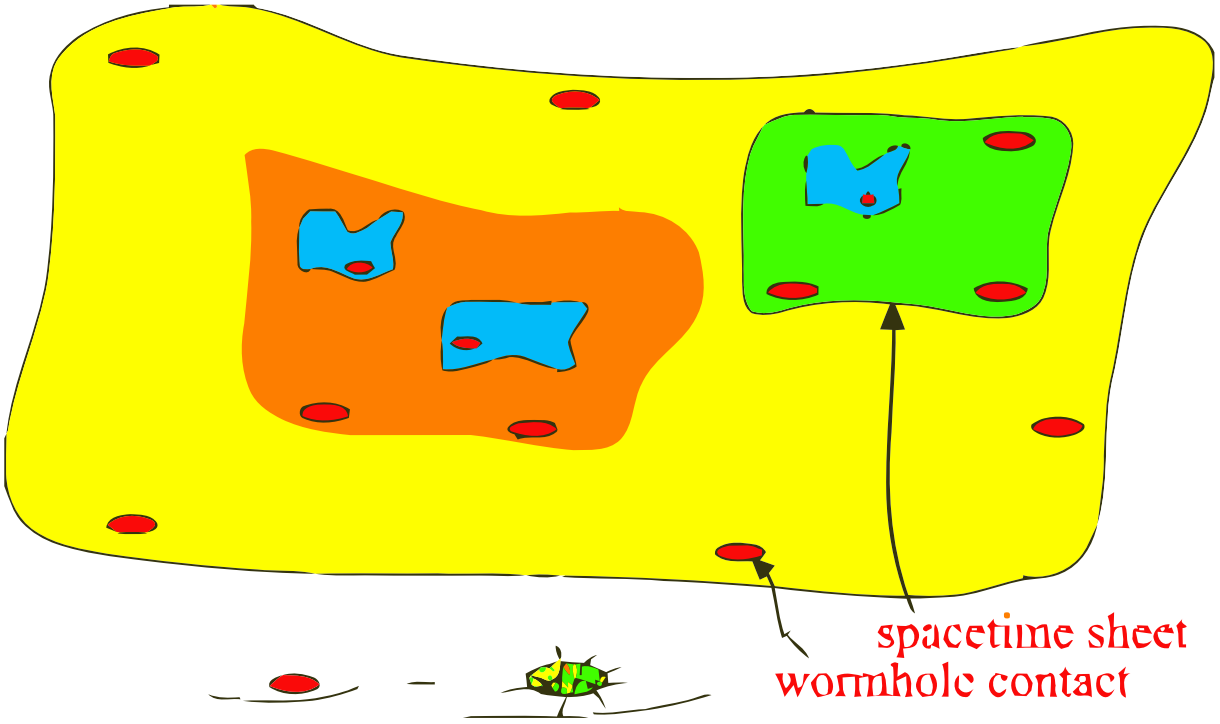

Figure 16.4: Many-sheeted space-time

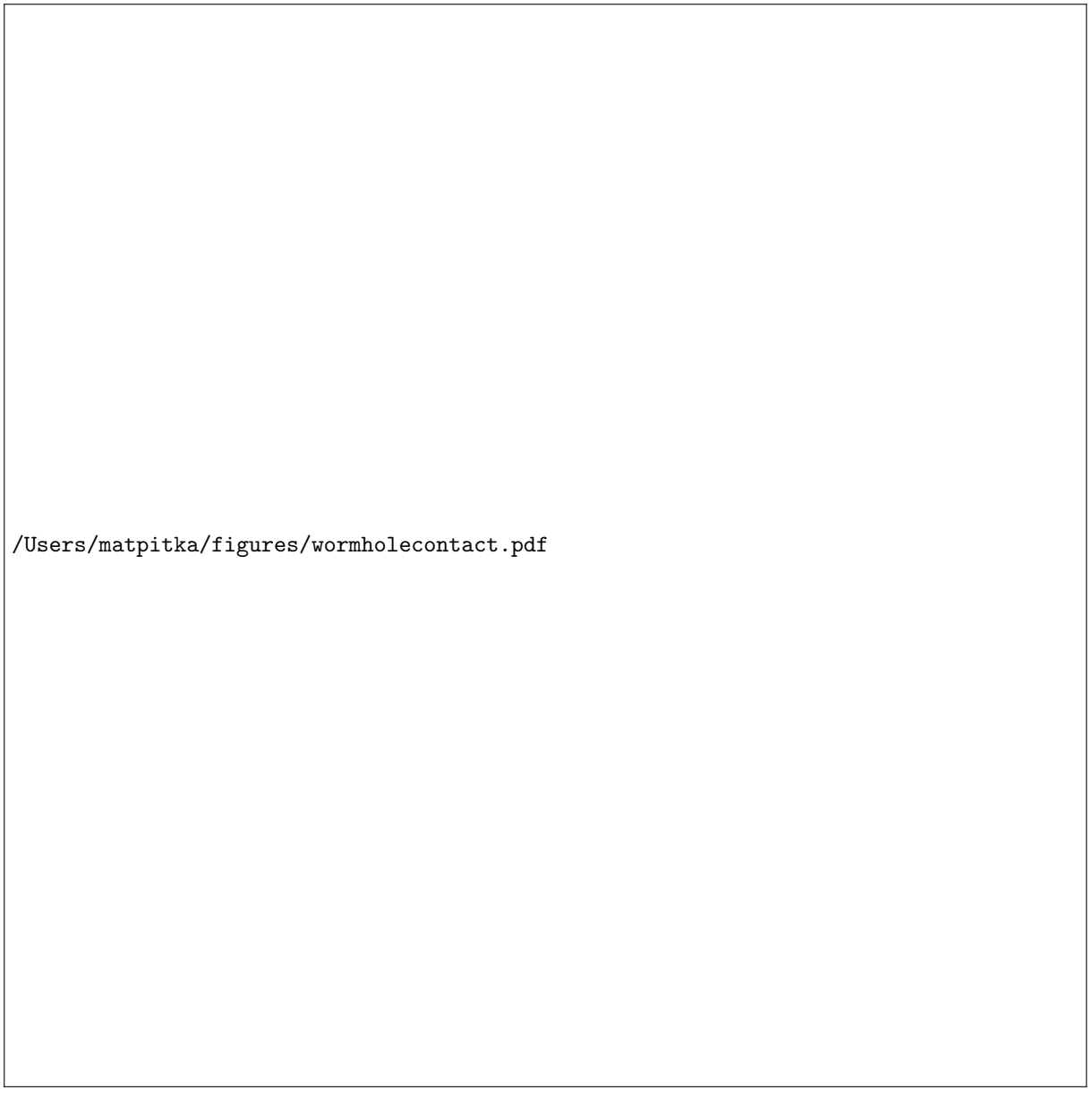

Figure 16.5: Wormhole contact.

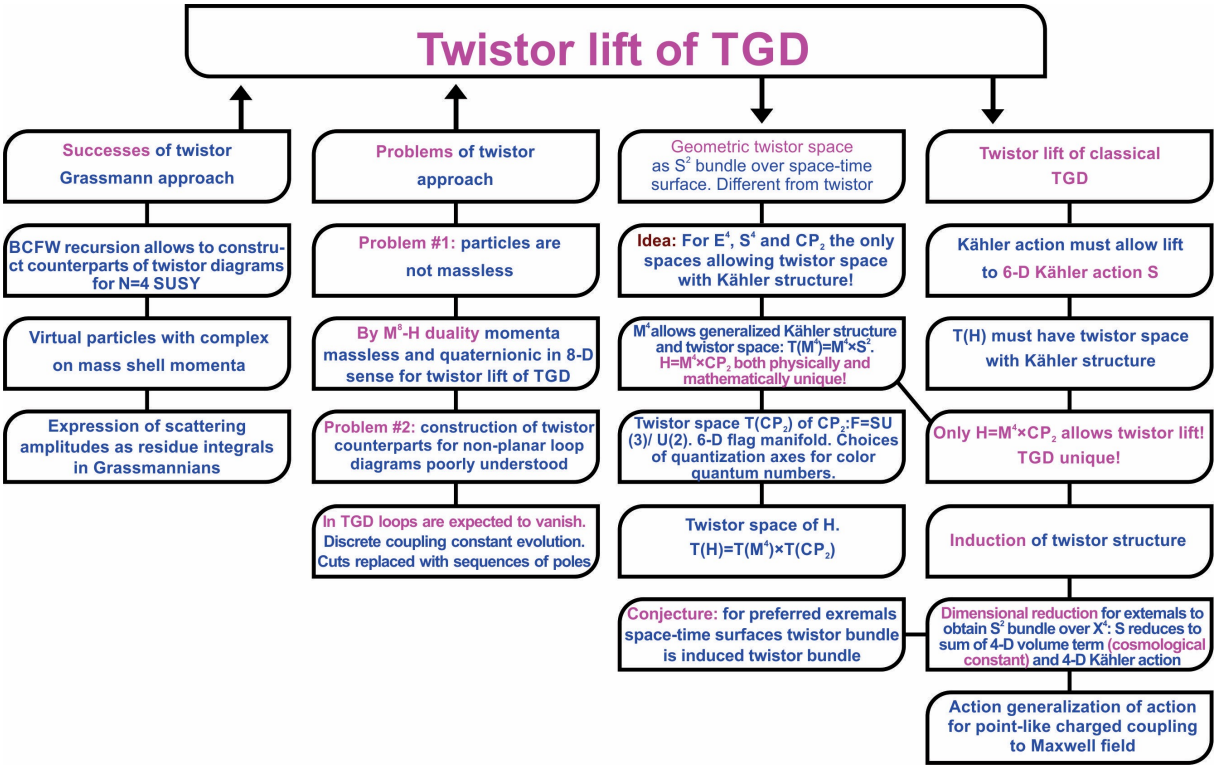

Figure 16.6: Twistor lift

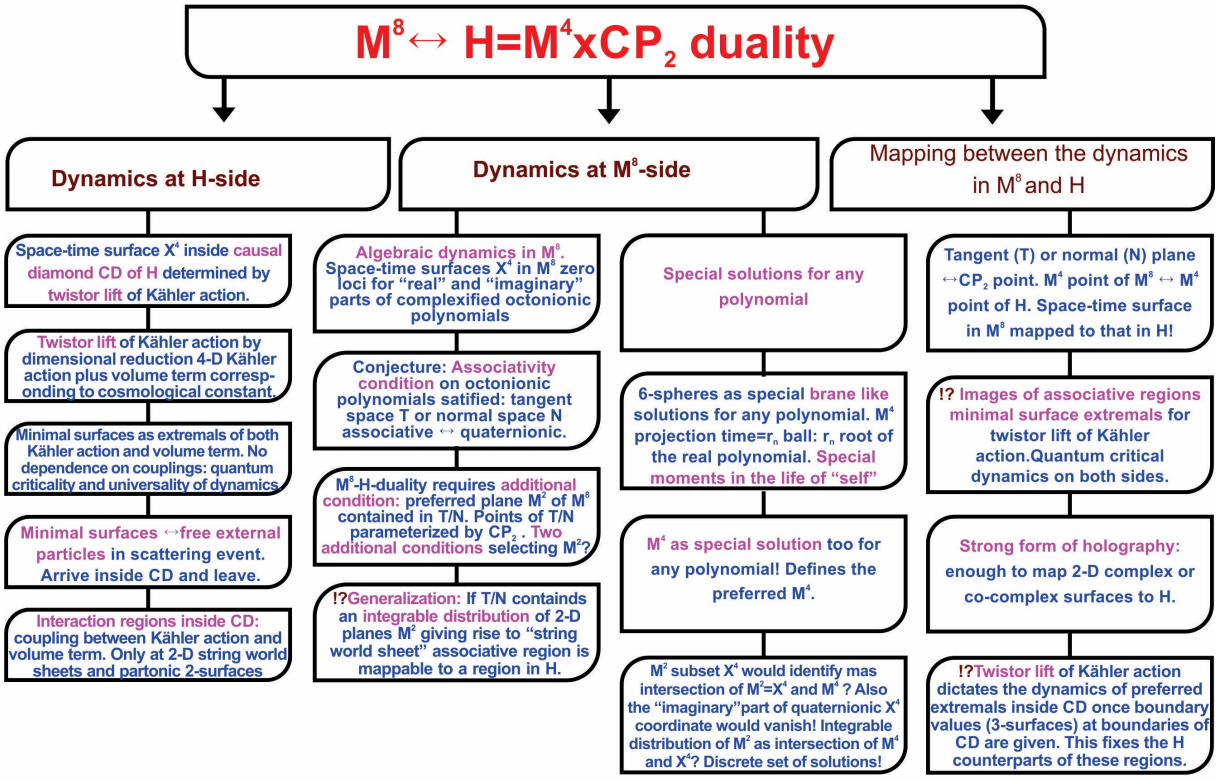

Figure 16.7: $M^8 - H$ duality

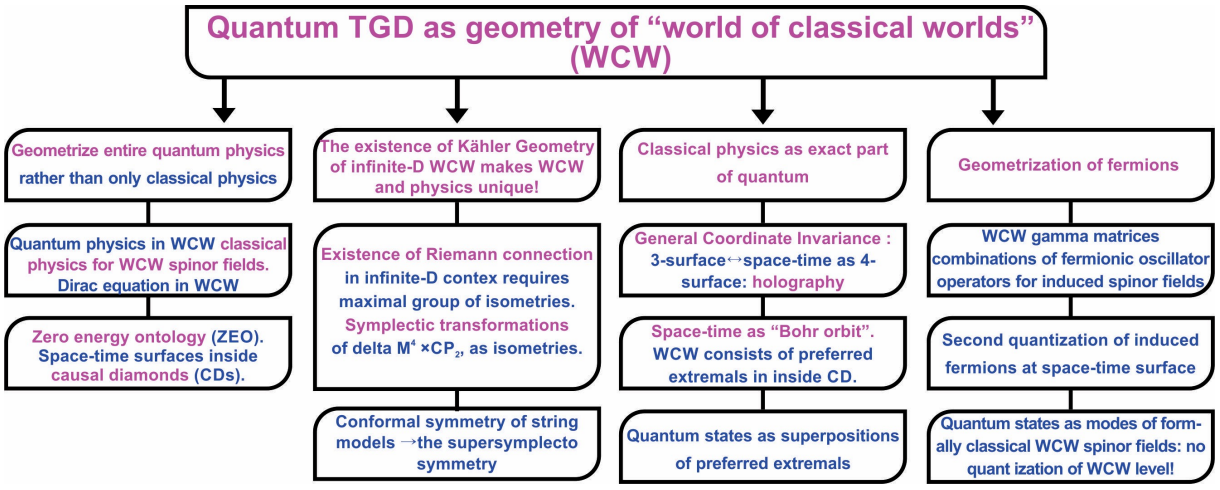

Figure 16.8: Geometrization of quantum physics in terms of WCW

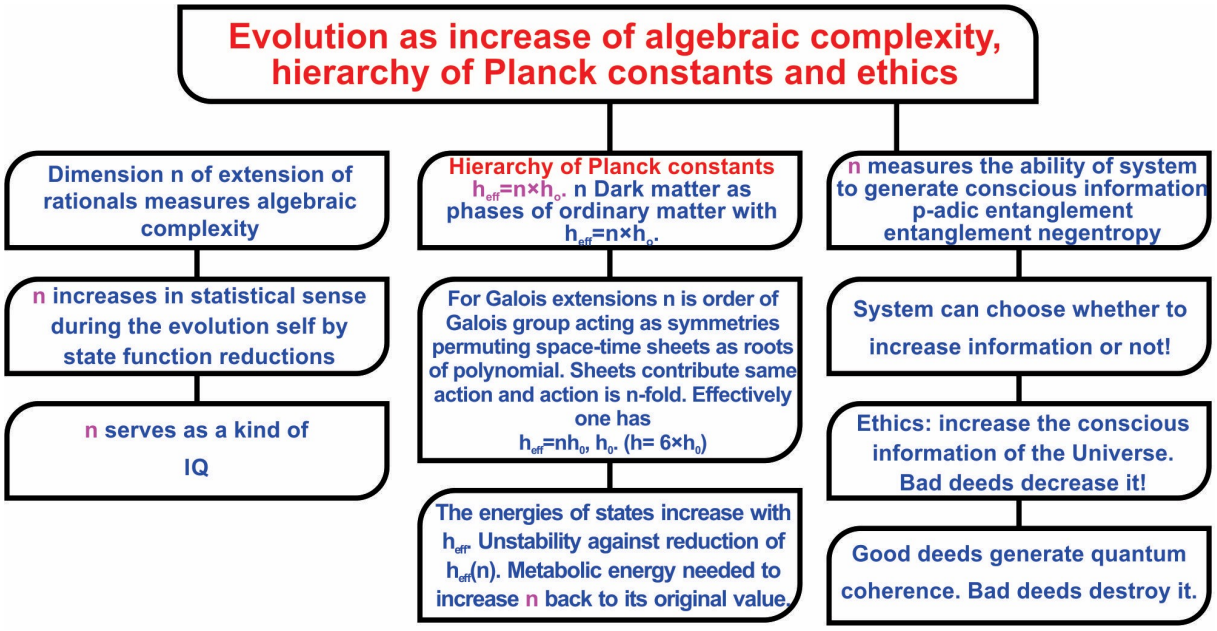

Figure 16.9: Number theoretic view of evolution

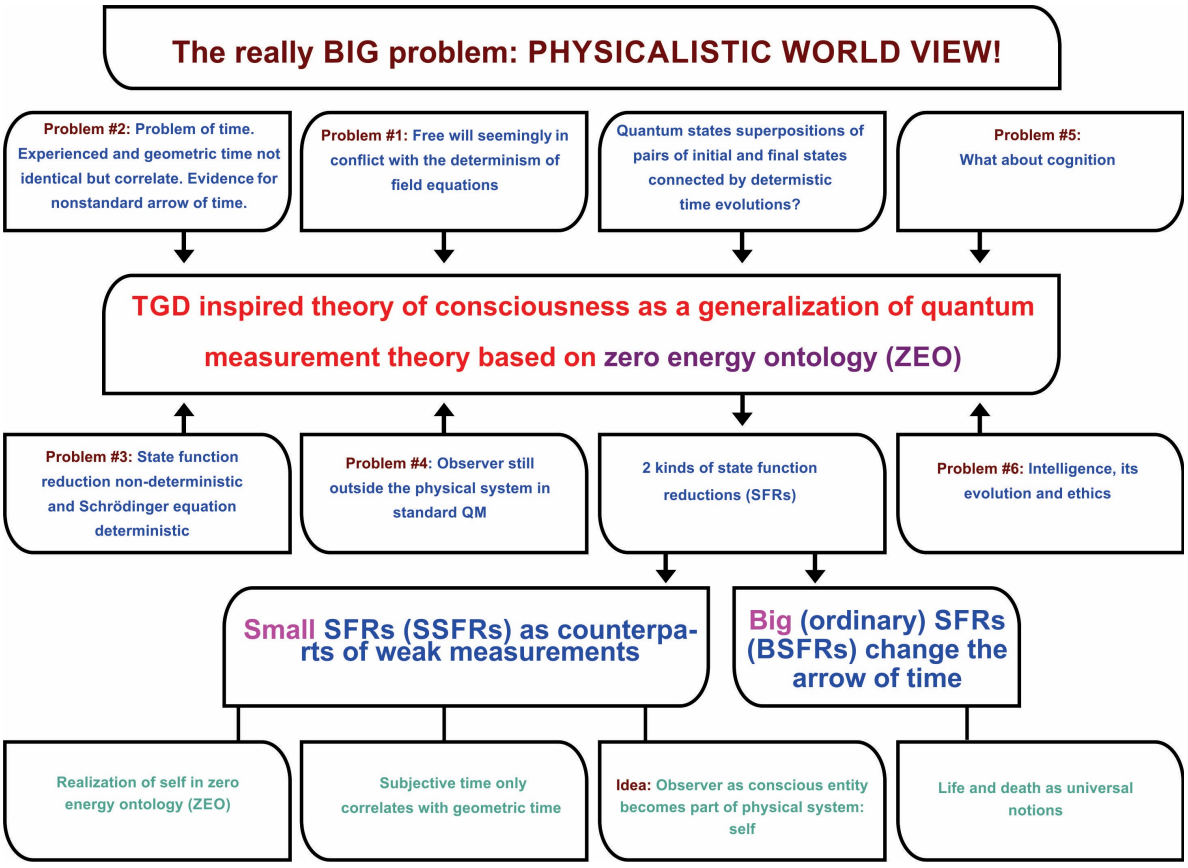

Figure 16.10: Consciousness theory from quantum measurement theory

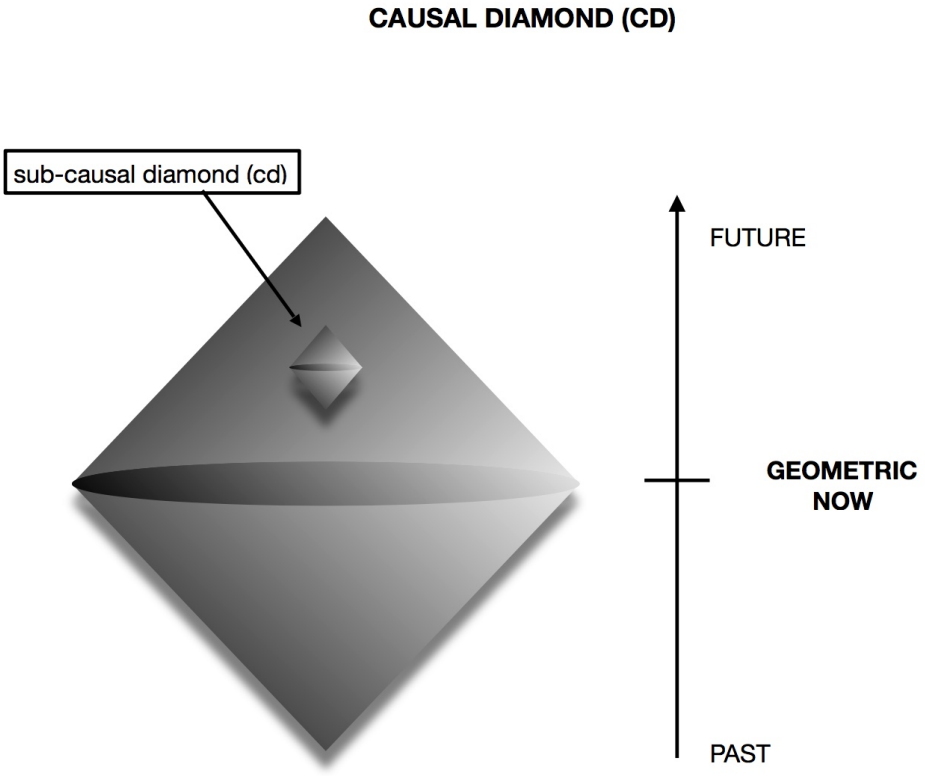

Figure 16.11: Causal diamond

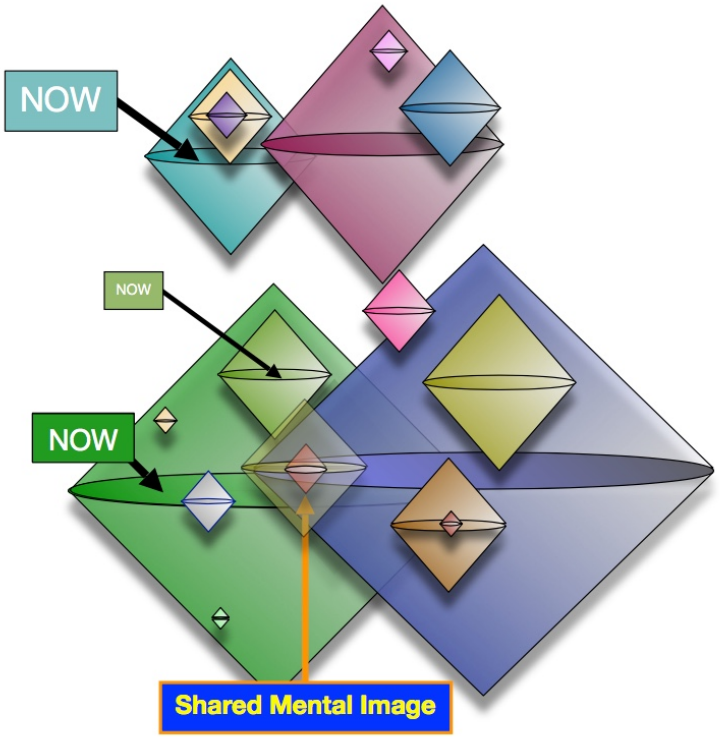

Figure 16.12: CDs define a fractal "conscious atlas"

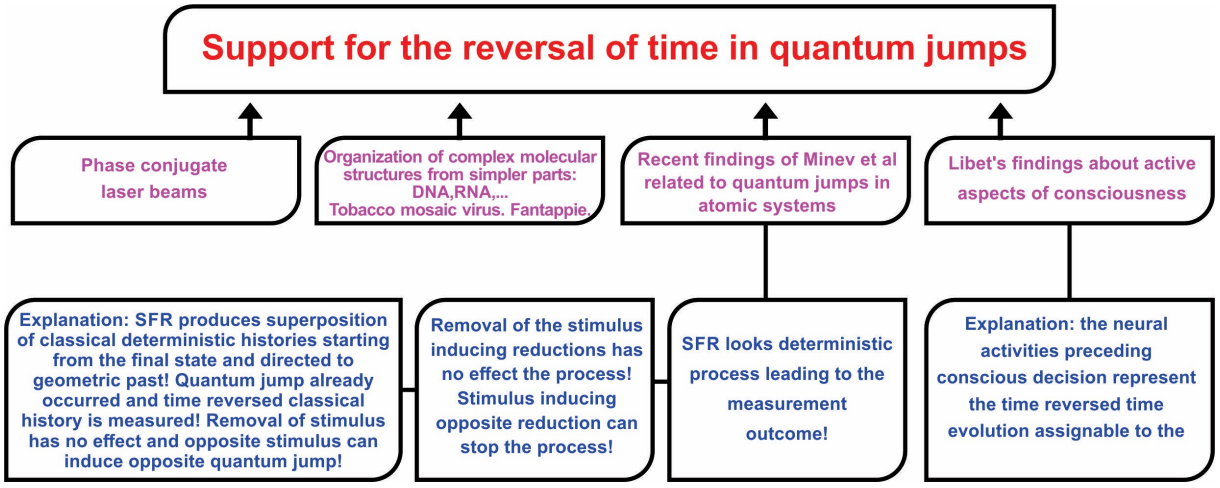

Figure 16.13: Time reversal occurs in BSFR

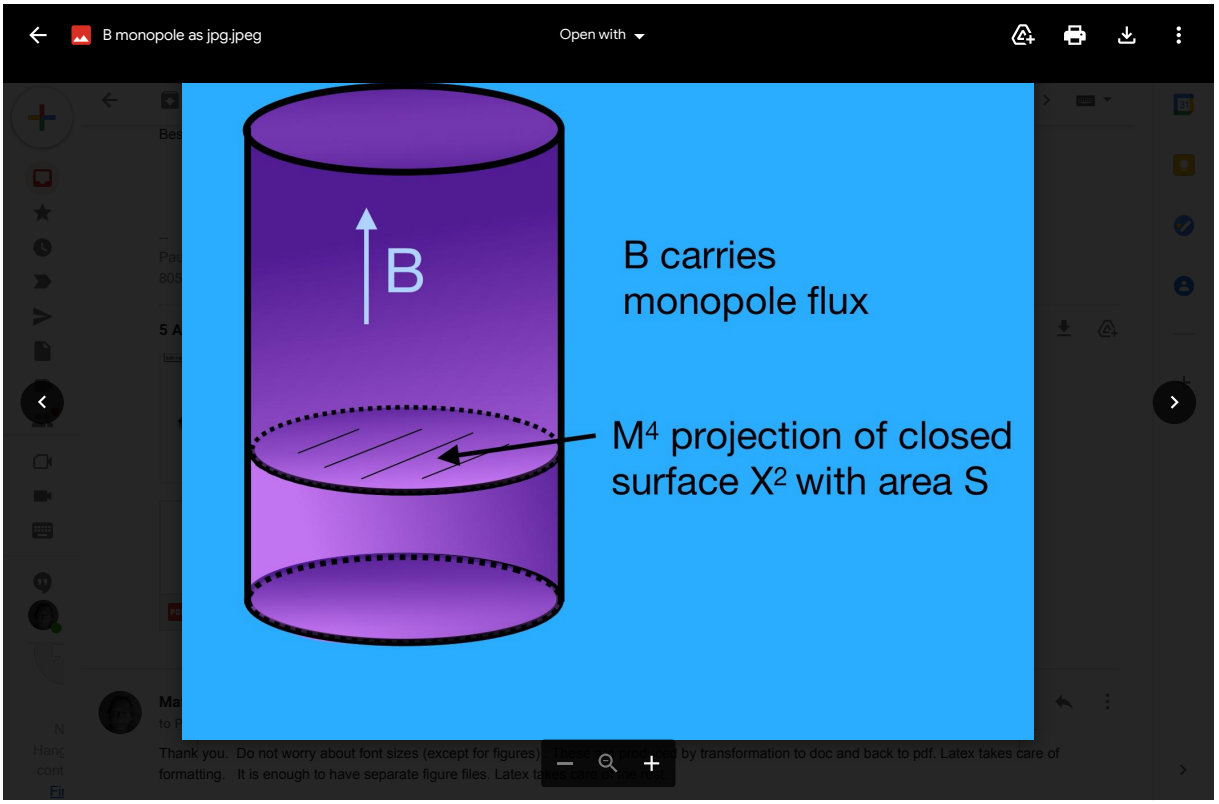

Figure 16.14: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e\oint B \cdot dS = eBS = kh$ at single sheet of n-sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

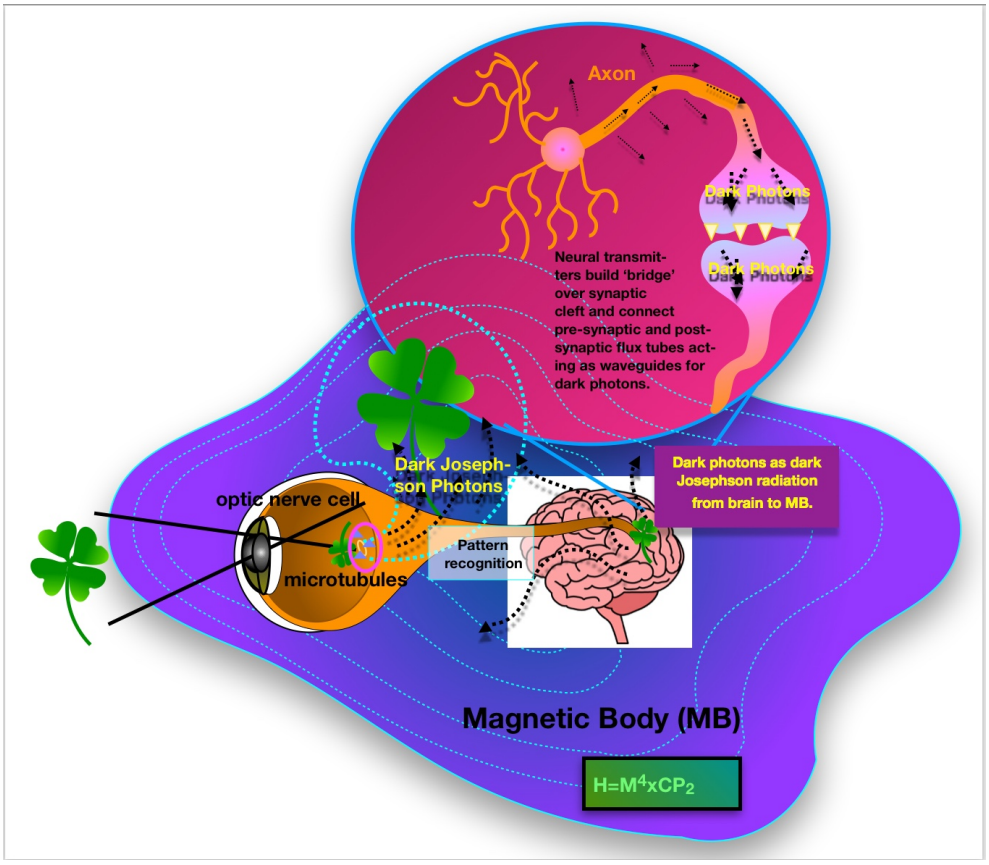

Figure 16.15: Dark Josephson photons communicate sensory data to the "big" part of MB. Also the back and forth communications between sensory organ and brain use dark photons.

Chapter i

Appendix

A-1 Introduction

Originally this appendix was meant to be a purely technical summary of basic facts but in its recent form it tries to briefly summarize those basic visions about TGD which I dare to regarded stabilized. I have added illustrations making it easier to build mental images about what is involved and represented briefly the key arguments. This chapter is hoped to help the reader to get fast grasp about the concepts of TGD.

The basic properties of embedding space and related spaces are discussed and the relationship of CP_2 to the standard model is summarized. The basic vision is simple: the geometry of the embedding space $H = M^4 \times CP_2$ geometrizes standard model symmetries and quantum numbers. The assumption that space-time surfaces are basic objects, brings in dynamics as dynamics of 3-D surfaces based on the induced geometry. Second quantization of free spinor fields of H induces quantization at the level of H, which means a dramatic simplification.

The notions of induction of metric and spinor connection, and of spinor structure are discussed. Many-sheeted space-time and related notions such as topological field quantization and the relationship many-sheeted space-time to that of GRT space-time are discussed as well as the recent view about induced spinor fields and the emergence of fermionic strings. Also the relationship to string models is discussed briefly.

Various topics related to p-adic numbers are summarized with a brief definition of p-adic manifold and the idea about generalization of the number concept by gluing real and p-adic number fields to a larger book like structure analogous to adele [L69, L70]. In the recent view of quantum TGD [L171], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L127, L128] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L108] [K143] has become a central part of quantum TGD and leads to a TGD inspired theory of consciousness as a generalization of quantum measurement theory having quantum biology as an application. Also these aspects of TGD are briefly discussed.

A-2 Embedding space $M^4 \times CP_2$

Space-times are regarded as 4-surfaces in $H = M^4 \times CP_2$ the Cartesian product of empty Minkowski space - the space-time of special relativity - and compact 4-D space CP_2 with size scale of order 10^4 Planck lengths. One can say that embedding space is obtained by replacing each point m of empty Minkowski space with 4-D tiny CP_2. The space-time of general relativity is replaced by a 4-D surface in H which has very complex topology. The notion of many-sheeted space-time gives an idea about what is involved.

Fig. 1. Embedding space $H = M^4 \times CP_2$ as Cartesian product of Minkowski space M^4 and complex projective space CP_2. `http://tgdtheory.fi/appfigures/Hoo.jpg`

Denote by M^4_+ and M^4_- the future and past directed lightcones of M^4. Denote their intersection, which is not unique, by CD. In zero energy ontology (ZEO) [L108, L158] [K143] causal

diamond (CD) is defined as cartesian product $CD \times CP_2$. Often I use CD to refer just to $CD \times CP_2$ since CP_2 factor is relevant from the point of view of ZEO.

Fig. 2. Future and past light-cones M^4_+ and M^4_-. Causal diamonds (CD) are defined as their intersections. `http://tgdtheory.fi/appfigures/futurepast.jpg`

Fig. 3. Causal diamond (CD) is highly analogous to Penrose diagram but simpler. `http://tgdtheory.fi/appfigures/penrose.jpg`

A rather recent discovery was that CP_2 is the only compact 4-manifold with Euclidian signature of metric allowing twistor space with Kähler structure. M^4 is in turn is the only 4-D space with Minkowskian signature of metric allowing twistor space with Kähler structure [A30] so that $H = M^4 \times CP_2$ is twistorially unique.

One can loosely say that quantum states in a given sector of "world of classical worlds" (WCW) are superpositions of space-time surfaces inside CDs and that positive and negative energy parts of zero energy states are localized and past and future boundaries of CDs. CDs form a hierarchy. One can have CDs within CDs and CDs can also overlap. The size of CD is characterized by the proper time distance between its two tips. One can perform both translations and also Lorentz boosts of CD leaving either boundary invariant. Therefore one can assign to CDs a moduli space and speak about wave function in this moduli space.

In number theoretic approach it is natural to restrict the allowed Lorentz boosts to some discrete subgroup of Lorentz group and also the distances between the tips of CDs to multiples of CP_2 radius defined by the length of its geodesic. Therefore the moduli space of CDs discretizes. The quantization of cosmic recession velocities for which there are indications, could relate to this quantization.

A-2.1 Basic facts about CP_2

CP_2 as a four-manifold is very special. The following arguments demonstrate that it codes for the symmetries of standard models via its isometries and holonomies.

CP_2 as a manifold

CP_2, the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \ . \tag{A-2.1}$$

Here λ is any non-zero complex number. Note that CP_2 can be also regarded as the coset space $SU(3)/U(2)$. The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2. As j runs from 1 to 3 one obtains an atlas of three coordinate charts covering CP_2, the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homoeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2. Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^4".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, $i = 1, 2$ the coordinates of Eguchi and Freund [A22] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it \ , \\ \xi^2 &= x + iy \ . \end{aligned} \tag{A-2.2}$$

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi+\Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= rexp(i\frac{(\Psi-\Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{A-2.3}$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second $b = 1$.

Fig. 4. CP_2 as manifold. `http://tgdtheory.fi/appfigures/cp2.jpg`

Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \to exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i \bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.4}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-2.5}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= log(F) \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-2.6}$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r, \phi) = (tan(\theta/2), \phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \tag{A-2.7}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ . \end{aligned} \tag{A-2.8}$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A \ , \tag{A-2.9}$$

are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , \quad e^1 = \tfrac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \tfrac{r\sigma_2}{\sqrt{F}} \ , \quad e^3 = \tfrac{r\sigma_3}{F} \ . \end{aligned} \tag{A-2.10}$$

The explicit representations of vierbein vectors are given by

$$\begin{aligned} e^0 &= \frac{dr}{F} \ , & e^1 &= \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\ e^2 &= \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 &= \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ . \end{aligned} \tag{A-2.11}$$

The explicit representation of the line element is given by the expression

$$ds^2/R^2 = \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2) \ . \tag{A-2.12}$$

From this expression one finds that at coordinate infinity $r = \infty$ line element reduces to $\frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2)$ of S^2 meaning that 3-sphere degenerates metrically to 2-sphere and one can say that CP_2 is obtained by adding to R^4 a 2-sphere at infinity.

The vierbein connection satisfying the defining relation

$$de^A = -V^A_B \wedge e^B \ , \tag{A-2.13}$$

is given by

$$\begin{aligned} V_{01} &= -\frac{e^1}{r} \ , & V_{23} &= \frac{e^1}{r} \ , \\ V_{02} &= -\frac{e^2}{r} \ , & V_{31} &= \frac{e^2}{r} \ , \\ V_{03} &= (r - \frac{1}{r})e^3 \ , & V_{12} &= (2r + \frac{1}{r})e^3 \ . \end{aligned} \tag{A-2.14}$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{aligned} R_{01} &= e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} &= e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} &= e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} &= -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\ R_{03} &= 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} &= 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{aligned} \tag{A-2.15}$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -is_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.16}$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$J^k_{\ r} J^{rl} = -s^{kl} \ . \tag{A-2.17}$$

The condition states that J and g give representations of real unit and imaginary units related by the formula $i^2 = -1$.

Kähler form is expressible locally in terms of Kähler gauge potential

$$J = dB \ , \tag{A-2.18}$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

$dJ = ddB = 0$ gives the topological half of Maxwell equations (vanishing of magnetic charges and Faraday's induction law) and self-duality $*J = J$ reduces the remaining equations to $dJ = 0$. Hence the Kähler form can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling).

The magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$\begin{aligned} B &= 2re^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2} dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F} sin\Theta d\Theta \wedge d\Phi \ . \end{aligned} \tag{A-2.19}$$

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1, 1).

Useful coordinates for CP_2 are the so called canonical (or symplectic or Darboux) coordinates in which the Kähler potential and Kähler form have very simple expressions

$$\begin{aligned} B &= \sum_{k=1,2} P_k dQ_k \ , \\ J &= \sum_{k=1,2} dP_k \wedge dQ_k \ . \end{aligned} \tag{A-2.20}$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$\begin{aligned} P_1 &= -\frac{1}{1+r^2} \ , \\ P_2 &= -\frac{r^2 cos\Theta}{2(1+r^2)} \ , \\ Q_1 &= \Psi \ , \\ Q_2 &= \Phi \ . \end{aligned} \tag{A-2.21}$$

Spinors In CP_2

CP_2 doesn't allow spinor structure in the conventional sense [A17]. However, the coupling of the spinors to a half odd multiple of the Kähler potential leads to a respectable spinor structure. Because the delicacies associated with the spinor structure of CP_2 play a fundamental role in TGD, the arguments of Hawking are repeated here.

To see how the space can fail to have an ordinary spinor structure consider the parallel transport of the vierbein in a simply connected space M. The parallel propagation around a closed curve with a base point x leads to a rotated vierbein at x: $e^A = R^A_B e^B$ and one can associate to each closed path an element of $SO(4)$.

Consider now a one-parameter family of closed curves $\gamma(v) : v \in (0, 1)$ with the same base point x and $\gamma(0)$ and $\gamma(1)$ trivial paths. Clearly these paths define a sphere S^2 in M and the element $R^A_B(v)$ defines a closed path in $SO(4)$. When the sphere S^2 is contractible to a point e.g., homologically trivial, the path in $SO(4)$ is also contractible to a point and therefore represents a trivial element of the homotopy group $\Pi_1(SO(4)) = Z_2$.

For a homologically nontrivial 2-surface S^2 the associated path in $SO(4)$ can be homotopically nontrivial and therefore corresponds to a nonclosed path in the covering group Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallel propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2. Now, however this path corresponds to a lift of the corresponding $SO(4)$ path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the non-allowed -1-factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a $U(1)$ gauge potential this factor is given by the exponential

$exp(i2\Phi)$, where Φ is the magnetic flux through the surface. This factor has the value -1 provided the $U(1)$ potential carries half odd multiple of Dirac charge $1/2g$. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of $B/2$.

Geodesic sub-manifolds of CP_2

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the embedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h^k_α (understood as vectors of H) are covariantly constant quantities with respect to the covariant derivative taking into account that the tangent vectors are vectors both with respect to H and X^4.

In [A43] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-2.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2.2 CP_2 geometry and Standard Model symmetries

Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [B22] and in particular that the right handed neutrinos decouple completely from the electro-weak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e = \pm 1$, CP_2-chirality l, r and M^4-chirality L, R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \tag{A-2.23}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \otimes \gamma_5$, $1 \otimes \gamma_5$ and $\gamma_5 \otimes 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electro-weak group: $SO(4)$ having as its covering group $SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \tag{A-2.24}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{array}{lllllll} V_{01} & = & -\frac{e^1}{r} \ , & & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} \ , & & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r - \frac{1}{r})e^3 \ , & & V_{12} & = & (2r + \frac{1}{r})e^3 \ , \end{array} \tag{A-2.25}$$

and

$$B = 2re^3 \ , \tag{A-2.26}$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of $SO(4)$, one finds that the charged part of the spinor connection is given by

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 \ , \tag{A-2.27}$$

where one have defined

$$\begin{array}{lll} I_L^1 & = & \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 & = & \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{array} \tag{A-2.28}$$

A_{ch} is clearly left handed so that one can perform the identification of the gauge potential as

$$W^\pm = \frac{2(e^1 \pm ie^2)}{r} \ , \tag{A-2.29}$$

where $W^\pm$ denotes the charged intermediate vector boson.

The covariantly constant curvature tensor is given by

$$\begin{array}{l} R_{01} = -R_{23} = e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} = -R_{31} = e^0 \wedge e^2 - e^3 \wedge e^1 \ , \\ R_{03} = 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , \\ R_{12} = 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{array} \tag{A-2.30}$$

The charged part of the curvature tensor is left handed.

This is to be compared with the Weyl tensor, which defines a representation of quaternionic imaginary units.

$$\begin{aligned} W_{03} = W_{12} \equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ W_{01} = W_{23} \equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ W_{02} = W_{31} \equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 \ . \end{aligned} \tag{A-2.31}$$

The charged part of the Weyl tensor is right-handed and that the relative sign of the two terms in the curvature tensor and Weyl tensor are opposite.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$\begin{aligned} X &= re^3 \ , \\ Y &= \frac{e^3}{r} \ , \end{aligned} \tag{A-2.32}$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$\begin{aligned} \bar{\gamma} &= aX + bY \ , \\ \bar{Z}^0 &= cX + dY \ , \end{aligned} \tag{A-2.33}$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$\begin{aligned} A_{nc} &= [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\ &+ [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ . \end{aligned} \tag{A-2.34}$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5\Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c = -d \ . \tag{A-2.35}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.36}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$\begin{aligned} Q_{em} &= \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} \ , \\ I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ . \end{aligned} \tag{A-2.37}$$

The fields γ and Z^0 are defined via the relations

$$\begin{aligned} \gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\ Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) \ . \end{aligned} \tag{A-2.38}$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \tag{A-2.39}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of the Weinberg angle is a dynamical problem. The original approach was based on the assumption that it makes sense to talk about electroweak action defined at fundamental level and introduce a symmetry breaking by adding an additional term proportional to Kähler action. The recent view is that Kähler action plus volume term defines the fundamental action.

The Weinberg angle is completely fixed if one requires that the electroweak action contains no cross term of type γZ^0. This leads to a definite value for the Weinberg angle.

One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle. As a matter fact, color gauge action identifying color gauge field as proportional to $H^A J_{\alpha\beta}$ is proportional to Kähler action. A possible interpretation would be as a sum of electroweak and color gauge interactions.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+ 1_+ + n_- 1_-) \ , \tag{A-2.40}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \tag{A-2.41}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.42}$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{A-2.43}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \tag{A-2.44}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + f J^{\alpha\beta} J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2} Tr(F^{\alpha\beta} F_{\alpha\beta}) \ , \end{aligned} \tag{A-2.45}$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$\begin{aligned} X &= -\frac{K}{2g^2} + \frac{fp}{18} \ , \\ K &= Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ , \end{aligned} \tag{A-2.46}$$

This parameter can be calculated by substituting the values of quark and lepton charges and weak isospins.

In the general case the value of the coefficient K is given by

$$K = \sum_i \left[-\frac{(18 + 2n_i^2)sin^2\theta_W}{9} \right] \ , \tag{A-2.47}$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18 + n_i^2))} \ . \tag{A-2.48}$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \ . \tag{A-2.49}$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is not far from the typical value 9/24 of GUTs at high energies [B6]. The experimental value at the scale length scale of the electron can be deduced from the ratio of W and Z boson masses as $sin^2\theta_W = 1 - (m_W/m_Z)^2 \simeq .22290$. This ratio and also the weak boson masses depend on the length scale.

If one interprets the additional term proportional to J as color action, one could perhaps interpret the value of Weinberg angle as expressing a connection between strong and weak coupling constant evolution. The limit $f \to 0$ should correspond to an infinite value of color coupling strength and at this limit one would have $sin^2\theta_W = \frac{9}{28}$ for $f/g^2 \to 0$. This does not make sense since the Weinberg angle is in the standard model much smaller in QCD scale Λ corresponding roughly to pion mass scale. The Weinberg angle is in principle predicted by the p-adic coupling constant evolution fixed by the number theoretical vision of TGD.

One could however have a sum of electroweak action, correction terms changing the value of Weinberg angle, and color action and coupling constant evolution could be understood in terms of the coupling parameters involved.

Electroweak symmetry breaking

One of the hardest challenges in the development of the TGD based view of weak symmetry breaking was the fact that classical field equations allow space-time surfaces with finite but arbitrarily large size. For a fixed space-time surface, the induced gauge fields, including classical weak fields, are long ranged. On the other hand, the large mass for weak bosons would require a short correlation length. How can one understand this together with the fact that a photon has a long correlation length?

In zero energy ontology quantum states are superpositions of space-time surfaces as analogs of almost unique Bohr orbits of particles identified as 3-D surfaces. For some reason the superposition should be such that the quantum averages of weak gauge boson fields vanish below the weak scale whereas the quantum average of electromagnetic fields is non-vanishing.

This is indeed the case.

1. The supersymplectic symmetries form isometries of the world of classical worlds (WCW) and they act in CP_2 degrees of freedom as symplectic transformations leaving the CP_2 symplectic form J invariant and therefore also its contribution to the electromagnetic field since this part is the same for all space-time surfaces in the superposition of space-time surfaces as a representation of supersymplectic isometry group (as a special case a representation of color group).

2. In TGD, color and electroweak symmetries acting as holonomies are not independent and for the $SU(2)_L$ part of induced spinor connection the symplectic transformations induces $SU(2)_L \times U(1)_R$ gauge transformation. This suggests that the quantum expectations of the induced weak fields over the space-time surfaces vanish above the quantum coherence scale. The averages of W and of the left handed part of Z^0 should therefore vanish.

3. $\langle Z^0 \rangle$ should vanish. For $U(1)_R$ part of Z^0, the action of gauge transformation is trivial in gauge theory. Now however the space-time surface changes under symplectic transformations and this could make the average of the right-handed part of Z^0 vanishing. The vanishing of the average of the axial part of the Z^0 is suggested by the partially conserved axial current hypothesis.

One can formulate this picture quantitatively.

1. The electromagnetic field [L181] contains, besides the induced Kähler form, also the induced curvature form R_{12}, which couples vectorially. Conserved vector current hypothesis suggests that the average of R_{12} is non-vanishing. One can express the neutral part of the induced gauge field in terms of induced spinor curvature and Kähler form J as

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) = J + 2e^0 \wedge e^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) = 3J - 2e^0 \wedge e^3 \quad , \end{aligned} \tag{A-2.50}$$

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} = 2(J + 2e^0 \wedge e^3) \end{aligned} \tag{A-2.51}$$

$$per. \tag{A-2.52}$$

The condition $\langle Z^0 \rangle = 0$ gives $2\langle e^0 \wedge e^3 \rangle = -2J$ and this in turn gives $\langle R_{12} \rangle = 4J$. The average over γ would be

$$\langle \gamma \rangle = (3 - 4sin^2\theta_W)J \ .$$

For $sin^2\theta_W = 3/4$ $langle\gamma\rangle$ would vanish.

The quantum averages of classical weak fields quite generally vanish. What about correlation functions?

1. One expects that the correlators of classical weak fields as color invariants, and perhaps even symplectic invariants, are non-vanishing below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as hadron.

2. The intuitive picture is that in longer length scales one has disjoint 3-surfaces with a size scale of Compton length. If the states associated with two disjoint 3-surfaces are separately color invariant there are no correlations in color degrees of freedom and correlators reduce to the products of expectations of classical weak fields and vanish. This could also hold when the 3-surfaces are connected by flux tube bonds.

   Below the Compton length weak bosons would thus behave as correlated massless fields. The Compton lengths of weak bosons are proportional to the value of effective Planck constant h_{eff} and in living systems the Compton lengths are proposed to be even of the order of cell size. This would explain the mysterious chiral selection in living systems requiring large parity violation.

3. What about the averages and correlators of color gauge fields? Classical color gauge fields are proportional to the products of Hamiltonians of color isometries induced Kähler form and the expectations of color Hamiltonians give vanishing average above Compton length and therefore vanishing average. Correlators are non-vanishing below the hadron scale. Gluons do not propagate in long scales for the same reason as weak bosons. This is implied by color confinement, which has also classical description in the sense that 3-surfaces have necessarily a finite size.

   A large value of h_{eff} allows colored states even in biological scales below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as dark hadron.

Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:

1. Symmetries must be realized as purely geometric transformations.

2. Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [B7] .

   The action of the reflection P on spinors of is given by

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0 \Psi \ . \tag{A-2.53}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \ , \\ \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \ . \end{aligned} \tag{A-2.54}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \Psi^\dagger \gamma^2\gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.55}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Induction procedure and many-sheeted space-time

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induction procedure for gauge fields and spinor connection

Induction procedure for gauge potentials and spinor structure is a standard procedure of bundle theory. If one has embedding of some manifold to the base space of a bundle, the bundle structure can be induced so that it has as a base space the imbedded manifold, whose points have as fiber the fiber if embedding space at their image points. In the recent case the embedding of space-time surface to embedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the embedding space to the space-time surface (see `http://tgdtheory.fi/appfigures/induct.jpg`).

Induction procedure makes sense also for the spinor fields of embedding space and one obtains geometrization of both electroweak gauge potentials and of spinors. The new element is induction of gamma matrices which gives their projections at space-time surface.

As a matter fact, the induced gamma matrices cannot appear in the counterpart of massless Dirac equation. To achieve super-symmetry, Dirac action must be replaced with Kähler-Dirac action for which gamma matrices are contractions of the canonical momentum currents of Kähler action with embedding space gamma matrices. Induced gamma matrices in Dirac action would correspond to 4-volume as action.

Fig. 9. Induction of spinor connection and metric as projection to the space-time surface. `http://tgdtheory.fi/appfigures/induct.jpg`.

A-3.2 Induced gauge fields for space-times for which CP_2 projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP_2 projection, only vacuum extremals and space-time surfaces for which CP_2 projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r = \infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \quad .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

$Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

A-3.3 Many-sheeted space-time

TGD space-time is many-sheeted: in other words, there are in general several space-sheets which have projection to the same M^4 region. Second manner to say this is that CP_2 coordinates are many-valued functions of M^4 coordinates. The original physical interpretation of many-sheeted space-time time was not correct: it was assumed that single sheet corresponds to GRT space-time and this obviously leads to difficulties since the induced gauge fields are expressible in terms of only four embedding space coordinates.

Fig. 10. Illustration of many-sheeted space-time of TGD. `http://tgdtheory.fi/appfigures/manysheeted.jpg`

Superposition of effects instead of superposition of fields

The first objection against TGD is that superposition is not possible for induced gauge fields and induced metric. The resolution of the problem is that it is effects which need to superpose, not the fields.

Test particle topologically condenses simultaneously to all space-time sheets having a projection to same region of M^4 (that is touches them). The superposition of effects of fields at various space-time sheets replaces the superposition of fields.This is crucial for the understanding also how GRT space-time relates to TGD space-time, which is also in the appendix of this book).

Wormhole contacts

Wormhole contacts are key element of many-sheeted space-time. One does not expect them to be stable unless there is non-trivial Kähler magnetic flux flowing through then so that the throats look like Kähler magnetic monopoles.

Fig. 11. Wormhole contact. `http://tgdtheory.fi/appfigures/wormholecontact.jpg`

Since the flow lines of Kähler magnetic field must be closed this requires the presence of another wormhole contact so that one obtains closed monopole flux tube decomposing to two Minkowskian pieces at the two space-time sheets involved and two wormhole contacts with Euclidian signature of the induced metric. These objects are identified as space-time correlates of elementary particles and are clearly analogous to string like objects.

The relationship between the many-sheeted space-time of TGD and of GRT space-time

The space-time of general relativity is single-sheeted and there is no need to regard it as surface in H although the assumption about representability as vacuum extremal gives very powerful constraints in cosmology and astrophysics and might make sense in simple situations.

The space-time of GRT can be regarded as a long length scale approximation obtained by lumping together the sheets of the many-sheeted space-time to a region of M^4 and providing it with an effective metric obtained as sum of M^4 metric and deviations of the induced metrics of various space-time sheets from M^4 metric. Also induced gauge potentials sum up in the similar manner so that also the gauge fields of gauge theories would not be fundamental fields.

Fig. 12. The superposition of fields is replaced with the superposition of their effects in many-sheeted space-time. `http://tgdtheory.fi/appfigures/fieldsuperpose.jpg`

Space-time surfaces of TGD are considerably simpler objects that the space-times of general relativity and relate to GRT space-time like elementary particles to systems of condensed matter physics. Same can be said about fields since all fields are expressible in terms of embedding space coordinates and their gradients, and general coordinate invariance means that the number of bosonic field degrees is reduced locally to 4. TGD space-time can be said to be a microscopic description whereas GRT space-time a macroscopic description. In TGD complexity of space-time topology replaces the complexity due to large number of fields in quantum field theory.

Topological field quantization and the notion of magnetic body

Topological field quantization also TGD from Maxwell's theory. TGD predicts topological light rays ("massless extremals (MEs)") as space-time sheets carrying waves or arbitrary shape propagating

with maximal signal velocity in single direction only and analogous to laser beams and carrying light-like gauge currents in the generi case. There are also magnetic flux quanta and electric flux quanta. The deformations of cosmic strings with 2-D string orbit as M^4 projection gives rise to magnetic flux tubes carrying monopole flux made possible by CP_2 topology allowing homological Kähler magnetic monopoles.

Fig. 13. Topological quantization for magnetic fields replaces magnetic fields with bundles of them defining flux tubes as topological field quanta. `http://tgdtheory.fi/appfigures/field.jpg`

The imbeddability condition for say magnetic field means that the region containing constant magnetic field splits into flux quanta, say tubes and sheets carrying constant magnetic field. Unless one assumes a separate boundary term in Kähler action, boundaries in the usual sense are forbidden except as ends of space-time surfaces at the boundaries of causal diamonds. One obtains typically pairs of sheets glued together along their boundaries giving rise to flux tubes with closed cross section possibly carrying monopole flux.

These kind of flux tubes might make possible magnetic fields in cosmic scales already during primordial period of cosmology since no currents are needed to generate these magnetic fields: cosmic string would be indeed this kind of objects and would dominated during the primordial period. Even superconductors and maybe even ferromagnets could involve this kind of monopole flux tubes.

A-3.4 Embedding space spinors and induced spinors

One can geometrize also fermionic degrees of freedom by inducing the spinor structure of $M^4 \times CP_2$.

CP_2 does not allow spinor structure in the ordinary sense but one can couple the opposite H-chiralities of H-spinors to an $n = 1$ ($n = 3$) integer multiple of Kähler gauge potential to obtain a respectable modified spinor structure. The em charges of resulting spinors are fractional (integer valued) and the interpretation as quarks (leptons) makes sense since the couplings to the induced spinor connection having interpretation in terms electro-weak gauge potential are identical to those assumed in standard model.

The notion of quark color differs from that of standard model.

1. Spinors do not couple to color gauge potential although the identification of color gauge potential as projection of $SU(3)$ Killing vector fields is possible. This coupling must emerge only at the effective gauge theory limit of TGD.

2. Spinor harmonics of embedding space correspond to triality $t = 1$ ($t = 0$) partial waves. The detailed correspondence between color and electroweak quantum numbers is however not correct as such and the interpretation of spinor harmonics of embedding space is as representations for ground states of super-conformal representations. The wormhole pairs associated with physical quarks and leptons must carry also neutrino pair to neutralize weak quantum numbers above the length scale of flux tube (weak scale or Compton length). The total color quantum numbers or these states must be those of standard model. For instance, the color quantum numbers of fundamental left-hand neutrino and lepton can compensate each other for the physical lepton. For fundamental quark-lepton pair they could sum up to those of physical quark.

The well-definedness of em charge is crucial condition.

1. Although the embedding space spinor connection carries W gauge potentials one can say that the embedding space spinor modes have well-defined em charge. One expects that this is true for induced spinor fields inside wormhole contacts with 4-D CP_2 projection and Euclidian signature of the induced metric.

2. The situation is not the same for the modes of induced spinor fields inside Minkowskian region and one must require that the CP_2 projection of the regions carrying induced spinor field is such that the induced W fields and above weak scale also the induced Z^0 fields vanish in order to avoid large parity breaking effects. This condition forces the CP_2 projection to be 2-dimensional. For a generic Minkowskian space-time region this is achieved only if the

spinor modes are localized at 2-D surfaces of space-time surface - string world sheets and possibly also partonic 2-surfaces.

3. Also the Kähler-Dirac gamma matrices appearing in the modified Dirac equation must vanish in the directions normal to the 2-D surface in order that Kähler-Dirac equation can be satisfied. This does not seem plausible for space-time regions with 4-D CP_2 projection.

4. One can thus say that strings emerge from TGD in Minkowskian space-time regions. In particular, elementary particles are accompanied by a pair of fermionic strings at the opposite space-time sheets and connecting wormhole contacts. Quite generally, fundamental fermions would propagate at the boundaries of string world sheets as massless particles and wormhole contacts would define the stringy vertices of generalized Feynman diagrams. One obtains geometrized diagrammatics, which brings looks like a combination of stringy and Feynman diagrammatics.

5. This is what happens in the the generic situation. Cosmic strings could serve as examples about surfaces with 2-D CP_2 projection and carrying only em fields and allowing delocalization of spinor modes to the entire space-time surfaces.

A-3.5 About induced gauge fields

In the following the induced gauge fields are studied for general space-time surface without assuming the preferred extremal property (Bohr orbit property). Therefore the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0, or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r, Θ, Ψ, Φ) for CP_2, the expression of Kähler form reads as

$$\begin{aligned} J &= \frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta) d\Phi) + \frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-3.1}$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3+2p)\frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta) d\Phi) + (3+p)\frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ p &= sin^2(\Theta_W) \ , \end{aligned} \tag{A-3.2}$$

where Θ_W denotes Weinberg angle.

1. The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi \ , \\ (3+2p)\frac{1}{r^2 F}(d(r^2)/d\Theta)(k + cos(\Theta)) &+ (3+p) sin(\Theta) = 0 \ , \end{aligned} \tag{A-3.3}$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$\begin{aligned} r &= \sqrt{\frac{X}{1-X}} \ , \\ X &= D\left[|\frac{k+u}{C}|\right]^{\epsilon} \ , \\ u &\equiv cos(\Theta) \ , \ C = k + cos(\Theta_0) \ , \ D = \frac{r_0^2}{1+r_0^2} \ , \ \epsilon = \frac{3+p}{3+2p} \ , \end{aligned} \tag{A-3.4}$$

where C and D are integration constants. $0 \leq X \leq 1$ is required by the reality of r. $r = 0$ would correspond to $X = 0$ giving $u = -k$ achieved only for $|k| \leq 1$ and $r = \infty$ to $X = 1$ giving $|u + k| = [(1 + r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$sign(u+k) \times [\frac{1+r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \leq k+1 \ ,$$

where $sign(x)$ denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$\begin{aligned} J &= -\frac{p}{3+2p} X du \wedge d\Phi \ , \\ Z^0 &= -\frac{6}{p} J \ . \end{aligned} \tag{A-3.5}$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

2. The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F} du \wedge d\Phi$ is useful.

3. The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$\begin{aligned} Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u} du \wedge d\Phi = (k+u) du \wedge d\Phi \ , \\ r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\ \gamma &= -\frac{p}{2} Z^0 \ . \end{aligned} \tag{A-3.6}$$

For a vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em,Z^0, or Kähler field is of practical value in the case of vacuum extremals and is given by

$$\begin{aligned} ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta}d\Theta^2 + s^{eff}_{\Phi\Phi}d\Phi^2] \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ , \end{aligned} \tag{A-3.7}$$

and is useful in the construction of vacuum embedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\begin{aligned} \Psi &= \omega_2 m^0 + k_2 m^3 + n_2\phi + \text{Fourier expansion} \ , \\ \Phi &= \omega_1 m^0 + k_1 m^3 + n_1\phi + \text{Fourier expansion} \ . \end{aligned} \tag{A-3.8}$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global embedding for, say a constant magnetic field. Although global embedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteeing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \ , \tag{A-3.9}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

A-4 The relationship of TGD to QFT and string models

The recent view of the relationship of TGD to QFT and string models has developed slowly during years and it seems that in a certain sense TGD means a return to roots: instead of QFT like description involving path integral one would have wave mechanics for 3-surfaces.

A-4.1 TGD as a generalization of wave mechanism obtained by replacing point-like particles with 3-surfaces

The first vision of TGD was as a generalization of quantum field theory (string models) obtained by replacing pointlike particles (strings) as fundamental objects with 3-surfaces.

The later work has revealed that TGD could be seen as a generalization of the wave mechanism based on the replacement of a point-like particle with 3-D surface. This is due to holography implied by general coordinate invariance. The definition of the metric of the "world of classical worlds" (WCW) must assign a unique or at least almost unique space-time surface to a given 3-surface. This 4-surface is analogous to Bohr orbit so that also Bohr orbitology becomes an exact part of quantum physics. The failure of strict determinism forces to replace 3-surfaces with 4-surfaces and this leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K55, K30, K104] [L159, L171].

Fig. 5. TGD replaces point-like particles with 3-surfaces. `http://tgdtheory.fi/appfigures/particletgd.jpg`

A-4.2 Extension of superconformal invariance

The fact that light-like 3-surfaces are effectively metrically 2-dimensional and thus possess generalization of 2-dimensional conformal symmetries with light-like radial coordinate defining the analog of second complex coordinate suggests that this generalization could work and extend the super-conformal symmetries to their 4-D analogs.

The boundary $\delta M^4_+ = S^2 \times R_+$- of 4-D light-cone M^4_+ is also metrically 2-dimensional and allows extended conformal invariance. Also the group of isometries of light-cone boundary and of light-like 3-surfaces is infinite-dimensional since the conformal scalings of S^2 can be compensated by S^2-local scaling of the light-like radial coordinate of R_+. These simple facts mean that 4-dimensional Minkowski space and 4-dimensional space-time surfaces are in a completely unique position as far as symmetries are considered.

In fact, this leads to a generalization of the Kac-Moody type symmetries of string models. $\delta M^4_+ \times CP_2$ allows huge supersymplectic symmetries for which the radial light-like coordinate of δM^4_+ plays the role of complex string coordinate in string models. These symmetries are assumed to act as isometries of WCW.

A-4.3 String-like objects and strings

String like objects obtained as deformations of cosmic strings $X^2 \times Y^2$, where X^2 is minimal surface in M^4 and Y^2 a holomorphic surface of CP_2 are fundamental extremals of Kähler action having string world sheet as M^4 projections. Cosmic strings dominate the primordial cosmology of the TGD Universe and the inflationary period corresponds to the transition to radiation dominated cosmology for which space-time sheets with 4-D M^4 projection dominate.

Also genuine string-like objects emerge from TGD. The conditions that the em charge of modes of induces spinor fields is well-defined requires in the generic case the localization of the modes at 2-D surfaces -string world sheets and possibly also partonic 2-surfaces. This in Minkowskian space-time regions.

Fig. 6. Well-definedness of em charge forces the localization of induced spinor modes to 2-D surfaces in generic situations in Minkowskian regions of space-time surface. `http://tgdtheory.fi/appfigures/fermistring.jpg`

A-4.4 TGD view of elementary particles

The TGD based view about elementary particles has two key aspects.

1. The space-time correlates of elementary particles are identified as pairs of wormhole contacts with Euclidean signature of metric and having 4-D CP_2 projection. Their throats behave effectively as Kähler magnetic monopoles so that wormhole throats must be connected by Kähler magnetic flux tubes with monopole flux so that closed flux tubes are obtained.

2. At the level of H Fermion number is carried by the modes of the induced spinor field. In space-time regions with Minkowski signature the modes are localized at string world sheets connecting the wormhole contacts.

Fig. 7. TGD view about elementary particles. a) Particle orbit corresponds to a 4-D generalization of a world line or b) with its light-like 3-D boundary (holography). c) Particle world lines have Euclidean signature of the induced metric. d) They can be identified as wormhole contacts. e) The throats of wormhole contacts carry effective Kähler magnetic charges so that wormhole contacts must appear as pairs in order to obtain closed flux tubes. f) Wormhole contacts are accompanied by fermionic strings connecting the throats at the same sheet: the strings do not extend inside the wormhole contacts. `http://tgdtheory.fi/appfigures/elparticletgd.jpg`

Particle interactions involve both stringy and QFT aspects.

1. The boundaries of string world sheets correspond to fundamental fermions. This gives rise to massless propagator lines in generalized Feynman diagrammatics. One can speak of "long" string connecting wormhole contacts and having a hadronic string as a physical counterpart. Long strings should be distinguished from wormhole contacts which due to their superconformal invariance behave like "short" strings with length scale given by CP_2 size, which is 10^4 times longer than Planck scale characterizing strings in string models.

2. Wormhole contact defines basic stringy interaction vertex for fermion-fermion scattering. The propagator is essentially the inverse of the superconformal scaling generator L_0. Wormhole contacts containing fermion and antifermion at its opposite throats behave like virtual bosons so that one has BFF type vertices typically.

3. In topological sense one has 3-vertices serving as generalizations of 3-vertices of Feynman diagrams. In these vertices 4-D "lines" of generalized Feynman diagrams meet along their 3-D ends. One obtains also the analogs of stringy diagrams but stringy vertices do not have the usual interpretation in terms of particle decays but in terms of propagation of particles along two different routes.

Fig. 8. a) TGD analogs of Feynman and string diagrammatics at the level of space-time topology. b) The 4-D analogs of both string diagrams and QFT diagrams appear but the interpretation of the analogs stringy diagrams is different. `http://tgdtheory.fi/appfigures/tgdgraphs.jpg`

A-5 About the selection of the action defining the Kähler function of the "world of classical worlds" (WCW)

The proposal is that space-time surfaces correspond to preferred extremals of some action principle, being analogous to Bohr orbits, so that they are almost deterministic. The action for the preferred extremal would define the Kähler function of WCW [K55, K104].

How unique is the choice of the action defining WCW Kähler metric? The problem is that twistor lift strongly suggests the identification of the preferred extremals as 4-D surfaces having 4-D generalization of complex structure and that a large number of general coordinate invariant actions constructible in terms of the induced geometry have the same preferred extremals.

A-5.1 Could twistor lift fix the choice of the action uniquely?

The twistor lift of TGD [L71] [L159, L163, L164] generalizes the notion of induction to the level of twistor fields and leads to a proposal that the action is obtained by dimensional reduction of the action having as its preferred extremals the counterpart of twistor space of the space-time surface identified as 6-D surface in the product $T(M^4) \times T(CP_2)$ twistor spaces of $T(M^4)$ and

$T(CP_2)$ of M^4 and CP_2. Only M^4 and CP_2 allow a twistor space with Kähler structure [A30] so that TGD would be unique. Dimensional reduction is forced by the condition that the 6-surface has S^2-bundle structure characterizing twistor spaces and the base space would be the space-time surface.

1. Dimensional reduction of 6-D Kähler action implies that at the space-time level the fundamental action can be identified as the sum of Kähler action and volume term (cosmological constant). Other choices of the action do not look natural in this picture although they would have the same preferred extremals.

2. Preferred extremals are proposed to correspond to minimal surfaces with singularities such that they are also extremals of 4-D Kähler action outside the singularities. The physical analogue are soap films spanned by frames and one can localize the violation of the strict determinism and of strict holography to the frames.

3. The preferred extremal property is realized as the holomorphicity characterizing string world sheets, which generalizes to the 4-D situation. This in turn implies that the preferred extremals are the same for any general coordinate invariant action defined on the induced gauge fields and induced metric apart from possible extremals with vanishing CP_2 Kähler action.

   For instance, 4-D Kähler action and Weyl action as the sum of the tensor squares of the components of the Weyl tensor of CP_2 representing quaternionic imaginary units constructed from the Weyl tensor of CP_2 as an analog of gauge field would have the same preferred extremals and only the definition of Kähler function and therefore Kähler metric of WCW would change. One can even consider the possibility that the volume term in the 4-D action could be assigned to the tensor square of the induced metric representing a quaternionic or octonionic real unit.

Action principle does not seem to be unique. On the other hand, the WCW Kähler form and metric should be unique since its existence requires maximal isometries.

Unique action is not the only way to achieve this. One cannot exclude the possibility that the Kähler gauge potential of WCW in the complex coordinates of WCW differs only by a complex gradient of a holomorphic function for different actions so that they would give the same Kähler form for WCW. This gradient is induced by a symplectic transformation of WCW inducing a U(1) gauge transformation. The Kähler metric is the same if the symplectic transformation is an isometry.

Symplectic transformations of WCW could give rise to inequivalent representations of the theory in terms of action at space-time level. Maybe the length scale dependent coupling parameters of an effective action could be interpreted in terms of a choice of WCW Kähler function, which maximally simplifies the computations at a given scale.

1. The 6-D analogues of electroweak action and color action reducing to Kähler action in 4-D case exist. The 6-D analog of Weyl action based on the tensor representation of quaternionic imaginary units does not however exist. One could however consider the possibility that only the base space of twistor space $T(M^4)$ and $T(CP_2)$ have quaternionic structure.

2. Kähler action has a huge vacuum degeneracy, which clearly distinguishes it from other actions. The presence of the volume term removes this degeneracy. However, for minimal surfaces having CP_2 projections, which are Lagrangian manifolds and therefore have a vanishing induced Kähler form, would be preferred extremals according to the proposed definition. For these 4-surfaces, the existence of the generalized complex structure is dubious.

   For the electroweak action, the terms corresponding to charged weak bosons eliminate these extremals and one could argue that electroweak action or its sum with the analogue of color action, also proportional Kähler action, defines the more plausible choice. Interestingly, also the neutral part of electroweak action is proportional to Kähler action.

Twistor lift strongly suggests that also M^4 has the analog of Kähler structure. M^8 must be complexified by adding a commuting imaginary unit i. In the E^8 subspace, the Kähler structure of E^4 is defined in the standard sense and it is proposed that this generalizes to M^4 allowing also

generalization of the quaternionic structure. M^4 Kähler structure violates Lorentz invariance but could be realized at the level of moduli space of these structures.

The minimal possibility is that the M^4 Kähler form vanishes: one can have a different representation of the Kähler gauge potential for it obtained as generalization of symplectic transformations acting non-trivially in M^4. The recent picture about the second quantization of spinors of $M^4 \times CP_2$ assumes however non-trivial Kähler structure in M^4.

A-5.2 Two paradoxes

TGD view leads to two apparent paradoxes.

1. If the preferred extremals satisfy 4-D generalization of holomorphicity, a very large set of actions gives rise to the same preferred extremals unless there are some additional conditions restricting the number of preferred extremals for a given action.

2. WCW metric has an infinite number of zero modes, which appear as parameters of the metric but do not contribute to the line element. The induced Kähler form depends on these degrees of freedom. The existence of the Kähler metric requires maximal isometries, which suggests that the Kähler metric is uniquely fixed apart from a conformal scaling factor Ω depending on zero modes. This cannot be true: galaxy and elementary particle cannot correspond to the same Kähler metric.

Number theoretical vision and the hierarchy of inclusions of HFFs associated with supersymplectic algebra actings as isometries of WcW provide equivalent realizations of the measurement resolution. This solves these paradoxes and predicts that WCW decomposes into sectors for which Kähler metrics of WCW differ in a natural way.

The hierarchy subalgebras of supersymplectic algebra implies the decomposition of WCW into sectors with different actions

Supersymplectic algebra of $\delta M^4_+ \times CP_2$ is assumed to act as isometries of WCW [L171]. There are also other important algebras but these will not be discussed now.

1. The symplectic algebra A of $\delta M^4_+ \times CP_2$ has the structure of a conformal algebra in the sense that the radial conformal weights with non-negative real part, which is half integer, label the elements of the algebra have an interpretation as conformal weights.

   The super symplectic algebra A has an infinite hierarchy of sub-algebras [L171] such that the conformal weights of sub-algebras $A_{n(SS)}$ are integer multiples of the conformal weights of the entire algebra. The superconformal gauge conditions are weakened. Only the subalgebra $A_{n(SS)}$ and the commutator $[A_{n(SS)}, A]$ annihilate the physical states. Also the corresponding classical Noether charges vanish for allowed space-time surfaces.

   This weakening makes sense also for ordinary superconformal algebras and associated Kac-Moody algebras. This hierarchy can be interpreted as a hierarchy symmetry breakings, meaning that sub-algebra $A_{n(SS)}$ acts as genuine dynamical symmetries rather than mere gauge symmetries. It is natural to assume that the super-symplectic algebra A does not affect the coupling parameters of the action.

2. The generators of A correspond to the dynamical quantum degrees of freedom and leave the induced Kähler form invariant. They affect the induced space-time metric but this effect is gravitational and very small for Einsteinian space-time surfaces with 4-D M^4 projection.

   The number of dynamical degrees of freedom increases with $n(SS)$. Therefore WCW decomposes into sectors labelled by $n(SS)$ with different numbers of dynamical degrees of freedom so that their Kähler metrics cannot be equivalent and cannot be related by a symplectic isometry. They can correspond to different actions.

Number theoretic vision implies the decomposition of WCW into sectors with different actions

The number theoretical vision leads to the same conclusion as the hierarchy of HFFs. The number theoretic vision of TGD based on $M^8 - H$ duality [L171] predicts a hierarchy with levels labelled by the degrees $n(P)$ of rational polynomials P and corresponding extensions of rationals characterized by Galois groups and by ramified primes defining p-adic length scales.

These sequences allow us to imagine several discrete coupling constant evolutions realized at the level H in terms of action whose coupling parameters depend on the number theoretic parameters.

1. Coupling constant evolution with respect to $n(P)$

The first coupling constant evolution would be with respect to $n(P)$.

1. The coupling constants characterizing action could depend on the degree $n(P)$ of the polynomial defining the space-time region by $M^8 - H$ duality. The complexity of the space-time surface would increase with $n(P)$ and new degrees of freedom would emerge as the number of the rational coefficients of P.

2. This coupling constant evolution could naturally correspond to that assignable to the inclusion hierarchy of hyperfinite factors of type II_1 (HFFs). I have indeed proposed [L171] that the degree $n(P)$ equals to the number $n(braid)$ of braids assignable to HFF for which super symplectic algebra subalgebra $A_{n(SS)}$ with radial conformal weights coming as $n(SS)$-multiples of those of entire algebra A. One would have $n(P) = n(braid) = n(SS)$. The number of dynamical degrees of freedom increases with n which just as it increases with $n(P)$ and $n(SS)$.

3. The actions related to different values of $n(P) = n(braid) = n(SS)$ cannot define the same Kähler metric since the number of allowed space-time surfaces depends on $n(SS)$.

   WCW could decompose to sub-WCWs corresponding to different actions, a kind of theory space. These theories would not be equivalent. A possible interpretation would be as a hierarchy of effective field theories.

4. Hierarchies of composite polynomials define sequences of polynomials with increasing values of $n(P)$ such that the order of a polynomial at a given level is divided by those at the lower levels. The proposal is that the inclusion sequences of extensions are realized at quantum level as inclusion hierarchies of hyperfinite factors of type II_1.

   A given inclusion hierarchy corresponds to a sequence $n(SS)_i$ such that $n(SS)_i$ divides $n(SS)_{i+1}$. Therefore the degree of the composite polynomials increases very rapidly. The values of $n(SS)_i$ can be chosen to be primes and these primes correspond to the degrees of so called prime polynomials [L167] so that the decompositions correspond to prime factorizations of integers. The "densest" sequence of this kind would come in powers of 2 as $n(SS)_i = 2^i$. The corresponding p-adic length scales (assignable to maximal ramified primes for given $n(SS)_i$) are expected to increase roughly exponentially, say as 2^{r2^i}. $r = 1/2$ would give a subset of scales $2^{r/2}$ allowed by the p-adic length scale hypothesis. These transitions would be very rare.

   A theory corresponding to a given composite polynomial would contain as sub-theories the theories corresponding to lower polynomial composites. The evolution with respect to $n(SS)$ would correspond to a sequence of phase transitions in which the action genuinely changes. For instance, color confinement could be seen as an example of this phase transition.

5. A subset of p-adic primes allowed by the p-adic length scale hypothesis $p \simeq 2^k$ defining the proposed p-adic length scale hierarchy could relate to n_S changing phase transition. TGD suggests a hierarchy of hadron physics corresponding to a scale hierarchy defined by Mersenne primes and their Gaussian counterparts [K74, K75]). Each of them would be characterized by a confinement phase transition in which n_S and therefore also the action changes.

2. Coupling constant evolutions with respect to ramified primes for a given value of $n(P)$

For a given value of $n(P)$, one could have coupling constant sub-evolutions with respect to the set of ramified primes of P and dimensions $n = h_{eff}/h_0$ of algebraic extensions. The action would only change by U(1) gauge transformation induced by a symplectic isometry of WCW. Coupling parameters could change but the actions would be equivalent.

The choice of the action in an optimal manner in a given scale could be seen as a choice of the most appropriate effective field theory in which radiative corrections would be taken into account. One can interpret the possibility to use a single choice of coupling parameters in terms of quantum criticality.

The range of the p-adic length scales labelled by ramified primes and effective Planck constants h_{eff}/h_0 is finite for a given value of $n(SS)$.

The first coupling constant evolution of this kind corresponds to ramified primes defining p-adic length scales for given $n(SS)$.

1. Ramified primes are factors of the discriminant $D(P)$ of P, which is expressible as a product of non-vanishing root differents and reduces to a polynomial of the n coefficients of P. Ramified primes define p-adic length scales assignable to the particles in the amplitudes scattering amplitudes defined by zero energy states.

   P would represent the space-time surface defining an interaction region in $N-$-particle scattering. The N ramified primes dividing $D(P)$ would characterize the p-adic length scales assignable to these particles. If $D(P)$ reduces to a single ramified prime, one has elementary particle [L167], and the forward scattering amplitude corresponds to the propagator.

   This would give rise to a multi-scale p-adic length scale evolution of the amplitudes analogous to the ordinary continuous coupling constant evolution of n-point scattering amplitudes with respect to momentum scales of the particles. This kind of evolutions extend also to evolutions with respect to $n(SS)$.

2. According to [L167], physical constraints require that $n(P)$ and the maximum size of the ramified prime of P correlate.

   A given rational polynomial of degree $n(P)$ can be always transformed to a polynomial with integer coefficients. If the integer coefficients are smaller than $n(P)$, there is an upper bound for the ramified primes. This assumption also implies that finite fields become fundamental number fields in number theoretical vision [L167].

3. p-Adic length scale hypothesis [L172] in its basic form states that there exist preferred primes $p \simeq 2^k$ near some powers of 2. A more general hypothesis states that also primes near some powers of 3 possibly also other small primes are preferred physically. The challenge is to understand the origin of these preferred scales.

   For polynomials P with a given degree $n(P)$ for which discriminant $D(P)$ is prime, there exists a maximal ramified prime. Numerical calculations suggest that the upper bound depends exponentially on $n(P)$.

   Could these maximal ramified primes satisfy the p-adic length scale hypothesis or its generalization? The maximal prime defines a fixed point of coupling constant evolution in accordance with the earlier proposal. For instance, could one think that one has $p \simeq 2^k$, $k = n(SS)$? Each p-adic prime would correspond to a p-adic coupling constant sub-evolution representable in terms of symplectic isometries.

Also the dimension n of the algebraic extension associated with P, which is identified in terms of effective Planck constant $h_{eff}/h_0 = n$ labelling different phases of the ordinary matter behaving like dark matter, could give rise to coupling constant evolution for given $n(SS)$. The range of allowed values of n is finite. Note however that several polynomials of a given degree can correspond to the same dimension of extension.

Number theoretic discretization of WCW and maxima of WCW Kähler function

Number theoretic approach involves a unique discretization of space-time surface and also of WCW. The question is how the points of the discretized WCW correspond to the preferred extremals.

1. The exponents of Kähler function for the maxima of Kähler function, which correspond to the universal preferred extremals, appear in the scattering amplitudes. The number theoretical approach involves a unique discretization of space-time surfaces defining the WCW coordinates of the space-time surface regarded as a point of WCW.

   In [L171] it is assumed that these WCW points appearing in the number theoretical discretization correspond to the maxima of the Kähler function. The maxima would depend on the action and would differ for ghd maxima associated with different actions unless they are not related by symplectic WCW isometry.

2. The symplectic transformations of WCW acting as isometries are assumed to be induced by the symplectic transformations of $\delta M^4_+ \times CP_2$ [K55, K30]. As isometries they would naturally permute the maxima with each other.

A-6 Number theoretic vision of TGD

Physics as number theory vision is complementary to the physics as geometry vision and has developed gradually since 1993. Langlands program is the counterpart of this vision in mathematics [L170].

The notion of p-adic number fields emerged with the motivation coming from the observation that elementary particle mass scales and mass ratios could be understood in terms of the so-called p-adic length scale hypothesis [K79, K66, K27]. The fusion of the various p-adic physics leads to what I call adelic physics [L69, L70]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K31, K32, K33, K34].

Eventually this led to that the values of effective Planck constant could be identified as the dimension of an algebraic extension of rationals assignable to polynomials with rational coefficients. This led to the number theoretic vision in which so-called $M^8 - H$ duality [L127, L128] plays a key role. M^8 (actually a complexification of real M^8) is analogous to momentum space so that the duality generalizes momentum position duality for point-like particles. M^8 has an interpretation as complexified octonions.

The dynamics of 4-surfaces in M^8 is coded by polynomials with rational coefficients, whose roots define mass shells H^3 of $M^4 \subset M^8$. It has turned out that the polynomials satisfy stringent additional conditions and one can speak of number theoretic holography [L167, L170]. Also the ordinary $3 \rightarrow 4$ holography is needed to assign 4-surfaces with these 3-D mass shells. The number theoretic dynamics is based on the condition that the normal space of the 4-surface in M^8 is associative (quaternionic) and contains a commutative complex sub-space. This makes it possible to assign to this surface space-time surface in $H = M^4 \times CP_2$.

At the level of H the space-time surfaces are by holography preferred extremals and are assumed to be determined by the twistor lift of TGD [L71] giving rise to an action which is sum of the Kähler action and volume term. The preferred extremals would be minimal surfaces analogous to soap films spanned by frames. Outside frames they would be simultaneous extremals of the Kähler action, which requires a generalization of the holomorphy characterizing string world sheets.

In the following only p-adic numbers and hierarchy of Planck constants will be discussed.

A-6.1 p-Adic numbers and TGD

p-Adic number fields

p-Adic numbers (p is prime: 2, 3, 5, ...) can be regarded as a completion of the rational numbers using a norm, which is different from the ordinary norm of real numbers [A14]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k \geq k_0} x(k) p^k, \; x(k) = 0, ..., p-1 \; . \tag{A-6.1}$$

The norm of a p-adic number is given by

$$|x| \;=\; p^{-k_0(x)} \;. \tag{A-6.2}$$

Here $k_0(x)$ is the lowest power in the expansion of the p-adic number. The norm differs drastically from the norm of the ordinary real numbers since it depends on the lowest pinary digit of the p-adic number only. Arbitrarily high powers in the expansion are possible since the norm of the p-adic number is finite also for numbers, which are infinite with respect to the ordinary norm. A convenient representation for p-adic numbers is in the form

$$x \;=\; p^{k_0}\varepsilon(x) \;, \tag{A-6.3}$$

where $\varepsilon(x) = k + ...$ with $0 < k < p$, is p-adic number with unit norm and analogous to the phase factor $exp(i\phi)$ of a complex number.

The distance function $d(x,y) = |x-y|_p$ defined by the p-adic norm possesses a very general property called ultra-metricity:

$$d(x,z) \;\leq\; max\{d(x,y), d(y,z)\} \;. \tag{A-6.4}$$

The properties of the distance function make it possible to decompose R_p into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \;\leq\; D \;. \tag{A-6.5}$$

This division of the metric space into classes has following properties:

1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.

2. Distances of points x and y inside single class are smaller than distances between different classes.

3. Classes form a hierarchical tree.

Notice that the concept of the ultra-metricity emerged in physics from the models for spin glasses and is believed to have also applications in biology [B16]. The emergence of p-adic topology as the topology of the effective space-time would make ultra-metricity property basic feature of physics.

Canonical correspondence between p-adic and real numbers

The basic challenge encountered by p-adic physicist is how to map the predictions of the p-adic physics to real numbers. p-Adic probabilities provide a basic example in this respect. Identification via common rationals and canonical identification and its variants have turned out to play a key role in this respect.

1. Basic form of the canonical identification

There exists a natural continuous map $I : R_p \to R_+$ from p-adic numbers to non-negative real numbers given by the "pinary" expansion of the real number for $x \in R$ and $y \in R_p$ this correspondence reads

$$\begin{aligned} y \;&=\; \sum_{k>N} y_k p^k \to x = \sum_{k<N} y_k p^{-k} \;, \\ y_k \;&\in\; \{0,1,..,p-1\} \;. \end{aligned} \tag{A-6.6}$$

This map is continuous as one easily finds out. There is however a little difficulty associated with the definition of the inverse map since the pinary expansion like also decimal expansion is not unique ($1 = 0.999...$) for the real numbers x, which allow pinary expansion with finite number of pinary digits

$$\begin{aligned} x &= \sum_{k=N_0}^{N} x_k p^{-k} \ , \\ x &= \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1)p^{-N} + (p-1)p^{-N-1} \sum_{k=0,..} p^{-k} \ . \end{aligned} \tag{A-6.7}$$

The p-adic images associated with these expansions are different

$$\begin{aligned} y_1 &= \sum_{k=N_0}^{N} x_k p^{k} \ , \\ y_2 &= \sum_{k=N_0}^{N-1} x_k p^{k} + (x_N - 1)p^{N} + (p-1)p^{N+1} \sum_{k=0,..} p^{k} \\ &= y_1 + (x_N - 1)p^N - p^{N+1} \ , \end{aligned} \tag{A-6.8}$$

so that the inverse map is either two-valued for p-adic numbers having expansion with finite pinary digits or single valued and discontinuous and non-surjective if one makes pinary expansion unique by choosing the one with finite pinary digits. The finite pinary digit expansion is a natural choice since in the numerical work one always must use a pinary cutoff on the real axis.

2. The topology induced by canonical identification

The topology induced by the canonical identification in the set of positive real numbers differs from the ordinary topology. The difference is easily understood by interpreting the p-adic norm as a norm in the set of the real numbers. The norm is constant in each interval $[p^k, p^{k+1})$ (see **Fig. A-6.1**) and is equal to the usual real norm at the points $x = p^k$: the usual linear norm is replaced with a piecewise constant norm. This means that p-adic topology is coarser than the usual real topology and the higher the value of p is, the coarser the resulting topology is above a given length scale. This hierarchical ordering of the p-adic topologies will be a central feature as far as the proposed applications of the p-adic numbers are considered.

Ordinary continuity implies p-adic continuity since the norm induced from the p-adic topology is rougher than the ordinary norm. p-Adic continuity implies ordinary continuity from right as is clear already from the properties of the p-adic norm (the graph of the norm is indeed continuous from right). This feature is one clear signature of the p-adic topology.

Fig. 14. The real norm induced by canonical identification from 2-adic norm. `http://tgdtheory.fi/appfigures/norm.png`

The linear structure of the p-adic numbers induces a corresponding structure in the set of the non-negative real numbers and p-adic linearity in general differs from the ordinary concept of linearity. For example, p-adic sum is equal to real sum only provided the summands have no common pinary digits. Furthermore, the condition $x +_p y < max\{x, y\}$ holds in general for the p-adic sum of the real numbers. p-Adic multiplication is equivalent with the ordinary multiplication only provided that either of the members of the product is power of p. Moreover one has $x \times_p y < x \times y$ in general. The p-Adic negative -1_p associated with p-adic unit 1 is given by $(-1)_p = \sum_k (p-1)p^k$ and defines p-adic negative for each real number x. An interesting possibility is that p-adic linearity might replace the ordinary linearity in some strongly nonlinear systems so these systems would look simple in the p-adic topology.

These results suggest that canonical identification is involved with some deeper mathematical structure. The following inequalities hold true:

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |x|_p|y|_R \leq (xy)_R &\leq x_R y_R \ , \end{aligned} \tag{A-6.9}$$

where $|x|_p$ denotes p-adic norm. These inequalities can be generalized to the case of $(R_p)^n$ (a linear vector space over the p-adic numbers).

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |\lambda|_p|y|_R \leq (\lambda y)_R &\leq \lambda_R y_R \ , \end{aligned} \tag{A-6.10}$$

where the norm of the vector $x \in T_p^n$ is defined in some manner. The case of Euclidian space suggests the definition

$$(x_R)^2 = (\sum_n x_n^2)_R \ . \tag{A-6.11}$$

These inequalities resemble those satisfied by the vector norm. The only difference is the failure of linearity in the sense that the norm of a scaled vector is not obtained by scaling the norm of the original vector. Ordinary situation prevails only if the scaling corresponds to a power of p.

These observations suggests that the concept of a normed space or Banach space might have a generalization and physically the generalization might apply to the description of some non-linear systems. The nonlinearity would be concentrated in the nonlinear behavior of the norm under scaling.

3. Modified form of the canonical identification

The original form of the canonical identification is continuous but does not respect symmetries even approximately. This led to a search of variants which would do better in this respect. The modification of the canonical identification applying to rationals only and given by

$$I_Q(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \tag{A-6.12}$$

is uniquely defined for rationals, maps rationals to rationals, has also a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$. It has turned out that it is this map which most naturally appears in the applications. The map is obviously continuous locally since p-adically small modifications of r and s mean small modifications of the real counterparts.

Canonical identification is in a key role in the successful predictions of the elementary particle masses. The predictions for the light elementary particle masses are within extreme accuracy same for I and I_Q but I_Q is theoretically preferred since the real probabilities obtained from p-adic ones by I_Q sum up to one in p-adic thermodynamics.

4. Generalization of number concept and notion of embedding space

TGD forces an extension of number concept: roughly a fusion of reals and various p-adic number fields along common rationals is in question. This induces a similar fusion of real and p-adic embedding spaces. Since finite p-adic numbers correspond always to non-negative reals n-dimensional space R^n must be covered by 2^n copies of the p-adic variant R_p^n of R^n each of which projects to a copy of R_+^n (four quadrants in the case of plane). The common points of p-adic and real embedding spaces are rational points and most p-adic points are at real infinity.

Real numbers and various algebraic extensions of p-adic number fields are thus glued together along common rationals and also numbers in algebraic extension of rationals whose number belong to the algebraic extension of p-adic numbers. This gives rise to a book like structure with rationals and various algebraic extensions of rationals taking the role of the back of the book. Note that Neper number is exceptional in the sense that it is algebraic number in p-adic number field Q_p satisfying $e^p \ mod \ p = 1$.

Fig. 15. Various number fields combine to form a book like structure. `http://tgdtheory.fi/appfigures/book.jpg`

For a given p-adic space-time sheet most points are literally infinite as real points and the projection to the real embedding space consists of a discrete set of rational points: the interpretation in terms of the unavoidable discreteness of the physical representations of cognition is natural. Purely local p-adic physics implies real p-adic fractality and thus long range correlations for the real space-time surfaces having enough common points with this projection.

p-Adic fractality means that M^4 projections for the rational points of space-time surface X^4 are related by a direct identification whereas CP_2 coordinates of X^4 at these points are related by I, I_Q or some of its variants implying long range correlates for CP_2 coordinates. Since only a discrete set of points are related in this manner, both real and p-adic field equations can be satisfied and there are no problems with symmetries. p-Adic effective topology is expected to be a good approximation only within some length scale range which means infrared and UV cutoffs. Also multi-p-fractality is possible.

The notion of p-adic manifold

The notion of p-adic manifold is needed in order to fuse real physics and various p-adic physics to a larger structure which suggests that real and p-adic number fields should be glued together along common rationals bringing in mind adeles. The notion is problematic because p-adic topology is totally disconnected implying that p-adic balls are either disjoint or nested so that ordinary definition of manifold using p-adic chart maps fails. A cure is suggested to be based on chart maps from p-adics to reals rather than to p-adics (see the appendix of the book)

The chart maps are interpreted as cognitive maps, "thought bubbles".

Fig. 16. The basic idea between p-adic manifold. `http://tgdtheory.fi/appfigures/padmanifold.jpg`

There are some problems.

1. Canonical identification does not respect symmetries since it does not commute with second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map arithmetic operations which requires pinary cutoff below which chart map takes rationals to rationals so that commutativity with arithmetics and symmetries is achieved in finite resolution: above the cutoff canonical identification is used

2. Canonical identification is continuous but does not map smooth p-adic surfaces to smooth real surfaces requiring second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map requiring completion of the image to smooth preferred extremal of Kähler action so that chart map is not unique in accordance with finite measurement resolution

3. Canonical identification violates general coordinate invariance of chart map: (cognition-induced symmetry breaking) minimized if p-adic manifold structure is induced from that for p-adic embedding space with chart maps to real embedding space and assuming preferred coordinates made possible by isometries of embedding space: one however obtains several inequivalent p-adic manifold structures depending on the choice of coordinates: these cognitive representations are not equivalent.

A-6.2 Hierarchy of Planck constants and dark matter hierarchy

Hierarchy of Planck constants was motivated by the "impossible" quantal effects of ELF em fields on vertebrate cyclotron energies $E = hf = \hbar \times eB/m$ are above thermal energy is possible only if $\hbar$ has value much larger than its standard value. Also Nottale's finding that planetary orbits migh be understood as Bohr orbits for a gigantic gravitational Planck constant.

Hierachy of Planck constant would mean that the values of Planck constant come as integer multiples of ordinary Planck constant: $h_{eff} = n \times h$. The particles at magnetic flux tubes characterized by h_{eff} would correspond to dark matter which would be invisible in the sense that only particle with same value of h_{eff} appear in the same vertex of Feynman diagram.

Hierarchy of Planck constants would be due to the non-determism of the Kähler action predicting huge vacuum degeneracy allowing all space-time surfaces which are sub-manfolds of any $M^4 \times Y^2$, where Y^2 is Lagrangian sub-manifold of CP_2. For agiven Y^2 one obtains new manifolds Y^2 by applying symplectic transformations of CP_2.

Non-determinism would mean that the 3-surface at the ends of causal diamond (CD) can be connected by several space-time surfaces carrying same conserved Kähler charges and having same values of Kähler action. Conformal symmetries defined by Kac-Moody algebra associated with the embedding space isometries could act as gauge transformations and respect the light-likeness property of partonic orbits at which the signature of the induced metric changes from Minkowskian to Euclidian (Minkowskianb space-time region transforms to wormhole contact say). The number of conformal equivalence classes of these surfaces could be finite number n and define discrete physical degree of freedom and one would have $h_{eff} = n \times h$. This degeneracy would mean "second quantization" for the sheets of n-furcation: not only one but several sheets can be realized.

This relates also to quantum criticality postulated to be the basic characteristics of the dynamics of quantum TGD. Quantum criticalities would correspond to an infinite fractal hierarchy of broken conformal symmetries defined by sub-algebras of conformal algebra with conformal weights coming as integer multiples of n. This leads also to connections with quantum criticality and hierarchy of broken conformal symmetries, p-adicity, and negentropic entanglement which by consistency with standard quantum measurement theory would be described in terms of density matrix proportional $n \times n$ identity matrix and being due to unitary entanglement coefficients (typical for quantum computing systems).

Formally the situation could be described by regarding space-time surfaces as surfaces in singular n-fold singular coverings of embedding space. A stronger assumption would be that they are expressible as as products of n_1 -fold covering of M^4 and n_2-fold covering of CP_2 meaning analogy with multi-sheeted Riemann surfaces and that M^4 coordinates are n_1-valued functions and CP_2 coordinates n_2 -valued functions of space-time coordinates for $n = n_1 \times n_2$. These singular coverings of embedding space form a book like structure with singularities of the coverings localizable at the boundaries of causal diamonds defining the back of the book like structure.

Fig. 17. Hierarchy of Planck constants. `http://tgdtheory.fi/appfigures/planckhierarchy.jpg`

A-6.3 $M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix 15.6.6) has changed considerably towards the end 2021 [L159] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \to m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L159] of the $M^8 - H$ duality map takes mass shells $p^2 = m^2$ of $M^4 \subset M^8$ to cds with size $L(m) = \hbar_{eff}/m$ with a common center. The slicing by mass shells is mapped to a Russian doll like slicing by cds. Therefore would be no CDs in M^8 contrary to what I believed first.

Quantum classical correspondence (QCC) inspires the proposal that the point $p^k \in M^8$ is mapped to a geodesic line corresponding to momentum p^k starting from the common center of cds. Its intersection with the opposite boundary of cd with size $L(m)$ defines the image point. This is not yet quite enough to satisfy UP but the additional details [L159] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M^8_c$ (M^8 is complexified to M^8_c) as a "root" of its octonionic continuation [L127, L128]. E_n has an interpretation as energy, which can be complex. The original interpretation was as moment of time. For this interpretation, $M^8 - H$ duality would be a linear identification and these hyper planes would be mapped to hyperplanes in $M^4 \subset H$.

This motivated the term "very special moment in the life of self" for the image of the $E = E_n$ section of $X^4 \subset M^8$ [L102]. This notion does not make sense at the level M^8 anymore.

The modified $M^8 - H$ duality forces us to modify the original interpretation [L159]. The point $(E_n, p = 0)$ is mapped $(t_n = \hbar_{eff}/E_n, 0)$. The momenta (E_n, p) in $E = E_n$ plane are mapped to the boundary of cd and correspond to a continuous time interval at the boundary of CD: "very special moment" becomes a "very special time interval".

The quantum state however corresponds to a set of points corresponding to quark momenta, which belong to a cognitive representation and are therefore algebraic integers in the extension determined by the polynomial. These active points in E_n are mapped to a discrete set at the boundary of cd(m). A "very special moment" is replaced with a sequence of "very special moments".

So called Galois confinement [L150] forces the total momenta for bound states of quarks and antiquarks to be rational integers invariant under Galois group of extension of rationals determined by the polynomial P [L159]. These states correspond to states at boundaries of sub-CDs so that one obtains a hierarchy. Galois confinement provides a universal number theoretic mechanism for the formation of bound states.

A-7 Zero energy ontology (ZEO)

ZEO is implied by the holography forced in the TGD framework by general coordinate invariance.

A-7.1 Basic motivations and ideas of ZEO

The following gives a brief summary of ZEO [L108] [K143].

1. In ZEO quantum states are not 3-dimensional but superpositions of 4-dimensional deterministic time evolutions connecting ordinary initial 3-dimensional states. By holography they are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution. One can say that in the TGD framework general coordinate invariance implies holography and the slight failure of its determinism in turn forces ZEO.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced with a new superposition. Classical determinism of individual time evolution is not violated and this solves the basic paradox of quantum measurement theory. There are two kinds of quantum jumps: ordinary ("big") state function reductions (BSFRs) changing the arrow of time and "small" state function reductions (SSFRs) (weak measurements) preserving it and giving rise to the analog of Zeno effect [L108].

2. To avoid getting totally confused it is good to emphasize some aspects of ZEO.

   (a) ZEO does not mean that physical states in the usual 3-D sense as snapshots of time evolution would have zero energy state pairs defining zero energy states as initial and final states have same conserved quantities such as energy. Conservation implies that one can adopt the conventions that the values of conserved quantities are opposite for these states so that their sum vanishes: one can think that incoming and outgoing particles come from geometric past and future is the picture used in quantum field theories.

   (b) ZEO means two times: subjective time as sequence of quantum jumps and geometric time as space-time coordinate. These times are identifiable but are strongly correlated.

3. In BSFRs the arrow of time is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. BSFRs can occur in all scales since TGD predicts a hierarchy of effective Planck constants with arbitrarily large values. There is empirical support for BSFRs.

   (a) The findings of Minev et al [L99] in atomic scale can be explained by the same mechanism [L99]. In BSFR a final zero energy state as a superposition of classical deterministic time evolutions emerges and for an observer with a standard arrow of time looks

like a superposition of deterministic smooth time evolutions leading to the final state. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution in which case the process does not lead to anywhere: the interpretation would be that BSFR back to the initial state occurs!

(b) Libets' experiments about active aspects of consciousness [J44] can be understood. Subject person raises his finger and neural activity starts before the conscious decision to do so. In the physicalistic framework it is thought to lead to raising of the finger. The problem with the explanation is that the activity beginning .5 seconds earlier seems to be dissipation with a reversed arrow of time: from chaotic and disordered to ordered at around .15 seconds. ZEO explanation is that macroscopic quantum jump occurred and generated a signal proceeding backwards in time and generated neural activity and dissipated to randomness.

(c) Earthquakes involve a strange anomaly: they are preceded by ELF radiation. One would expect that they generate ELF radiation. The identification as BSFR would explain the anomaly [L101]. In biology the reversal of the arrow of time would occur routinely and be a central element of biological self-organization, in particular self-organized quantum criticality (see [L104, L194].

A-7.2 Some implications of ZEO

ZEO has profound implications for understanding self-organization and self-organized quantum criticality in terms of dissipation with non-standard arrow of time looking like generation of structures [L104, L194]. ZEO could also allow understanding of what planned actions - like realizing the experiment under consideration - could be.

1. Second law in the standard sense does not favor - perhaps even not allow - realization of planned actions. ZEO forces a generalization of thermodynamics: dissipation with a non-standard arrow of time for a subsystem would look like self-organization and planned action and its realization.

   Could most if not all planned action be like this - induced by BSFR in the geometric future and only apparently planned? There would be however the experience of planning and realizing induced by the signals from geometric future by a higher level in the hierarchy of conscious entities predicted by TGD! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than agents with completely free will.

2. The notion of magnetic body (MB) serving as a boss of ordinary matter would be central. MB carries dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n serving as a measure for algebraic complexity of extension of rationals as its dimension and defining a kind of universal IQ. There is a hierarchy of these phases and MBs labelled by extension of rationals and the value of n.

   MBs would form a hierarchy of bosses - a realization for master slave hierarchy. Ordinary matter would be at the bottom and its coherent behavior would be induced from quantum coherence at higher levels. BSFR for higher level MB would give rise to what looks like planned actions and experienced as planned action at the lower levels of hierarchy. One could speak of planned actions inducing a cascade of planned actions in shorter time scales and eventually proceeding to atomic level.

A-8 Some notions relevant to TGD inspired consciousness and quantum biology

Below some notions relevant to TGD inspired theory of consciousness and quantum biology.

A-8.1 The notion of magnetic body

Topological field quantization inspires the notion of field body about which magnetic body is especially important example and plays key role in TGD inspired quantum biology and consciousness theory. This is a crucial departure fromt the Maxwellian view. Magnetic body brings in third level to the description of living system as a system interacting strongly with environment. Magnetic body would serve as an intentional agent using biological body as a motor instrument and sensory receptor. EEG would communicated the information from biological body to magnetic body and Libet's findings from time delays of consciousness support this view.

The following pictures illustrate the notion of magnetic body and its dynamics relevant for quantum biology in TGD Universe.

Fig. 18. Magnetic body associated with dipole field. `http://tgdtheory.fi/appfigures/fluxquant.jpg`

Fig. 19. Illustration of the reconnection by magnetic flux loops. `http://tgdtheory.fi/appfigures/reconnect1.jpg`

Fig. 20. Illustration of the reconnection by flux tubes connecting pairs of molecules. `http://tgdtheory.fi/appfigures/reconect2.jpg`

Fig. 21. Flux tube dynamics. a) Reconnection making possible magnetic body to "recognize" the presence of another magnetic body, b) braiding, knotting and linking of flux tubes making possible topological quantum computation, c) contraction of flux tube in phase transition reducing the value of h_{eff} allowing two molecules to find each other in dense molecular soup. `http://tgdtheory.fi/appfigures/fluxtubedynamics.jpg`

A-8.2 Number theoretic entropy and negentropic entanglement

TGD inspired theory of consciousness relies heavily p-Adic norm allows an to define the notion of Shannon entropy for rational probabilities (and even those in algebraic extension of rationals) by replacing the argument of logarithm of probability with its p-adic norm. The resulting entropy can be negative and the interpretation is that number theoretic entanglement entropy defined by this formula for the p-adic prime minimizing its value serves as a measure for conscious information. This negentropy characterizes two-particle system and has nothing to do with the formal negative negentropy assignable to thermodynamic entropy characterizing single particle. Negentropy Maximization Principle (NMP) implies that number theoretic negentropy increases during evolution by quantum jumps. The condition that NMP is consistent with the standard quantum measurement theory requires that negentropic entanglement has a density matrix proportional to unit matrix so that in 2-particle case the entanglement matrix is unitary.

Fig. 22. Schrödinger cat is neither dead or alive. For negentropic entanglement this state would be stable. `http://tgdtheory.fi/appfigures/cat.jpg`

A-8.3 Life as something residing in the intersection of reality and p-adicities

In TGD inspired theory of consciousness p-adic space-time sheets correspond to space-time correlates for thoughts and intentions. The intersections of real and p-adic preferred extremals consist of points whose coordinates are rational or belong to some extension of rational numbers in preferred embedding space coordinates. They would correspond to the intersection of reality and various p-adicities representing the "mind stuff" of Descartes. There is temptation to assign life to the intersection of realities and p-adicities. The discretization of the chart map assigning to real space-time surface its p-adic counterpart would reflect finite cognitive resolution.

At the level of "world of classical worlds" (WCW) the intersection of reality and various p-adicities would correspond to space-time surfaces (or possibly partonic 2-surfaces) representable in terms of rational functions with polynomial coefficients with are rational or belong to algebraic extension of rationals.

The quantum jump replacing real space-time sheet with p-adic one (vice versa) would correspond to a buildup of cognitive representation (realization of intentional action).

Fig. 23. The quantum jump replacing real space-time surface with corresponding p-adic manifold can be interpreted as formation of though, cognitive representation. Its reversal would correspond to a transformation of intention to action. `http://tgdtheory.fi/appfigures/padictoreal.jpg`

A-8.4 Sharing of mental images

The 3-surfaces serving as correlates for sub-selves can topologically condense to disjoint large space-time sheets representing selves. These 3-surfaces can also have flux tube connections and this makes possible entanglement of sub-selves, which unentangled in the resolution defined by the size of sub-selves. The interpretation for this negentropic entanglement would be in terms of sharing of mental images. This would mean that contents of consciousness are not completely private as assumed in neuroscience.

Fig. 24. Sharing of mental images by entanglement of subselves made possible by flux tube connections between topologically condensed space-time sheets associated with mental images. `http://tgdtheory.fi/appfigures/sharing.jpg`

A-8.5 Time mirror mechanism

Zero energy ontology (ZEO) is crucial part of both TGD and TGD inspired consciousness and leads to the understanding of the relationship between geometric time and experience time and how the arrow of psychological time emerges. One of the basic predictions is the possibiity of negative energy signals propagating backwards in geometric time and having the property that entropy basically associated with subjective time grows in reversed direction of geometric time. Negative energy signals inspire time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig.** 24 in the appendix of this book) providing mechanisms of both memory recall, realization of intentational action initiating action already in geometric past, and remote metabolism. What happens that negative energy signal travels to past and is reflected as positive energy signal and returns to the sender. This process works also in the reverse time direction.

Fig. 25. Zero energy ontology allows time mirror mechanism as a mechanism of memory recall. Essentially "seeing" in time direction is in question. `http://tgdtheory.fi/appfigures/timemirror.jpg`

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REFERENCES

Mathematics

[A1] Catastrophe Theory. Available at: https://en.wikipedia.org/wiki/Catastrophe_theory#Cusp_catastrophe.

[A2] Classification of finite simple groups. Available at: https://en.wikipedia.org/wiki/Classification_of_finite_simple_groups.

[A3] Pythagorean triangles. Available at: https://en.wikipedia.org/wiki/Pythagorean_triangle.

[A4] Super Virasoro algebra. Available at: https://en.wikipedia.org/wiki/Super_Virasoro_algebra.

[A5] Yangian symmetry. Available at: https://en.wikipedia.org/wiki/Yangian.

[A6] Stern A. *Matrix Logic*. North-Holland, 1988.

[A7] Khrennikov AYu. p-Adic Probability and Statistics. *Dokl Akad Nauk*, (6), 1992.

[A8] Schroer B. Lectures on Algebraic Quantum Field Theory and Operator Algebras, 2001. Available at: https://xxx.lanl.gov/abs/math-ph/0102018.

[A9] Shipman B. Investigating bee behavior from the standpoint of fundamental physical principles. *Am Bee J*, 136(5):339–340, 1996.

[A10] Shipman B. The geometry of momentum mappings on generalized flag manifolds, connections with a dynamical system, quantum mechanics and the dance of honeybee, 1998. Available at: https://math.cornell.edu/~oliver/Shipman.gif.

[A11] Shipman B. On the geometry of certain isospectral sets in the full Kostant-Toda lattice., 1998. Available at: https://nyjm.albany.edu:8000/PacJ/1997/Shipman.html.

[A12] Shipman B. A symmetry of order two in the full Kostant-Toda lattice., 1998. Available at: https://www.math.rochester.edu:8080/u/shipman/symmetrypaper/.

[A13] Shipman B. The full Kostant -Toda lattice: Geometry of its singularities and its connection to honeybees and new developments in physics. 2007.

[A14] Shafarevich IR Borevich ZI. *Number Theory*. Academic Press, 1966.

[A15] Freund PG Brekke L. p-Adic Numbers in Physics. *Phys Rep*, 233(1), 1993.

[A16] Kassel C. *Quantum Groups*. Springer Verlag, 1995.

[A17] Pope CN. Eigenfunctions and $Spin^c$ Structures on CP_2, 1980.

[A18] Kreimer D Connes A. *Hofp algebras, renormalization, and non-commutative geometry*, volume 1999. Kluwer, 1998. Available at: https://arxiv.org/abs/hep-th/9912092.

[A19] Freed DS. The Geometry of Loop Groups, 1985.

[A20] Witten E. Quantum field theory and the Jones polynomial. *Comm Math Phys*, 121:351–399, 1989.

[A21] Zeeman EC. *Catastrophe Theory.* Addison-Wessley Publishing Company, 1977.

[A22] Hanson J Eguchi T, Gilkey B. *Phys Rep*, 66, 1980.

[A23] Hanson J Eguchi T, Gilkey B. *Phys Rep*, 66, 1980.

[A24] Eisenhart. *Riemannian Geometry.* Princeton University Press, 1964.

[A25] Jones FR. *Braid groups, Hecke algebras and type II_1 factors.* 1983.

[A26] Shapiro ZYa Gelfand IM, Minklos RA. *Representations of the rotation and Lorentz groups and their applications.* Pergamon Press, 1963.

[A27] Pope CN Gibbons GW. CP_2 as gravitational instanton. *Comm Math Phys*, 55, 1977.

[A28] Kastler D Haag R. An Algebraic Approach to Quantum Field Theory. *J Math Phys*, 5:848–861, 1964.

[A29] Pope CN Hawking SW. Generalized Spin Structures in Quantum Gravity. *Phys Lett*, (1), 1978.

[A30] N. Hitchin. Kählerian twistor spaces. *Proc London Math Soc*, 8(43):133–151, 1981.. Available at: `https://tinyurl.com/pb8zpqo`.

[A31] Borchers HJ. On Revolutionizing QFT with Tomita's Modular Theory. *J Math Phys*, pages 3604–3673, 2000. Available at: `https://www.lqp.uni-goettingen.de/papers/99/04/99042900.html`.

[A32] Zuber J-B Iztykson C. *Quantum Field Theory*, volume 549. Mc Graw-Hill, New York, 1980.

[A33] Dixmier J. *Von Neumann Algebras.* North-Holland, Amsterdam, 1981. First published in French in 1957: Les Algebres d'Operateurs dans l'Espace Hilbertien, Paris: Gauthier-Villars.

[A34] Milnor J. *Topology form Differential Point of View.* The University Press of Virginia, Virginia, 1965.

[A35] Baez JC. The Octonions. *Bull Amer Math Soc*, 39(2002), 2001. Available at: `https://math.ucr.edu/home/baez/Octonions/octonions.html`.

[A36] Schwartz L. Generalisation de la Notion de Fonction, de Derivation, de Transformation de Fourier et Applications Mathematiques et Physiques. *Publications de l'Institut de Mathematique de l'Universite de Strasbourg, Vols 9-10, Paris: Hermann*, 1945.

[A37] Rotelli P Leo de S. A New Definition of Hypercomplex Analyticity, 1997. Available at: `https://arxiv.org/pdf/funct-an/9701004.pdf`.

[A38] Spivak M. *Differential Geometry I,II,III,IV.* Publish or Perish, Boston, 1970.

[A39] Takesaki M. *Tomita's Theory of Modular Hilbert Algebras and Its Applications*, volume 128. Springer, Berlin, 1970.

[A40] Sneyd J McKenzie A. *On the Formation and Breakup of Spiral Waves of Calcium*, volume 8. World Scientific, 1999.

[A41] Thom R. *Comm Math Helvet*, 28, 1954.

[A42] Rivers RJ. *Path Integral Methods in Quantum Field Theory.* Cambridge University Press, Cambridge, 1987.

[A43] Helgason S. *Differential Geometry and Symmetric Spaces.* Academic Press, New York, 1962.

[A44] Sawin S. Links, Quantum Groups, and TQFT's, 1995.Available at: `https://arxiv.org/abs/q-alg/9506002`.

[A45] Jones V. In and around the origin of quantum groups, 2003. Available at: https://arxiv.org/abs/math/0309199.

[A46] Wallace. *Differential Topology.* W. A. Benjamin, New York, 1968.

[A47] Vandoren S Wit de B, Rocek M. Hypermultiplets, Hyperkähler Cones and Quaternion-Kähler Geometry, 2001. Available at: https://arxiv.org/pdf/hep-th/0101161.pdf.

[A48] Ge ML Yang CN. *Braid Group, Knot Theory, and Statistical Mechanics.* World Scientific, 1989.

Theoretical Physics

[B1] Elitzur–Vaidman bomb-testing problem. Available at: https://en.wikipedia.org/wiki/Elitzur\OT1\textendashVaidman_bomb-testing_problem.

[B2] Montonen Olive Duality. Available at: https://en.wikipedia.org/wiki/Montonen-Olive_duality.

[B3] No-cloning theorem. Available at: https://en.wikipedia.org/wiki/No_cloning_theorem.

[B4] Das A. *Integrable Models.* World Scientific, 1989.

[B5] Verlinde A. On the Origin of Gravity and the Laws of Newton, 2010. Available at: https://arxiv.org/abs/1001.0785.

[B6] Zee A. *The Unity of Forces in the Universe.* World Sci Press, Singapore, 1982.

[B7] Drell S Björken J. *Relativistic Quantum Fields.* Mc Graw-Hill, New York, 1965.

[B8] Rapoport D. Stochastic processes in conformal Riemann-Cartan-Weyl gravitation, 1991. Available at: https://link.springer.com/article/10.1007/BF00675614.

[B9] Witten E Dolan L, Nappi CR. Yangian Symmetry in $D = 4$ superconformal Yang-Mills theory, 2004. Available at: https://arxiv.org/abs/hep-th/0401243.

[B10] Plefka J Drummond J, Henn J. Yangian symmetry of scattering amplitudes in $\mathcal{N} = 4$ super Yang-Mills theory, 2009. Available at: https://cdsweb.cern.ch/record/1162372/files/jhep052009046.pdf.

[B11] Rafelski J Ericson T. The tale of the Hagedorn temperature. *Cern Courier*, 43(7), 2002. Available at: https://www.cerncourier.com/main/toc/43/7.

[B12] Arkani-Hamed N et al. The All-Loop Integrand For Scattering Amplitudes in Planar N=4 SYM, 2010. Available at: https://arxiv.org/abs/1008.2958.

[B13] Minev ZK et al. To catch and reverse a quantum jump mid-flight, 2019. Available at: https://arxiv.org/abs/1803.00545.

[B14] Sokolov IV et al. Quantum holographic teleportation of light fields, 2001. Available at: https://arxiv.org/abs/quant-ph/0007026v1.

[B15] Wang Z Freedman M, Larsen H. A modular functor which is universal for quantum computation. *Comm Math Phys*, 1(2):605–622, 2002. Available at: https://arxiv.org/abs/quant-ph/0001108.

[B16] Parisi G. *Field Theory, Disorder and Simulations*. World Scientific, 1992.

[B17] Carmichael HJ. *An Open Systems Approach to Quantum Optics*. Springer, Berlin,Heidelberg, 1993.

[B18] Zuber J-B Itzykson C. *Quantum Field Theory*. Mc Graw-Hill, New York, 1980.

[B19] Maldacena J. Entanglement and the Geometry of Spacetime. *IAS Inst Lett*, 2013. Available at: https://www.ias.edu/files/pdfs/publications/IL_FALL2013_FINAL.pdf.

[B20] Maldacena J and Susskind L. Cool horizons for entangled black holes, 2013. Available at: https://arxiv.org/abs/1306.0533.

[B21] Schwartz JH. *Super strings. The first 15 years of Superstring Theory*. World Scientific, 1985.

[B22] Huang K. *Quarks,Leptons & Gauge Fields*. World Scientific, 1982.

[B23] Lomonaco SJ Jr Kauffmann LH. Braiding operations are universal quantum gates, 2004. Available at: https://arxiv.org/abs/quant-ph/0401090.

[B24] Adamo T and Newman ET. The Kerr-Newman metric: A Review. *Scholarpedia*, 9(10), 2014. Available at:https://arxiv.org/abs/1410.6626.

Particle and Nuclear Physics

[C1] Davies DT et al. Precise Charm to Strange Mass Ratio and Light Quark Masses from Full Lattice QCD. *Phys Rev*, 104, 2010. Available at: https://prl.aps.org/abstract/PRL/v104/i13/e132003.

[C2] Egede U. A theoretical limit on Higgs mass, 1998. Available at: https://www.hep.lu.se/atlas//thesis/egede/thesis-node20.html.

Condensed Matter Physics

[D1] Burning salt water. Available at: https://www.youtube.com/watch?v=aGg0ATfoBgo.

[D2] Fractional quantum Hall Effect. Available at: https://en.wikipedia.org/wiki/Fractional_quantum_Hall_effect.

[D3] Liquid crystals on line. Available at: https://www.lcionline.net/.

[D4] Chatterjee S et al. Lifshitz transition from valence fluctuations in YbAl3. *Nature Communications*, 8(852), 2017. Available at: https://www.nature.com/articles/s41467-017-00946-1.

[D5] Evans DJ et al. Experimental Demonstration of Violations of the Second Law of Thermodynamics for Small Systems and Short Time Scales. *Phys Rev*, 89, 2002.

[D6] Gammaitoni L et al. Stochastic Resonance. *Rev Mod Phys* ., 70, 1998.Available at: https://www.umbrars.com/sr/.

[D7] Lin X et al. Beating the thermodynamic limit with photo-activation of n-doping in organic semiconductors. *Nature Materials*, 16:1209–1215, 2017.Available at: https://www.nature.com/articles/nmat5027.

[D8] Micadei K et al. Reversing the thermodynamic arrow of time using quantum correlations, 2017. Available at:https://arxiv.org/abs/1711.03323.

[D9] Mills R et al. Spectroscopic and NMR identification of novel hybrid ions in fractional quantum energy states formed by an exothermic reaction of atomic hydrogen with certain catalysts, 2003. Available at: https://www.blacklightpower.com/techpapers.html.

[D10] Chown M. Quantum Rebel. *New Scientist*, (2457), 2004.

[D11] Ho M-W. Can Water burn, 2009. Available at: https://www.i-sis.org.uk/canWaterBurn.php.

[D12] Anderson PW. *Rev Mod Phys*, 38, 1966.

[D13] Tilley K Tilley DR. *Super Fluidity and Super Conductivity.* Adam Hilger Ltd, 1986.

Cosmology and Astro-Physics

[E1] Nottale L Da Rocha D. Gravitational Structure Formation in Scale Relativity, 2003. Available at: https://arxiv.org/abs/astro-ph/0310036.

[E2] Freeman PE et al. Examining the Effect of the Map-making Algorithm on Observed Power Asymmetry in WMAP Data. *Astrophys J*, 638, 2006. Available at: https://arxiv.org/abs/astro-ph/0510406.

[E3] Neugebauer M et al. The solar magnetic field and the solar wind: Existence of preferred longitudes. *J Geophys Res*, 105:2315–2324, 2000. Available at: https://spacephysics.jpl.nasa.gov/pr/longitude.htm.

[E4] Tajmar M et al. Experimental Detection of Gravimagnetic London Moment, 2006. Available at: https://arxiv.org/abs/gr-gc0603033. See also the popular article "Towards new tests of general relativity", at https://www.esa.int/SPECIALS/GSP/SEM0L6OVGJE_0.html.

[E5] Matos de CJ Tajmar M. Local Photon and Graviton Mass and Its Consequences, 2006. Available at: https://arxiv.org/abs/gr-gc0603032.

Physics of Earth

[F1] Sentman DD. *Schumann Resonances*, volume 1, pages 267–295. Boca Raton: CRC Press, 1995.

[F2] Hecht J. The Giant Crystal at the Heart of the Earth. *New Scientist*, page 17, 1994.

Fringe Physics

[H1] M. B. King. Free-energy devices. Available at: `https://www.free-energy-info.co.uk/MorayKing.pdf`.

[H2] Akimov et al. Predvaritelnyye rezultaty astronomicheskikh nabludenii po metodike N. A. Kozyreva. Preliminary results of astronomical observations using N. A. Kozyrev's method, 1992.

[H3] King MB. Water Electrolyzers and the Zero-Point Energy. *Phys Procedia*, 20:335–445, 2011. Available at: `https://www.sciencedirect.com/science/journal/18753892`.

[H4] Kozyrev NA. *Izbrannyye trudy*. Leningrad State University, 1991.

[H5] Sokolov AN Nachalov YuV. Experimental investigation of new long-range interactions, 1999. Available at: `https://www.amasci.com/freenrg/tors/doc17.html`.

[H6] Modanese G Podkletnov E. Investigation of high voltage discharges in low pressure gases through large ceramic super-conducting electrodes, 2002. Available at: `https://xxx.lanl.gov/abs/physics/0209051`.

[H7] Nieminen R Podkletnov E. Weak gravitational shielding properties of composite bulk YBa2Cu3O7-x super-conductor below 70 K under electro-magnetic field, 1992. Available at: `https://arxiv.org/abs/cond-mat/9701074`. Report MSU-chem 95, improved version at `https://arxiv.org/abs/cond-mat/9701074`.

[H8] Godin SM Roshchin VV. An Experimental Investigation of the Physical Effects in a Dynamic Magnetic System. *New Energy Technologies*, 1, 2001.

[H9] Flandern van T. *Phys Lett A*, 250(1-3):1–11.

[H10] Nachalov YuV. Theoretical basis of experimental phenomena, 1999. Available at: `https://www.amasci.com/freenrg/tors/tors3.html`.

Biology

[I1] Acetyl group. Available at: https://en.wikipedia.org/wiki/Acetyl_group.

[I2] Acetylation. Available at: https://en.wikipedia.org/wiki/Acetylation.

[I3] Brief introduction into WaveGenetics. Its scope and opporturnities. Available at: https://www.wavegenetics.jino-net.ru.

[I4] Chirality (chemistry). Available at: https://en.wikipedia.org/wiki/Chirality_(chemistry).

[I5] CpG-island. Available at: https://en.wikipedia.org/wiki/CpG-island.

[I6] Cytochrome P450. Available at: https://en.wikipedia.org/wiki/Cytochrome_P450.

[I7] Deacetylation. Available at: https://en.wikipedia.org/wiki/Deacetylation.

[I8] Demethylase. Available at: https://en.wikipedia.org/wiki/Demethylase.

[I9] Demethylation. Available at: https://en.wikipedia.org/wiki/Demethylation.

[I10] High energy phosphate. Available at: https://en.wikipedia.org/wiki/High-energy_phosphate.

[I11] Homeopathy. Available at: https://en.wikipedia.org/wiki/Homeopathy.

[I12] Housekeeping gene. Available at: https://en.wikipedia.org/wiki/Housekeeping_gene.

[I13] Methyl group. Available at: https://en.wikipedia.org/wiki/Methyl_group.

[I14] Methylation. Available at: https://en.wikipedia.org/wiki/Methylation.

[I15] Methyltransferase. Available at: https://en.wikipedia.org/wiki/Methyltransferase.

[I16] Pollack Laboratory- Biographical Sketch. Available at: https://faculty.washington.edu/ghp/cv/.

[I17] Protein folding. Available at: https://en.wikipedia.org/wiki/Protein_folding.

[I18] Quantum Mechanics Boosts Photosynthesis. Available at: https://physicsworld.com/cws/article/news/41632.

[I19] Sirtuin. Available at: https://en.wikipedia.org/wiki/Sirtuin.

[I20] The Fourth Phase of Water: Dr. Gerald Pollack at TEDxGuelphU, 2014. Available at: https://www.youtube.com/watch?v=i-T7tCMUDXU.

[I21] Balinsky A. *An Introduction to Embryology.* Saunders, London, 1965.

[I22] Kane AE and Sinclair DA. Epigenetic changes during aging and their reprogramming potential. *Crit Rev Biochem Mol Biol.*, 54(1):61–83, 2019. Available at: https://www.tandfonline.com/doi/abs/10.1080/10409238.2019.1570075.

[I23] Smith C. *Learning From Water , A Possible Quantum Computing Medium.* CHAOS, 2001.

[I24] Testa U Castelli G, Pelosi E. Targeting histone methyltransferase and demethylase in acute myeloid leukemia therapy. *Onco Targets Ther*, 11:131–155, 2018. Available at: `https://doi.org/10.2147/OTT.S145971`.

[I25] Sinclair DA and Laplante MD. *Lifespan: Why we age - and we don't have to.* Thorsons, 2019.

[I26] Woodbury DJ. Pure lipid vesicles can induce channel-like conductances in planar bilayers., 1989.

[I27] Benveniste J et al. Transatlantic transfer of digitized antigen signal by telephone link. *J Allergy and Clinical Immunology*, 99:175, 1989. Available at: `https://www.digibio-.com/`.

[I28] Gariaev P et al. *The DNA-wave biocomputer*, volume 10. CHAOS, 2001.

[I29] Gariaev PP et al. The spectroscopy of bio-photons in non-local genetic regulation. *J Non-Locality and Remote Mental Interactions*, (3), 2002. Available at: `https://www.emergentmind.org/gariaevI3.htm`.

[I30] H Han et al. DNA methylation directly silences genes with non-CpG island promoters and establishes a nucleosome occupied promoter. *Hum Mol Genet*, 20(22):4299–4310, 2011. Available at: `https://pubmed.ncbi.nlm.nih.gov/21835883/`.

[I31] Johnson A et al. The Role of DNA Methylation in Aging, Rejuvenation, and Age-Related Disease. *Rejuvenation Res*, 15(5):483–494, 20129.Available at: `https://www.liebertpub.com/doi/abs/10.1089/rej.2012.1324`.

[I32] Lev AA et al. Rapid switching of ion current in narrow pores: implications for biological ion channels. *Proc R Soc London. Series B: Biological Sci s*, pages 187–192, 1993.

[I33] Parbin S et al. Histone Deacetylases: A Saga of Perturbed Acetylation Homeostasis in Cancer. *J Histochem Cytochem*, 62(1):11–33, 2014. Available at: `https://doi.org/10.1369/0022155413506582`.

[I34] Popp F-A et al. Emission of Visible and Ultraviolet Radiation by Active Biological Systems. *Collective Phenomena*, 3, 1981.

[I35] Sen P et al. Epigenetic mechanisms regulating longevity and aging. *Cell*, 166(4):822–839, 2016. Available at:https://pubmed.ncbi.nlm.nih.gov/27518561/.

[I36] Albrecht-Buehler G. Surface extensions of 3T3 cells towards distant infrared sources. *J Cell Biology*, 114:493–502, 1991.

[I37] Albrecht-Buehler G. Changes of cell behavior by near-infrared signals. *Cell Motility and the Cytoskeleton*, 32:43–50, 1995.

[I38] Albrecht-Buehler G. Reversible excitation light-induced enhancement of fluorescence of live mammalian mitochondria. *FASEB J* . Available at: `https://www.basic.northwestern.edu/g-buehler/relief.htm`, 2000.

[I39] Pollack G. *Cells, Gels and the Engines of Life.* Ebner and Sons, 2000. Available at: `https://www.cellsandgels.com/`.

[I40] Pollack G. *Cells, Gels and the Engines of Life.* Ebner and Sons, 2000. Available at: `https://www.cellsandgels.com/`.

[I41] Tovmash AV Gariaev PP, Tertishni GG. Experimental investigation in vitro of holographic mapping and holographic transposition of DNA in conjuction with the information pool encircling DNA. *New Medical Technologies*, 9:42–53, 2007.

[I42] Ling GN. *A physical theory of the living state: the association-induction hypothesis; with considerations of the mechanics involved in ionic specificity.* Blaisdell Pub. Co., New York, 1962.

[I43] Turberfield J A Green SJ, Lubrich D. DNA Hairpins: Fuel for Autonomous DNA Devices. *Biophys J*, 2006. Available at: https://findarticles.com/p/articles/mi_qa3938/is_200610/ai_n16779588/pg_1.

[I44] Fröhlich H. The extraordinary dielectric properties of biological materials and the action of enzymes. *Nature*, 72(1968):641–649, 1975.

[I45] Saunders PT Ho M-W. *Liquid Crystalline Mesophase in living organisms*. World Scientific, Singapore, 1994.

[I46] Slavinski J. Biophotons from stressed and dying organisms: toxicological aspects. *Indian J Exp Biol*, 41(5):483–493, 2003.

[I47] Wright J and Schneider BL. Cell size control is sirtuin(ly) exciting. *Mol Syst Biol*, 9(706), 2013.

[I48] Fiaxat JD. A hypothesis on the rhythm of becoming. *World Futures*, 36:31–36, 1993.

[I49] Fiaxat JD. The hidden rhythm of evolution, 2014. Available at: https://byebyedarwin.blogspot.fi/p/english-version_01.html.

[I50] Gull K Lange BHH. Structure and function of the centriole in animal cells: Progress and questions. *Cell*, 6, 1996.

[I51] Anderson M. Is Quantum mechanics controlling your thoughts? *Discover Magazine*, 2009. Available at: https://tinyurl.com/9nc2qx.

[I52] Levin M. The wisdom of the body: future techniques and approaches to morphogenetic fields in regenerative medicine, developmental biology and cancer. *Regen Med* . Available at: https://www.futuremedicine.com/doi/pdf/10.2217/rme.11.69, 6(6):667–673, 2011.

[I53] Levin M. Morphogenetic fields in embryogenesis, regeneration, and cancer: Non-local control of complex patterning. *Biosystems*, 109(3):243–261, 2012. Available at: https://www.ncbi.nlm.nih.gov/pubmed/22542702.

[I54] Bannister AJ Dawson MA Michalak EM, Burr ML. The roles of DNA, RNA and histone methylation in ageing and cancer. *Nat Rev Mol Cell Biol*, 20(10):573–589, 2019.Available at: https://doi.org/10.1038/s41580-019-0143-1.

[I55] Willcox BJ Morris BJ and Donlon TA. Genetic and epigenetic regulation of human aging and longevity. *Biochim Biophys Acta Mol Basis Dis.*, 1865(7):1718–1744, 2019. Available at: https://www.sciencedirect.com/science/article/pii/S0925443918303326.

[I56] Benford MS. Probable Axion Detection via Consistent Radiographic Findings after Exposure to a Shpilman Axion Generator. *J Theoretics*, 4, 1999.

[I57] Volkenstein MV. *Biophysics*. Mir Publishers, Moscow, 1983.

[I58] Ho MW. *The Rainbow and the Worm*. World Scientific, Singapore, 1993.

[I59] England J Perunov N, Marsland R. Statistical Physics of Adaptation, 2014. Available at: https://arxiv.org/pdf/1412.1875v1.pdf.

[I60] Zhao Q Pollack GH, Figueroa X. Molecules, water, and radiant energy: new clues for the origin of life. *Int J Mol Sci*, 10:1419–1429, 2009. Available at: https://tinyurl.com/ntkfhlc.

[I61] Callahan PS. Moth and Candle: the Candle Flame as a Sexual Mimic of the Coded Infrared Wavelengths from a Moth Sex Scent. *Appl Opt*, 16(12), 1977.

[I62] Dawkins R. *The Blind Watchmaker*. Penguin Books, 1986.

[I63] Kauffman S. Quantum Criticality at the Origin of Life, 2015. Available at: https://arxiv.org/pdf/1502.06880v2.pdf.

[I64] Qin F Sachs F. Gated, ion-selective channels observed with patch pipettes in the absence of membranes: novel properties of a gigaseal. *Biophys J*, pages 1101–1107, 1993.

[I65] Bejaoui Y Salameen Y and El Hajj N. DNA Methylation Biomarkers in Aging and Age-Related Diseases, 2020. Available at:https://doi.org/10.3389/fgene.2020.00171.

[I66] Tshitshinadze G Shaduri M. On the problem of application of Bioenergography in medicine. *Georgian Eng News*, 2, 1999.

[I67] Levin M Somrat T. An automated training paradigm reveals long-term memory in planarians and its persistence through head regeneration. *The J Experimental Biology*, 216:3799–3810, 2013. Available at: https://tinyurl.com/ntlxpep.

[I68] Creighton TE. *Proteins: Structures and Molecular Properties*. Freeman, New York, 1993.

[I69] Poponin V. DNA PHANTOM EFFECT: Direct Measurement of a New Field in the Vacuum Substructure, 1996. Available at: https://www.webcom/~hrtmath/IHM/ResearchPapers/DNAPhantom/DNAPhantom.html.

[I70] Smirnov IV Vysotskii VI, Kornilova AA. *Applied Biophysics of Activated Water* . Word Scientific. Available at: https://tinyurl.com/p8mb97n., 2009.

[I71] Xie L Wang Y, Yuan Q. Histone Modifications in Aging: The Underlying Mechanisms and Implications. *Curr Stem Cell Res Ther*, 13(2), 2018. Available at: https://doi.org/10.2174/1574888X12666170817141921.

[I72] Li Y and Heroux P. *Electromagnetic Biology ad Mecicine*, 33(4), 2014. Available at: https://tinyurl.com/y9lv47qp.

[I73] Merali Z. Water gave live on Earth a guiding hand. *New Scientist*, (2540), 2006.

[I74] Pollack GH Zheng J-M. Long-range forces extending from polymer-gel surfaces. *Phys Rev E*, 68:031408–, 2003. Available at: https://tinyurl.com/ntkfhlc.

Neuroscience and Consciousness

[J1] Available at: https://www.hia.com/pcr. See also https://listserv.arizona.edu/lsv/www/quantum-mind.html.

[J2] Visual short term memory. Available at: https://en.wikipedia.org/wiki/Visual_short-term_memory.

[J3] A Secret Sense in The Human Nose? Available at: https://www.hhmi.org/senses/.

[J4] Action potential. Available at: https://en.wikipedia.org/wiki/Action_potential.

[J5] AMPA receptor. Available at: https://en.wikipedia.org/wiki/AMPA_receptor.

[J6] Brain . Available at: https://en.wikipedia.org/wiki/Brain.

[J7] Breaking the Code of Color. Available at: https://www.hhmi.org/senses/b/b120.htm.

[J8] Bulerias. Available at: https://en.wikipedia.org/wiki/Bulerias.

[J9] CaMKII. Available at: https://en.wikipedia.org/wiki/CaMKII.

[J10] Chemical synapse. Available at: https://en.wikipedia.org/wiki/Chemical_synapse.

[J11] Color vision. Available at: https://en.wikipedia.org/wiki/Color_vision.

[J12] Frontal lobes. Available at: https://en.wikipedia.org/wiki/Frontal_lobes.

[J13] Hebbian theory. Available at: https://en.wikipedia.org/wiki/Hebbian_theory.

[J14] Hippocampus . Available at: https://en.wikipedia.org/wiki/Hippocampus.

[J15] In a First, Experiment Links Brain s of Two Rats. New York Times, Available at: https://tinyurl.com/c2azg67.

[J16] In a First, Experiment Links Brains of Two Rats. Science News. Available at: https://www.sciencedaily.com/releases/2013/02/130227183311.htm.

[J17] Limbic system. Available at: https://en.wikipedia.org/wiki/Limbic_system.

[J18] Long term depression. Available at: https://en.wikipedia.org/wiki/Long-term_depression.

[J19] Long term potentiation. Available at: https://en.wikipedia.org/wiki/Long-term_potentiation.

[J20] Microtubules. Available at: https://en.wikipedia.org/wiki/Microtubules.

[J21] Near-death experience. Available at: https://en.wikipedia.org/wiki/Near-death_experience.

[J22] Photoreceptor cell. Available at: https://en.wikipedia.org/wiki/Photoreceptor_cell.

[J23] Pythagorean tuning. Available at: https://en.wikipedia.org/wiki/Pythagorean_tuning.

[J24] Retinal Transduction: Hyperpolarization of Primary Photoreceptors by Ligh. Available at: https://www.acbrown.com/neuro/Lectures/NrVisn/NrVisnRtnlHprp.htm.

[J25] Short term memory. Available at: https://en.wikipedia.org/wiki/Short_term_memory.

[J26] Split-brain. Available at: https://en.wikipedia.org/wiki/Split-brain.

[J27] Synaptic plasticity. Available at: https://en.wikipedia.org/wiki/Synaptic_plasticity.

[J28] Synaptic Plasticity. Available at: https://en.wikipedia.org/wiki/Synaptic_plasticity.

[J29] Synaptic transmission. Available at: https://en.wikipedia.org/wiki/Synaptic_transmission.

[J30] The Plants Respond: An Interview with Cleve Backster. Available at: https://www.derrickjensen.org/backster.html. Published in "The Sun" July 1997 and in "Free Spirit".

[J31] Vibration theory of olfaction. Available at: https://en.wikipedia.org/wiki/Vibration_theory_of_olfaction.

[J32] The zombie within. *New Scientist*, 159(2150), 1998.

[J33] How the mind senses the movement. *New Scientist*, 2537, 2006. Available at: https://www.newscientist.com/channel/being-human/mg18925375.000.html.

[J34] Neuroscience of free will, 2018. Available at: https://en.wikipedia.org/wiki/Neuroscience_of_free_will.

[J35] Damasio A. *The Feeling of What Happens*. Sane Töregard Agency, 1999.

[J36] Revonsuo A. Is synchronization the direct neural correlate of visual consciousness?, 1998. Available at: https://www.phil.vt.edu/ASSC/engel/revonsuo1.html.

[J37] Vannini A. Advanced Waves, Retrocausality, and Consciousness. 2007. textnormalAvailable at: https://www.scientificexploration.org/.

[J38] Botkin AL. The Induction of After-Dearth Communications Utilizing Eye-Movement Desensitization and Reprocessing: A New Discovery. *J Near-Death Studies*, (3):181, 2000.

[J39] Sackett AM Armor DA. Accuracy, error, and bias in predictions for real versus hypothetical events. *J Pers Soc Psychol*, 91(4):583–600, 2006.

[J40] Khrennikov AY. Classical and quantum mechanics on information spaces with applications to cognitive, psychological, social, and anomalous phenomena. *Found Phys*, 29:1065–2098, 1999.

[J41] Greyson B. Implications of near-death experiences for a postmaterialist psychology. *Psychology of Religion and Spirituality*, 2(1), 2010. Available at: https://doi.org/10.1037/a0018548.

[J42] Greyson B. *A Doctor Explores What Near-Death Experiences Reveal about Life and Beyond.* St. Martin's Publishing Group, 2021.

[J43] Haisch B. *The God Theory.* Weiser Books, 2006.

[J44] Libet B. Readiness potentials preceding unrestricted spontaneous and preplanned voluntary acts, 1982. Available at: https://tinyurl.com/jqp1. See also the article *Libet's Research on Timing of Conscious Intention to Act: A Commentary* of Stanley Klein at https://tinyurl.com/jqp1.

[J45] Selden G Becker RO. *The Body Electric: Electromagnetism and the Foundation of Life.* William Morrow & Company, Inc., New York, 1990.

[J46] Radin DI Bierman DJ. Anomalous Anticipatory Response on Randomized Future Conditions. *Percept & Mot Skills*, 84:689–690, 1997.

[J47] Radin DI Bierman J D. Anomalous unconscious emotional responses: Evidence for a reversal of the arrow of time, 1998. Available at: https://www-psy.uva.nl/resedu/pn/PUBS/BIERMAN/1998/tucson/tucson3.html.

[J48] Baars BJ. Understanding Subjectivity: Global Workspace Theory and the Resurrection of the Observing Self. *J Conscious Stud*, 3(3):211–16, 1996.

[J49] Levin M Blackinston DJ. Ectopic Eyes Outside the Head in Xenopus Tadpoles Provide Sensory Data For Light-Mediated Learning. *J Exp Biol*, 216((6)):1031–1040, 2013. Available at: https://jeb.biologists.org/content/216/6/1031.abstract.

[J50] Blackman CF Blanchard JP. A model of magnetic field effects on biological system with conforming data from a cell culture preparation. *On the Nature of Electromagnetic Field Interactions with Biological Systems*, 1994.

[J51] Diequez S Blanke O, Faivre O. Leaving Body and Life Behind: Out-of-Body and Near-Death Experience. In book "The Neurology of Consciousness" (Eds: Laureys S, a Gosseries O and Tononi G. , 2015. Available at: https://cutt.ly/hk5kguk.

[J52] Tuszynski JA Bokkon I, Mallick BN. Near death experiences: a multidisciplinary hypothesis. *Front. Hum. Neurosci*, 2013. Available at: https://doi.org/10.3389/fnhum.2013.00533.

[J53] Backster C. Evidence of a Primary Perception in Plant Life. *Int J Parapsych*, 10(4):329–348, 1968.

[J54] French C. Near-death experiences in cardiac arrest survivors. The Boundaries of Consciousness: Neurobiology and Neuropathology. *Progress in Brain Research*, 150:351–367, 2005 Available at: https://doi.org/10.1016/S0079-6123(05)50025-6.

[J55] Pert CB. *Molecules of Emotion.* Simon & Schuster Inc., 1997.

[J56] Hiew CC. Hemi-Synch into creativity. *Hemi-Synch J*, (1):3–5, 1995.

[J57] Blackman CF. *Effect of Electrical and Magnetic Fields on the Nervous System*, pages 331–355. Plenum, New York, 1994.

[J58] Vanderwolf CH. Hippocampal electrical activity and voluntary movement in the rat. *Electroenceph & Clin Neurophysiol*, 26:407–18, 1969.

[J59] Chalmers D. *The conscious mind: in search of a fundamental theory.* Oxford University Press, New York, 1996.

[J60] Dennett D. *Quining the Qualia.* MIT Press, Oxford, 1988. Available at: `https://ase.tufts.edu/cogstud/papers/quinqual.htm`.

[J61] Eagleman D, 2011. Available at: `https://tinyurl.com/p9pvefz`. Talk about the neuroscientist's view about time in fQXI conference "Setting time aright: investigating the nature of time. Bergen-Copehagen. 27.8.1.1, 2011".

[J62] Pouzzner D. The symphonic architecture of mind: the circulating wavetrain of consciousness., 1999. Available at: `https://www-douzzer.ai.mit.edu:8080/wavetrain.html`.

[J63] Pouzzner D. The symphonic architecture of mind: the circulating wavetrain of consciousness, 1999. Available at: `https://www-douzzer.ai.mit.edu:8080/wavetrain.html`.

[J64] Yarrow D. Spin the tale of the dragon, 1990. Available at: `https://www.ratical.org/reatvlle/RofD2.html`.

[J65] Treffert DA. The idiot savant: a review of the syndrome. *Am J Psychiatry*, 145(5):563–572, 1988. Available at:`https://psycnet.apa.org/record/1988-26936-001`.

[J66] DelaWarr G Day L. *New Worlds Beyond the Atom.* Vincent Stuart Publishers Ltd., London, 1956.

[J67] Radin DI. Unconscious perception of future emotions: An experiment in presentiment. *J Sci Expl*, 11(2), 1997.

[J68] Benor DJ. *Spiritual Healing: scientific validation of a healing revolution Vol. I.* Vision publications, Southfield MI, 2001.

[J69] Nanopoulos DV. Theory of Brain function, Quantum Mechanics, and Superstrings, 1995. Available at: `https://arxiv.org/abs/hep-ph/9505374`.

[J70] Ackerman E. *Biophysical Science.* Prentice Hall, 1962. Available at: `https://en.wikipedia.org/wiki/Electroencephalography`.

[J71] Alexander E. *Proof of Heaven: A Neurosurgeon's Journey into the Afterlife.* Simon and Schuster, 2012.

[J72] Laszlo E. Psi, Grof, Jung and the Quantum Vacuum, 1996. Available at: `https://godel.psy.uwa.edu.au/dynapsych/1996/subtle.html`.

[J73] Baconnier S et al. Calcite microcrystals in the pineal gland of the human brain: first physical and chemical studies. *Bioelectromagnetics*, 23(7):488–495, 2002. Available at: `https://onlinelibrary.wiley.com/doi/abs/10.1002/bem.10053`.

[J74] Blackman CF et al. Multiple power density windows and their possible origin. *Bioelectromagn*, 10(2):115–128, 1989.

[J75] Borjigin J et al. Surge of neurophysiological coherence and connectivity in the dying brain. *PNAS*, 110(35):14432–14437, 2013. Available at: `https://doi.org/10.1073/pnas.1308285110`.

[J76] Cacciola A et al. Coalescent embedding in the hyperbolic space unsupervisedly discloses the hidden geometry of the brain, 2017. Available at:https://arxiv.org/pdf/1705.04192.pdf.

[J77] Cheron G et al. Inactivation of Calcium-Binding Pr ein Genes Induces 160 Hz Oscillations in the Cerebellar Cortex of Alert Mice. *J Neurosci*, 2004:434–441, 2004.Available at: https://www.jneurosci.org/cgi/content/full/24/2/434.

[J78] Dean JG et al. Biosynthesis and Extracellular Concentrations of N,N-dimethyltryptamine (DMT) in Mammalian Brain. *Scientific Reports*, 9(1), 2019.Available at: https://www.nature.com/articles/s41598-019-45812-w.

[J79] Fingelkurts A et al. Consciousness as a phenomenon in the operational architectonics of brain organization: Critality and self-organization considerations. *Chaos, Solitons & Fractals*, 2013. Available at: https://dx.doi.org/10.1016/locate/j.chaos.2013.02.007.

[J80] Giuditta A et al. The sequential hypothesis of the function of sleep. *Behavioural Brain Res*, 69, 1995.

[J81] Grinberg-Zylverbaum J et al. Human communication and the electrophysiological activity of the brain. *Subtle Energies*, 3.

[J82] Hodgkin AK et al. The ionic selectivity and calcium dependence of the light sensitive pathay in toad rods. *J Physiol*, 358:447–468, 1985.

[J83] Hunter JP et al. The effect of tactile and visual sensory inputs on phantom limb awareness. *Brain*, 126(3), 2003.

[J84] Jibu M et al. Quantum optical coherence in cytosceletal microtubules: implications for brain function. *Biosystems*, 32, 1994.

[J85] Kiviniemi V et al. Comparison of methods for determining non-deterministic BOLD fluctuation in fMRI. *Magn Reson Imaging*, 22, 2004.

[J86] Kosslyn SM et al. Hypnotic Visual Illusion Alters Color Processing in the Brain . *Am J Psychiatry*, 157:1279–1284, 2000.

[J87] Libet B et al. Subjective referral of the timing for a conscious sensory experience. *Brain*, 102, 1979.

[J88] Lindenberger U et al. Brains swinging in concert: cortical phase synchronization while playing guitar. *BMC Neurosci*, 10:22, 2009. Available at: https://tinyurl.com/oxyptn3.

[J89] Martial C et al. Temporality of Features in Near-Death Experience Narratives. *Front Hum Neurosci*, 11(311), 2017. Available at: https://cutt.ly/Yk5b2YC.

[J90] Pais-Vieira M et al. A Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information. *Sci Rep*, 3(1319), 2013. Available at: https://jeb.biologists.org/content/216/6/1031.abstract.

[J91] Paqueron X et al. The phenomenology of body image distortions induced by regional anaesthesia. *Brain*, 126(3), 2003.

[J92] Spaak E et al. Layer-specific entrainment of gamma-band neural activity by the alpha rhythm in monkey visual cortex. *Curr Biol*, 22(24):2313–2318, 2012. Available at: https://doi.org/10.1073/pnas.1308285110.

[J93] Strassman R et al. *Inner paths to Outer Space.* Available at: https://www.amazon.com/Inner-Paths-Outer-Space-Psychedelics/dp/159477224X. Park Street Press, Rochester Vermont, 2008.

[J94] Turin L et al. Molecular vibration-sensing component in Drosophila melanogaster olfaction. *PNAS*, 2011. Available at: https://www.pnas.org/content/108/9/3797.

[J95] Tyszka JM et al. Intact Bilateral Resting-State Networks in the Absence of the Corpus Callosum. *The Journal of Neuroscience*, 2011. Available at:https://tinyurl.com/3gjhtgb.

[J96] Ernould F. The perfect pitch, 2003. Available at: https://www.macmusic.org/articles/view.php/lang/EN/id/10/.

[J97] Shapiro F. *Eye moment densensitization and reprocessing: Principles, processes and procedures*. Guilford, New York, 1995.

[J98] Raichle ME Fox MD. Spontaneous fluctuations in brain activity observed with functional magnetic resonance imaging. *Nature Reviews/Neuroscience*, 8:700, 2007. Available at: https://www.nature.com/reviews/neuro.

[J99] Lichtfield G. The Science of Near-Death Experiences: Empirically investigating brushes with the afterlife, 2018. Available at: https://cutt.ly/fk5nt5Q.

[J100] Collins GP. Magnetic revelations: Functional MRI Highlights Neuron s Receiving Signals. *Sci Am*, 21, 2001.

[J101] Hameroff S Graddock T, Tuszynksi A. Cytoskeletal Signaling: Is Memory Encoded in Microtubule Lattices by CaMKII Phosphorylation? *PLoS Comput Biol*, 8(3), 2012. Available at: https://www.ploscompbiol.org/article/info:doi/10.1371/journal.pcbi.1002421.

[J102] Phillips H. Perchange to learn. *New Scientist*, 163:2205, 1999.

[J103] Stapp H. Theoretical model of a purported empirical violation of the predictions of quantum theory. *Phys*, 1994.

[J104] Geissler H-G. Is there a way from behavior to non-linear brain dynamics? On quantal periods in cognition and the place of alpha in brain resonances. *Int J Psychophysiol*, 26, 1997.

[J105] James D (Eds) Holden JM, Greyson B. *The Handbook of Near-Death Experiences: Thirty Years of Investigation*. 2009. Available at: https://med.virginia.edu/perceptual-studies/book/the-handbook-of-near-death-experiences-thirty-years-of-investigation/.

[J106] Wu M Hu H. Thinking outside the box: the essence and implications of quantum entanglement. *NeuroQuantology*, 5:5–16, 2006.

[J107] Bolz J Hubener M. Relationships between dendritic morphology and cytochrome oxidase compartments in monkey striate cortex. *J Comp Neurol*, 324(1):67–80, 1992.

[J108] Barbour J. *The End of Time; The Next Revolution in Physics*. Weidenfeld & Nicholson, 1999.

[J109] Hawkins J. *On Intelligence*. St. Martin's Griffin, New York, 2004.

[J110] Henkel J. How life learns: an epistemological basis for consciousness, 1998. Available at: https://www.tiac.net/users/knowweb/liflern2.htm.

[J111] Jaynes J. *The origin of consciousness in the breakdown of the bicameral mind*. Princeton University Press, 1982.

[J112] McCrone J. Left Brain , Right Brain , 1999. Available at: https://www.rense.com/general2/rb.html.

[J113] McMoneagle J. *Remote Viewing Secrets*. Hampton Roads Publishing Company, Inc., 2000.

[J114] Spottiswoode J. Geomagnetic fluctuations and free response anomalous cognition: a new understanding. *J Parapsychol*, 2002. Available at: https://www.jsasoc.com/docs/JP-GMF.pdf.

[J115] Zhen J and Meister M. The unbearable slowness of being: Why do we live at 10 bits/s? *Neuron*, 2024.Available at: https://www.cell.com/neuron/abstract/S0896-6273(24)00808-0. .

[J116] Miller JP. Brain Waves Deciphered. *Nature*, 1996. Article about the work of Wehr and Laurent.

[J117] Miller JP. Brain Waves Deciphered. *Nature*, 384:6605, 1996. Article about the work of Wehr and Laurent.

[J118] Dunne JW. *An experiment with time*. Hampton Roads Publishing Company, Inc., 2001. First published in 1927.

[J119] Jessel TM Kandel ER, Schwartz JH. *Principles of neural science*. Prentice-Hall International Inc., 1991.

[J120] Leibovic KN. *Sci of Vision*. Springer Verlag, New York, 1990.

[J121] Fantappie L. *Teoria Unitaria del Mondo Fisico e Biologico*. Di Renzo Editore, Roma, 1942.

[J122] Osborne L. Savant for a Day, 2003. Available at: https://www.nytimes.com/2003/06/22/magazine/22SAVANT.html.

[J123] Turin L. A spectroscopic mechanism for primary olfactory perception. *Chem Senses*, pages 773–791, 1996. Available at: https://www.flexitral.com/research/chemical_senses_complete.pdf.

[J124] Turin L. *The Secret of Scent: Adventures in Perfume and the Sci of Smell*. Ecco Available at: https://en.wikipedia.org/wiki/Luca_Turin, New York, 2006.

[J125] Jaffe LF. Calcium Waves, 2001. Available at: https://waves.mbl.edu/calcium.waves.html.

[J126] Linde-Domingo and Wimber et al. Evidence that neural information flow is reversed between object perception and object reconstruction from memory. *Nature Communications*, 10(179), 2019. Available at:https://www.nature.com/articles/s41467-018-08080-2.

[J127] Squire LR. Memory and the Hippocampus : A Synthesis From Findings With Rats, Monkeys, and Humans. *Psychol Rev*, 99(2):195–231, 1992.

[J128] Fordahl M. Scientists trigger neuron regeneration in mouse brain, 2000. Available at: https://www.nandotimes.com.

[J129] Germine M. Experimental verification of Stapp's theory', 2000. Available at: https://listserv.arizona.edu/lsv/www/quantum-mind.html.

[J130] Persinger M. *Neuropsychological Bases of God Beliefs*. Praeger Publishers, 1987.

[J131] Persinger M. On the possibility of directly accessing every human brain by electromagnetic induction of fundamental algorithms. *Percept Mot Skills*, 80(3):791–799, 1995.

[J132] Persinger M. The tectonic strain theory as an explanation for UFO phenomena, 1999. Available at: https://www.laurentian.ca/www/neurosci/tectonicedit.htm.

[J133] Persinger M. The tectonic strain theory as an explanation for UFO phenomena, 1999. Available at: https://www.laurentian.ca/www/neurosci/tectonicedit.htm.

[J134] Tegmark M. The importance of quantum de-coherence in brain processes, 1999. Available at: https://arxiv.org/abs/quant-ph/9907009.

[J135] James CL May EC, Spottiswoode SJP. Shannon entropy as an intrinsic target property: towards a reductionistic model of anomalous cognition, 1994. Available at: https://www.jsasoc.com/docs/entropy.pdf.

[J136] Neal MC. *To Heaven and Back: A Doctor's Extraordinary Account of Her Death, Heaven, Angels, and Life Again: a True Story*. WaterBrook, 2012.

[J137] Daneman M Mericle PM. Memory for unconsciously perceived events: evidence for anesthetized patients. *Conscious & Cognition*, 5:525, 1996.

[J138] Fisher MPA. Quantum Cognition: The possibility of processing with nuclear spins in the brain), 2015. Available at: `https://arxiv.org/abs/1508.05929`.

[J139] Cherry N. Conference report on effects of ELF fields on brain, 2000. Available at: `https://www.tassie.net.au/emfacts/icnirp.txt`.

[J140] Reissman SS Nevandee DA. Measurement of the electroencephalogram (EEG) coherence in group meditation. 1996.

[J141] Sacks O. *The man who mistook his wife for a hat*. 1998. Available at: First edition 1985.

[J142] Sacks O. *Musicophilia*. Picador, 2011.

[J143] Tononi G Oizumi M, Albantakis L. *PLOS. Computational Biology*, 2014.Available at:`https://tinyurl.com/z9s4k7n`.

[J144] Noe A O'Regan JK. A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences.*, 2000. Available at: `https://nivea.psycho.univ-paris5.fr`.

[J145] Ball P. Flies can smell the difference between normal hydrogen and deuterium. *Nature News*, 2011.Available at: `https://tinyurl.com/6equps5`.

[J146] Pietch P. Shuffle Brain: the The Quest for Hologramic Mind, 1972. Available at: `https://www.indiana.edu/~pietsch/shufflebrain-book00.html`.

[J147] Van Lommel P. *Consciousness Beyond Life: The Science of the Near-Death Experience*. Harper Collins. New York, 2010.

[J148] Lavallee F C Persinger MA. Theoretical and Experimental Evidence of Macroscopic Entanglement between Human Brain Activity and Photon Emissions: Implications for Quantum Consciousness and Future Applications. *J Consc Expl & Res*, 1(7):785–807, 2010.

[J149] Nunez PL. Toward a Quantitative Description of Large Scale Neocortical Dynamic Function and EEG. *Behav & Brain Sci*, 23, 2000.

[J150] Goldman-Rakic PS. The "psychic" neuron of the cerebral cortex. *Ann N Y Acad Sci*, 868:13–26.

[J151] Cytowich R. *Psyche*, 2(10), 1995. Available at: `https://psyche.cs.monash.edu.au/v2/psyche-2-10-cytowic.html`.

[J152] Moody R. *Life After Life*. Covinda, Gal: Mockingbird, 1975.

[J153] Moody R. *Life After Life*. Mockingbird Books, 1975.

[J154] Penrose R. *The Emperor's New Mind*. Oxford University Press, Oxford, 1989.

[J155] Peoch R. Chicken-robot interaction. *Medical Network.*, 62, 1995. Available at: `https://paranormal.se/psi/pk/djur.html`.

[J156] Schuerger R. Alien abductions, seismic activity, and the brain em- are they related? *NeuroSci*, 1999. Available at: `https://neuroscience.miningco.com/health/neuroscience/library/weekly/aa122898.htm`.

[J157] Strassman R. *The Spirit Molecule: A Doctor's Revolutionary Research into the Biology of Near-Death and Mystical Experiences*. Simon and Schuster, 2000. Available at: `https://books.google.fi/books/about/DMT_The_Spirit_Molecule.html`.

[J158] Becker RO. *Cross Currents*. Penguin Putnam Inc., New York, 1990.

[J159] Blackmore S. *Beyond the Body*. Granada, London, 1983.

[J160] Blackmore S. Near death experiences: in or out of the body? *Skeptical Inquirer*, 1991:34–45, 1991. Available at: https://www.uwe.ac.uk/fas/staff/sb/si91nde.html.

[J161] Blackmore S. *Dying to Live: Science and the Near-death Experience*. London: Grafton, 1993.

[J162] Blackmore S. *The Meme Machine*. Oxford University Press, Oxford, 1999.

[J163] Grof S. *The Adventure of Self-discovery*. State University of New York Press, Albany, 1988.

[J164] Klein S. Libet's Research on Timing of Conscious Intention to Act: A Commentary. *Consc & Cogn*, 11, 2002. Available at: https://tinyurl.com/jqp1.

[J165] Parnia S. *What happens when we die : a groundbreaking study into the nature of life and death*. Hayhouse, 2007.Available at: https://archive.org/details/whathappenswhenw00samp.

[J166] Parnia S. Death and consciousness–an overview of the mental and cognitive experience of death. *Annals of the New York Academy of Sciences*, 1330:75–93, 2014. Available at: https://doi.org/10.1111/nyas.12582. .

[J167] Parnia S and Young J. *The Lazarus effect : the science that is rewriting the boundaries between life and death*. St. Martin's Publishing Group, 2013. https://archive.org/details/lazaruseffectsci0000parn.

[J168] Pinker S. *How the Mind Works*. W. W. Norton & Company, Inc., New York, 1997.

[J169] Palmer SE. Color, Consciousness, and the Isomorphism Constraint. *Behav & Brain Sci*, 22(6), 1999.

[J170] Puthoff H Targ R. Information transmission under conditions of sensory shielding. *Nature*, 251, 1974.

[J171] Corpo Di U. The conflict between entropy and syntropy: the vital needs model. 2007. Available at: https://www.scientificexploration.org/.

[J172] Fidelman U. Cerebral asymmetry implies that a total theory of the universe amd of the mind is impossible. *Science*, 2002.

[J173] Krippner S Ullman M. Dream Studies and Telepathy: An Experimental Approach, 1970. New York: Parapsychology Foundation.

[J174] Eastman KE Vertes RP. The case against memory consolidation in REM sleep. *Behav & Brain Sci*, 23(6).

[J175] Frisch von K. *The Dance Language and Orientation of Bees*. Harward University Press, 1967.

[J176] Guzman-Karlsson MC Zovkic IB and Sweatt JD. Epigenetic regulation of memory formation and maintenance. *Learn Mem*, 20(2):61–74, 2013. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3549063/.

Books related to TGD

[K1] Pitkänen M. *Topological Geometrodynamics*. 1983. Thesis in Helsinki University 1983.

[K2] Pitkänen M. *Life and Consciousness: TGD based vision.* Lambert. Available at: https://tinyurl.com/zn98vka., 2014.

[K3] Pitkänen M. DNA as Topological Quantum Computer. In *Quantum - and Classical Computation in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdcomp.html*. Available at: https://tgdtheory.fi/pdfpool/dnatqc.pdf, 2015.

[K4] Pitkänen M. Topological Quantum Computation in TGD Universe. In *Quantum - and Classical Computation in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdcomp.html*. Available at: https://tgdtheory.fi/pdfpool/tqc.pdf, 2015.

[K5] Pitkänen M. *Topological Geometrodynamics: Revised Edition.* Bentham.Available at: https://tinyurl.com/h26hqul., 2016.

[K6] Pitkänen M. Philosophy of Adelic Physics. In *TGD as a Generalized Number Theory: Part I. https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/adelephysics.pdf, 2017.

[K7] Pitkänen M. Some comments related to Zero Energy Ontology (ZEO). In *TGD and Nuclear Physics. https://tgdtheory.fi/tgdhtml/Bnucl.html*. Available at: https://tgdtheory.fi/pdfpool/zeoquestions.pdf, 2019.

[K8] Pitkänen M. A Model for Protein Folding and Bio-catalysis. In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/foldcat.pdf, 2023.

[K9] Pitkänen M. About Absolute Galois Group. In *TGD as a Generalized Number Theory: Part III. https://tgdtheory.fi/tgdhtml/Btgdnumber3.html*. Available at: https://tgdtheory.fi/pdfpool/agg.pdf, 2023.

[K10] Pitkänen M. About Nature of Time. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/timenature.pdf, 2023.

[K11] Pitkänen M. About Preferred Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/prext.pdf, 2023.

[K12] Pitkänen M. About the New Physics Behind Qualia. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/newphys.pdf, 2023.

[K13] Pitkänen M. About twistor lift of TGD? In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/hgrtwistor.pdf, 2023.

[K14] Pitkänen M. Anomalies Related to the Classical Z^0 Force and Gravitation. In *TGD and Fringe Physics. https://tgdtheory.fi/tgdhtml/Bfreenergies.html*. Available at: https://tgdtheory.fi/pdfpool/Zanom.pdf, 2023.

[K15] Pitkänen M. Are dark photons behind biophotons? In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/biophotonslian.pdf, 2023.

[K16] Pitkänen M. Basic Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/class.pdf, 2023.

[K17] Pitkänen M. Basic Properties of CP_2 and Elementary Facts about p-Adic Numbers. In *Quantum TGD: Part I. https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://www.tgdtheory.fi/public_html/pdfpool/append.pdf, 2023.

[K18] Pitkänen M. *Bio-Systems as Conscious Holograms*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/holography.html., 2023.

[K19] Pitkänen M. Bio-Systems as Conscious Holograms. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/hologram.pdf, 2023.

[K20] Pitkänen M. *Bio-Systems as Self-Organizing Quantum Systems*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/bioselforg.html., 2023.

[K21] Pitkänen M. Bio-Systems as Super-Conductors: Part I. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/superc1.pdf, 2023.

[K22] Pitkänen M. Bio-Systems as Super-Conductors: part II. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/superc2.pdf, 2023.

[K23] Pitkänen M. Biological Realization of Self Hierarchy. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/bioselfc.pdf, 2023.

[K24] Pitkänen M. Classical TGD. In *Topological Geometrodynamics: Overview: Part I:https://tgdtheory.fi/tgdhtml/Btgdview1.html*. Available at: https://tgdtheory.fi/pdfpool/tgdclass.pdf, 2023.

[K25] Pitkänen M. Comments on the recent experiments by the group of Michael Persinger. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/persconsc.pdf, 2023.

[K26] Pitkänen M. Conscious Information and Intelligence. In *TGD Inspired Theory of Consciousness: Part II. https://tgdtheory.fi/tgdhtml/Btgdconsc2.html*. Available at: https://tgdtheory.fi/pdfpool/intsysc.pdf, 2023.

[K27] Pitkänen M. Construction of elementary particle vacuum functionals. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/elvafu.pdf, 2023.

[K28] Pitkänen M. Construction of Quantum Theory: M-matrix. In *Quantum TGD: Part I. https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://tgdtheory.fi/pdfpool/towards.pdf, 2023.

[K29] Pitkänen M. Construction of Quantum Theory: Symmetries. In *Quantum TGD: Part I. https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://tgdtheory.fi/pdfpool/quthe.pdf, 2023.

[K30] Pitkänen M. Construction of WCW Kähler Geometry from Symmetry Principles. In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/compl1.pdf, 2023.

[K31] Pitkänen M. Criticality and dark matter: part I. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark1.pdf, 2023.

[K32] Pitkänen M. Criticality and dark matter: part II. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark2.pdf, 2023.

[K33] Pitkänen M. Criticality and dark matter: part III. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark3.pdf, 2023.

[K34] Pitkänen M. Criticality and dark matter: part IV. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark4.pdf, 2023.

[K35] Pitkänen M. Dance of the honeybee and new physics. In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/Shipmanagain.pdf, 2023.

[K36] Pitkänen M. Dark Forces and Living Matter. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/darkforces.pdf, 2023.

[K37] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/eegdark.pdf, 2023.

[K38] Pitkänen M. Dark Nuclear Physics and Condensed Matter. In *TGD and Nuclear Physics. https://tgdtheory.fi/tgdhtml/Bnucl.html*. Available at: https://tgdtheory.fi/pdfpool/exonuclear.pdf, 2023.

[K39] Pitkänen M. Did Tesla Discover the Mechanism Changing the Arrow of Time? In *TGD and Fringe Physics. https://tgdtheory.fi/tgdhtml/Bfreenergies.html*. Available at: https://tgdtheory.fi/pdfpool/tesla.pdf, 2023.

[K40] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry?: Part I. In *TGD as a Generalized Number Theory: Part II. https://tgdtheory.fi/tgdhtml/Btgdnumber2.html*. Available at: https://tgdtheory.fi/pdfpool/ratpoints1, 2023.

[K41] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry?: Part I. In *TGD as a Generalized Number Theory: Part II. https://tgdtheory.fi/tgdhtml/Btgdnumber2.html*. Available at: https://tgdtheory.fi/pdfpool/ratpoints2, 2023.

[K42] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry?: Part III. In *TGD as a Generalized Number Theory: Part II. https://tgdtheory.fi/tgdhtml/Btgdnumber2.html*. Available at: https://tgdtheory.fi/pdfpool/ratpoints3, 2023.

[K43] Pitkänen M. Does Riemann Zeta Code for Generic Coupling Constant Evolution? In *TGD as a Generalized Number Theory: Part III. https://tgdtheory.fi/tgdhtml/Btgdnumber3.html*. Available at: https://tgdtheory.fi/pdfpool/fermizeta.pdf, 2023.

[K44] Pitkänen M. Does TGD Predict a Spectrum of Planck Constants? In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/Planck, 2023.

[K45] Pitkänen M. Evolution in Many-Sheeted Space-Time: Part I. In *Evolution in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdevolution.html*. Available at: https://tgdtheory.fi/pdfpool/prebio1.pdf, 2023.

[K46] Pitkänen M. Evolution in Many-Sheeted Space-Time: Part II. In *Evolution in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdevolution.html*. Available at: https://tgdtheory.fi/pdfpool/prebio2.pdf, 2023.

[K47] Pitkänen M. Evolution of Ideas about Hyper-finite Factors in TGD. In *Topological Geometrodynamics: Overview: Part II. https://tgdtheory.fi/tgdhtml/Btgdoverview2*. Available at: https://tgdtheory.fi/pdfpool/vNeumannnew, 2023.

[K48] Pitkänen M. From Principles to Diagrams. In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/diagrams.pdf, 2023.

[K49] Pitkänen M. Fusion of p-Adic and Real Variants of Quantum TGD to a More General Theory. In *TGD as a Generalized Number Theory: Part I. https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/mblocks.pdf, 2023.

[K50] Pitkänen M. General Theory of Qualia. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/qualia.pdf, 2023.

[K51] Pitkänen M. *Genes and Memes*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/genememe.html., 2023.

[K52] Pitkänen M. Genes and Memes. In *Genes and Memes: Part I. https://tgdtheory.fi/tgdhtml/Bgenememe1.html*. Available at: https://tgdtheory.fi/pdfpool/genememec.pdf, 2023.

[K53] Pitkänen M. Homeopathy in Many-Sheeted Space-Time. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/homeoc.pdf, 2023.

[K54] Pitkänen M. *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/neuplanck.html., 2023.

[K55] Pitkänen M. Identification of the WCW Kähler Function. In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/kahler.pdf., 2023.

[K56] Pitkänen M. Knots and TGD. In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/knotstgd.pdf, 2023.

[K57] Pitkänen M. Life and Death, and Consciousness. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/lifedeath.pdf, 2023.

[K58] Pitkänen M. Macro-Temporal Quantum Coherence and Spin Glass Degeneracy. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/macro.pdf, 2023.

[K59] Pitkänen M. Macroscopic Quantum Coherence and Quantum Metabolism as Different Sides of the Same Coin: Part I. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/metab.pdf, 2023.

[K60] Pitkänen M. Macroscopic Quantum Coherence and Quantum Metabolism as Different Sides of the Same Coin: Part II. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/molephoto.pdf, 2023.

[K61] Pitkänen M. Macroscopic Quantum Phenomena and CP_2 Geometry. In *TGD and Condensed Matter. https://tgdtheory.fi/tgdhtml/BTGDcondmat.html*. Available at: https://tgdtheory.fi/pdfpool/super.pdf, 2023.

[K62] Pitkänen M. Magnetic Sensory Canvas Hypothesis. In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/mec.pdf, 2023.

[K63] Pitkänen M. *Magnetospheric Consciousness*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/magnconsc.html., 2023.

[K64] Pitkänen M. Magnetospheric Sensory Representations. In *Magnetospheric Consciousness. https://tgdtheory.fi/tgdhtml/Bmagnconsc.html*. Available at: https://tgdtheory.fi/pdfpool/srepres.pdf, 2023.

[K65] Pitkänen M. Many-Sheeted DNA. In *Genes and Memes: Part I. https://tgdtheory.fi/tgdhtml/Bgenememe1.html*. Available at: https://tgdtheory.fi/pdfpool/genecodec.pdf, 2023.

[K66] Pitkänen M. Massless states and particle massivation. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/mless.pdf, 2023.

[K67] Pitkänen M. *Mathematical Aspects of Consciousness Theory*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/mathconsc.html, 2023.

[K68] Pitkänen M. Matter, Mind, Quantum. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/conscic.pdf, 2023.

[K69] Pitkänen M. Meditation, Mind-Body Medicine and Placebo: TGD point of view. In *TGD Inspired Theory of Consciousness: Part III. https://tgdtheory.fi/tgdhtml/Btgdconsc3.html*. Available at: https://tgdtheory.fi/pdfpool/panel.pdf, 2023.

[K70] Pitkänen M. More about TGD Inspired Cosmology. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/cosmomore.pdf, 2023.

[K71] Pitkänen M. More Precise TGD View about Quantum Biology and Prebiotic Evolution. In *Evolution in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdevolution.html*. Available at: https://tgdtheory.fi/pdfpool/geesink.pdf, 2023.

[K72] Pitkänen M. Motives and Infinite Primes. In *TGD as a Generalized Number Theory: Part III. https://tgdtheory.fi/tgdhtml/Btgdnumber3.html*. Available at: https://tgdtheory.fi/pdfpool/infmotives.pdf, 2023.

[K73] Pitkänen M. Negentropy Maximization Principle. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/nmpc.pdf, 2023.

[K74] Pitkänen M. New Physics Predicted by TGD: Part I. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/TGDnewphys1.pdf, 2023.

[K75] Pitkänen M. New Physics Predicted by TGD: Part II. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/TGDnewphys2.pdf, 2023.

[K76] Pitkänen M. Non-locality in quantum theory, in biology and neuroscience, and in remote mental interactions: TGD perspective. In *TGD Inspired Theory of Consciousness: Part III. https://tgdtheory.fi/tgdhtml/Btgdconsc3.html*. Available at: https://tgdtheory.fi/pdfpool/nonlocal.pdf, 2023.

[K77] Pitkänen M. Nuclear String Hypothesis. In *TGD and Nuclear Physics. https://tgdtheory.fi/tgdhtml/Bnucl.html*. Available at: https://tgdtheory.fi/pdfpool/nuclstring.pdf, 2023.

[K78] Pitkänen M. Number theoretic vision, Hyper-finite Factors and S-matrix. In *Quantum TGD: Part I. https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://tgdtheory.fi/pdfpool/UandM.pdf, 2023.

[K79] Pitkänen M. *p-Adic length Scale Hypothesis*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/padphys.html., 2023.

[K80] Pitkänen M. p-Adic Particle Massivation: Hadron Masses. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/mass3.pdf, 2023.

[K81] Pitkänen M. p-Adic Physics as Physics of Cognition and Intention. In *TGD Inspired Theory of Consciousness: Part II. https://tgdtheory.fi/tgdhtml/Btgdconsc2.html*. Available at: https://tgdtheory.fi/pdfpool/cognic.pdf, 2023.

[K82] Pitkänen M. p-Adic Physics: Physical Ideas. In *TGD as a Generalized Number Theory: Part I. https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/phblocks.pdf, 2023.

[K83] Pitkänen M. Physics as a Generalized Number Theory. In *Topological Geometrodynamics: Overview: Part I. https://tgdtheory.fi/tgdhtml/Btgdview1.html*. Available at: https://tgdtheory.fi/pdfpool/tgdnumber.pdf, 2023.

[K84] Pitkänen M. Quantum Adeles. In *TGD as a Generalized Number Theory: Part III. https://tgdtheory.fi/tgdhtml/Btgdnumber3.html*. Available at: https://tgdtheory.fi/pdfpool/galois.pdf, 2023.

[K85] Pitkänen M. Quantum Antenna Hypothesis. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/tubuc.pdf, 2023.

[K86] Pitkänen M. Quantum Arithmetics and the Relationship between Real and p-Adic Physics. In *TGD as a Generalized Number Theory: Part III. https://tgdtheory.fi/tgdhtml/Btgdnumber3.html*. Available at: https://tgdtheory.fi/pdfpool/qarithmetics.pdf, 2023.

[K87] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/qastro.pdf, 2023.

[K88] Pitkänen M. Quantum Control and Coordination in Bio-Systems. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/qcococII.pdf, 2023.

[K89] Pitkänen M. Quantum Control and Coordination in Bio-systems: Part I. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/qcococI.pdf, 2023.

[K90] Pitkänen M. Quantum gravity, dark matter, and prebiotic evolution. In *Evolution in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdevolution.html*. Available at: https://tgdtheory.fi/pdfpool/hgrprebio.pdf, 2023.

[K91] Pitkänen M. *Quantum Hardware of Living Matter*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/bioware.html., 2023.

[K92] Pitkänen M. Quantum Mind and Neuroscience. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/lianPN.pdf, 2023.

[K93] Pitkänen M. Quantum Mind, Magnetic Body, and Biological Body. In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/lianPB.pdf, 2023.

[K94] Pitkänen M. Quantum Model for Bio-Superconductivity: I. In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/biosupercondI.pdf, 2023.

[K95] Pitkänen M. Quantum Model for Bio-Superconductivity: II. In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/biosupercondII.pdf, 2023.

[K96] Pitkänen M. Quantum Model for Hearing. In *TGD and EEG: Part II. https://tgdtheory.fi/tgdhtml/Btgdeeg2.html*. Available at: https://tgdtheory.fi/pdfpool/hearing.pdf, 2023.

[K97] Pitkänen M. Quantum Model for Nerve Pulse. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/nervepulse.pdf, 2023.

[K98] Pitkänen M. Quantum Model for Paranormal Phenomena. In *TGD Inspired Theory of Consciousness: Part III. https://tgdtheory.fi/tgdhtml/Btgdconsc3.html*. Available at: https://tgdtheory.fi/pdfpool/parac.pdf, 2023.

[K99] Pitkänen M. Quantum Model for Sensory Representations. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/expc.pdf, 2023.

[K100] Pitkänen M. Quantum Model of EEG. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/eegII.pdf, 2023.

[K101] Pitkänen M. Quantum Model of Memory. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/memoryc.pdf, 2023.

[K102] Pitkänen M. *Quantum TGD*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/tgdquantum.html., 2023.

[K103] Pitkänen M. Quantum Theory of Self-Organization. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/selforgac.pdf, 2023.

[K104] Pitkänen M. Recent View about Kähler Geometry and Spin Structure of WCW . In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/wcwnew.pdf, 2023.

[K105] Pitkänen M. Self and Binding: Part I. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/selfbindc.pdf, 2023.

[K106] Pitkänen M. Self and Binding: Part II. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/selfbindcapp.pdf, 2023.

[K107] Pitkänen M. Semi-trance, Mental Illness, and Altered States of Consciousness. In *Magnetospheric Consciousness. https://tgdtheory.fi/tgdhtml/Bmagnconsc.html*. Available at: https://tgdtheory.fi/pdfpool/semitrancec.pdf, 2023.

[K108] Pitkänen M. Semitrance, Language, and Development of Civilization. In *Magnetospheric Consciousness. https://tgdtheory.fi/tgdhtml/Bmagnconsc.html*. Available at: https://tgdtheory.fi/pdfpool/langsoc.pdf, 2023.

[K109] Pitkänen M. Some questions related to the twistor lift of TGD. In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/twistquestions.pdf, 2023.

[K110] Pitkänen M. SUSY in TGD Universe. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/susychap.pdf, 2023.

[K111] Pitkänen M. Symmetries and Geometry of the "World of Classical Worlds". In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/wcwsymm.pdf, 2023.

[K112] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/astro.pdf, 2023.

[K113] Pitkänen M. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/cosmo.pdf, 2023.

[K114] Pitkänen M. *TGD and EEG*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/tgdeeg.html, 2023.

[K115] Pitkänen M. *TGD and Fringe Physics*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/freenergy.html., 2023.

[K116] Pitkänen M. TGD and M-Theory. In *Topological Geometrodynamics: Overview: Part I. https://tgdtheory.fi/tgdhtml/Btgdview1.html*. Available at: https://tgdtheory.fi/pdfpool/MTGD.pdf, 2023.

[K117] Pitkänen M. TGD and Potential Anomalies of GRT. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/granomalies.pdf., 2023.

[K118] Pitkänen M. TGD as a Generalized Number Theory: Infinite Primes. In *TGD as a Generalized Number Theory: Part I. https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/visionc.pdf, 2023.

[K119] Pitkänen M. TGD as a Generalized Number Theory: p-Adicization Program. In *Quantum Physics as Number Theory: Part I. https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/visiona.pdf, 2023.

[K120] Pitkänen M. TGD as a Generalized Number Theory: Quaternions, Octonions, and their Hyper Counterparts. In *TGD as a Generalized Number Theory: Part I. https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/visionb.pdf, 2023.

[K121] Pitkänen M. TGD Based Model for OBEs. In *TGD Inspired Theory of Consciousness: Part III. https://tgdtheory.fi/tgdhtml/Btgdconsc3.html*. Available at: https://tgdtheory.fi/pdfpool/OBE.pdf, 2023.

[K122] Pitkänen M. *TGD Based View About Living Matter and Remote Mental Interactions*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/tgdlian.html, 2023.

[K123] Pitkänen M. TGD Inspired Comments about Integrated Information Theory of Consciousness. In *TGD Inspired Theory of Consciousness: Part II. https://tgdtheory.fi/tgdhtml/Btgdconsc2.html*. Available at: https://tgdtheory.fi/pdfpool/tononikoch.pdf, 2023.

[K124] Pitkänen M. *TGD Inspired Theory of Consciousness*. Online book. Available at: https://www.tgdtheory.fi/tgdhtml/tgdconsc.html., 2023.

[K125] Pitkänen M. TGD inspired view about remote mental interactions and paranormal. In *TGD Inspired Theory of Consciousness: Part III. https://tgdtheory.fi/tgdhtml/Btgdconsc3.html*. Available at: https://tgdtheory.fi/pdfpool/lianPRM.pdf, 2023.

[K126] Pitkänen M. The classical part of the twistor story. In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/twistorstory.pdf, 2023.

[K127] Pitkänen M. The Geometry of the World of the Classical Worlds. In *Topological Geometrodynamics: Overview: Part I:https://tgdtheory.fi/tgdhtml/Btgdview1.html*. Available at: https://tgdtheory.fi/pdfpool/tgdgeom.pdf, 2023.

[K128] Pitkänen M. The Notion of Free Energy and Many-Sheeted Space-Time Concept. In *TGD and Fringe Physics. https://tgdtheory.fi/tgdhtml/Bfreenergies.html*. Available at: https://tgdtheory.fi/pdfpool/freenergy.pdf, 2023.

[K129] Pitkänen M. The Notion of Wave-Genome and DNA as Topological Quantum Computer. In *Quantum - and Classical Computation in TGD Universe.* *https://tgdtheory.fi/tgdhtml/Btgdcomp.html*. Available at: https://tgdtheory.fi/pdfpool/gari.pdf, 2023.

[K130] Pitkänen M. The Recent Status of Lepto-hadron Hypothesis. In *p-Adic Physics.* *https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/leptc.pdf, 2023.

[K131] Pitkänen M. The Recent View about Twistorialization in TGD Framework. In *Quantum TGD: Part III.* *https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/smatrix.pdf, 2023.

[K132] Pitkänen M. The Relationship Between TGD and GRT. In *Physics in Many-Sheeted Space-Time: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/tgdgrt.pdf., 2023.

[K133] Pitkänen M. Time and Consciousness. In *TGD Inspired Theory of Consciousness: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/timesc.pdf, 2023.

[K134] Pitkänen M. *Topological Geometrodynamics.* Luniver Press. Available at: https://tinyurl.com/hgd585n., 2023.

[K135] Pitkänen M. *Topological Geometrodynamics: an Overview.* Online book.Available at: https://www.tgdtheory.fi/tgdhtml/tgdview.html., 2023.

[K136] Pitkänen M. Topological Geometrodynamics: Three Visions. In *Topological Geometrodynamics: Overview: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdview1.html*. Available at: https://tgdtheory.fi/pdfpool/tgd2010.pdf, 2023.

[K137] Pitkänen M. Unified Number Theoretical Vision. In *TGD as a Generalized Number Theory: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/numbervision.pdf, 2023.

[K138] Pitkänen M. Was von Neumann Right After All? In *TGD and Hyper-finite Factors.* *https://tgdtheory.fi/tgdhtml/BHFF.html*. Available at: https://tgdtheory.fi/pdfpool/vNeumann.pdf, 2023.

[K139] Pitkänen M. WCW Spinor Structure. In *Quantum Physics as Infinite-Dimensional Geometry.* *https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/cspin.pdf, 2023.

[K140] Pitkänen M. What p-Adic Icosahedron Could Mean? And What about p-Adic Manifold? In *TGD as a Generalized Number Theory: Part III.* *https://tgdtheory.fi/tgdhtml/Btgdnumber3.html*. Available at: https://tgdtheory.fi/pdfpool/picosahedron.pdf, 2023.

[K141] Pitkänen M. Why TGD and What TGD is? In *Topological Geometrodynamics: an Overview.* *https://tgdtheory.fi/tgdhtml/Btgdview1.html*. Available at: https://tgdtheory.fi/pdfpool/WhyTGD.pdf, 2023.

[K142] Pitkänen M. Wormhole Magnetic Fields. In *Bio-Systems as Self-Organizing Quantum Systems.* *https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/wormc.pdf, 2023.

[K143] Pitkänen M. Zero Energy Ontology. In *Quantum TGD: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://tgdtheory.fi/pdfpool/ZEO.pdf, 2023.

Articles about TGD

[L1] Pitkänen M. Spectroscopy of consciousness. *Int J Comp Anticip Systems*, 11, 2001.

[L2] Pitkänen M. Basic Properties of CP_2 and Elementary Facts about p-Adic Numbers. Available at: `https://tgdtheory.fi/pdfpool/append.pdf`., 2006.

[L3] Pitkänen M. Further Progress in Nuclear String Hypothesis. Available at: `https://tgdtheory.fi/public_html/articles/nuclstring.pdf`., 2007.

[L4] Pitkänen M. A Model for Protein Folding and Bio-catalysis. Available at: `https://tgdtheory.fi/public_html/articles/prebiotic.pdf`., 2008.

[L5] Pitkänen M. DNA as Topological Quantum Computer. Available at: `https://tgdtheory.fi/public_html/articles/dnatqcart.pdf`., 2008.

[L6] Pitkänen M. Evolution in Many-Sheeted Space-Time. Available at: `https://tgdtheory.fi/public_html/articles/prebiotic.pdf`., 2008.

[L7] Pitkänen M. Quantum Model for Nerve Pulse and EEG . Available at: `https://tgdtheory.fi/public_html/articles/pulseeg.pdf`., 2008.

[L8] Pitkänen M. TGD Inspired Quantum Model of Living Matter. Available at: `https://tgdtheory.fi/quantumbio.pdf`., 2008.

[L9] Pitkänen M. TGD Inspired Quantum Model of Living Matter. Available at: `https://tgdtheory.fi/public_html/articles/quantumbio.pdf`., 2008.

[L10] Pitkänen M. TGD Inspired Theory of Consciousness. Available at: `https://tgdtheory.fi/tgdconsc.pdf`., 2008.

[L11] Pitkänen M. TGD Inspired Theory of Consciousness. Available at: `https://tgdtheory.fi/public_html/articles/tgdconsc.cpdf`., 2008.

[L12] Pitkänen M. Topological Geometrodynamics: What Might Be the Basic Principles. Available at: `https://tgdtheory.fi/public_html/articles/tgd2008.pdf`., 2008.

[L13] Pitkänen M. Physics as Generalized Number Theory II: Classical Number Fields, 2010.

[L14] Pitkänen M. Physics as Infinite-dimensional Geometry I: Identification of the Configuration Space Kähler Function, 2010.

[L15] Pitkänen M. Physics as Infinite-dimensional Geometry II: Configuration Space Kähler Geometry from Symmetry Principles, 2010.

[L16] Pitkänen M. Physics as Generalized Number Theory I: p-Adic Physics and Number Theoretic Universality, 2010.

[L17] Pitkänen M. Physics as Generalized Number Theory III: Infinite Primes, 2010.

[L18] Pitkänen M. Physics as Infinite-dimensional Geometry III: Configuration Space Spinor Structure, 2010.

[L19] Pitkänen M. Physics as Infinite-dimensional Geometry IV: Weak Form of Electric-Magnetic Duality and Its Implications, 2010.

[L20] Pitkänen M. The Geometry of CP_2 and its Relationship to Standard Model, 2010.

[L21] Pitkänen M. The Geometry of CP_2 and its Relationship to Standard Model. *Pre-Space-Time Journal*, 1(4), 2010.

[L22] Pitkänen M. Physics as Infinite-dimensional Geometry II: Configuration Space Kähler Geometry from Symmetry Principles. *Pre-Space-Time Journal*, 1(4), 2010. See also `https://tgdtheory.fi/pdfpool/compl1.pdf`.

[L23] Pitkänen M. Physics as Infinite-dimensional Geometry I: Identification of the Configuration Space Kähler Function. *Pre-Space-Time Journal*, 1(4), 2010. See also `https://tgdtheory.fi/pdfpool/kahler.pdf`.

[L24] Pitkänen M. Particle Massivation in TGD Universe. *Pre-Space-Time Journal*, 2(10), 2011. See also `https://tgdtheory.fi/pdfpool/mless.pdf` and `https://tgdtheory.fi/pdfpool/elvafu.pdf`.

[L25] Pitkänen M. Quantum Adeles. Available at: `https://tgdtheory.fi/public_html/articles/galois.pdf`., 2012.

[L26] Pitkänen M. Hypnosis as Remote Mental Interaction. Available at: `https://tgdtheory.fi/public_html/articles/hypnosisarticle.pdf`., 2013.

[L27] Pitkänen M. Are dark photons behind biophotons? *Journal of Non-Locality*, 2(1), 2013. See also `https://tgdtheory.fi/pdfpool/biophotonslian.pdf`.

[L28] Pitkänen M. Comments on the Recent Experiments by the Group of Michael Persinger. *Journal of Non-Locality*, 2(1), 2013. See also `https://tgdtheory.fi/public_html/articles/persconsc.pdf`.

[L29] Pitkänen M. CMAP representations about TGD, and TGD inspired theory of consciousness and quantum biology. Available at: `https://www.tgdtheory.fi/tgdglossary.pdf`., 2014.

[L30] Pitkänen M. Geometric theory of harmony. Available at: `https://tgdtheory.fi/public_html/articles/harmonytheory.pdf`., 2014.

[L31] Pitkänen M. Pollack's Findings about Fourth phase of Water : TGD View. Available at: `https://tgdtheory.fi/public_html/articles/PollackYoutube.pdf`., 2014.

[L32] Pitkänen M. Psychedelic induced experiences as key to the understanding of the connection between magnetic body and information molecules? Available at: `https://tgdtheory.fi/public_html/articles/psychedelics.pdf`., 2014.

[L33] Pitkänen M. Music, Biology and Natural Geometry (Part I). *DNA Decipher Journal*, 4(2), 2014. See also `https://tgtheory.fi/public_html/articles/harmonytheory.pdf`.

[L34] Pitkänen M. Music, Biology and Natural Geometry (Part II). *DNA Decipher Journal*, 4(2), 2014. See also `https://tgtheory.fi/public_html/articles/harmonytheory.pdf`.

[L35] Pitkänen M. Jeremy England's vision about life and evolution: comparison with TGD approach . Available at: `https://tgdtheory.fi/public_html/articles/englandtgd.pdf`., 2015.

[L36] Pitkänen M. What Music Could Teach about Consciousness? Available at: `https://tgdtheory.fi/public_html/articles/musicophilia.pdf`., 2015.

[L37] Pitkänen M. What went wrong with symmetries? Available at: `https://tgdtheory.fi/public_html/articles/whatiswrong.pdf`., 2015.

[L38] Pitkänen M. Recent View about Kähler Geometry and Spinor Structure of WCW. *Pre-Space-Time Journal*, 6(4), 2015. See also `https://tgtheory.fi/pdfpool/wcwnew.pdf`.

[L39] Pitkänen M. Comparison of Jeremy England's View about Life and Evolution with TGD. *Journal of Consciousness Exploration and Research*, 6(11), 2015. See also https://tgtheory.fi/public_html/articles/englandtgd.pdf.

[L40] Pitkänen M. Psychedelic Induced Experiences, Magnetic Body and Information Molecules. *Journal of Consciousness Exploration and Research*, 6(11), 2015. See also https://tgtheory.fi/public_html/articles/psychedelics.pdf.

[L41] Pitkänen M. About minimal surface extremals of Kähler action. Available at: https://tgdtheory.fi/public_html/articles/minimalkahler.pdf., 2016.

[L42] Pitkänen M. About Physical Representations of Genetic Code in Terms of Dark Nuclear Strings. Available at: https://tgdtheory.fi/public_html/articles/genecodemodels.pdf., 2016.

[L43] Pitkänen M. Are lithium, phosphate, and Posner molecule fundamental for quantum biology? Available at: https://tgdtheory.fi/public_html/articles/fisherP.pdf., 2016.

[L44] Pitkänen M. Bio-catalysis, morphogenesis by generalized Chladni mechanism, and bio-harmonies. Available at: https://tgdtheory.fi/public_html/articles/chladnicata.pdf., 2016.

[L45] Pitkänen M. Cyclic cosmology from TGD perspective. Available at: https://tgdtheory.fi/public_html/articles/turok.pdf., 2016.

[L46] Pitkänen M. Hydrinos again. Available at: https://tgdtheory.fi/public_html/articles/Millsagain.pdf., 2016.

[L47] Pitkänen M. Is the sum of p-adic negentropies equal to real entropy? Available at: https://tgdtheory.fi/public_html/articles/adelicinfo.pdf., 2016.

[L48] Pitkänen M. Non-locality in quantum theory, in biology and neuroscience, and in remote mental interactions: TGD perspective. Available at: https://tgdtheory.fi/public_html/articles/nonlocal.pdf., 2016.

[L49] Pitkänen M. Number theoretical feats TGD inspired theory of consciousness. Available at: https://tgdtheory.fi/public_html/articles/numberfeats.pdf., 2016.

[L50] Pitkänen M. p-Adicizable discrete variants of classical Lie groups and coset spaces in TGD framework. Available at: https://tgdtheory.fi/public_html/articles/padicgeom.pdf., 2016.

[L51] Pitkänen M. Questions related to self and time. Available at: https://tgdtheory.fi/public_html/articles/selfquestions.pdf., 2016.

[L52] Pitkänen M. The anomalies in rotating magnetic systems as a key to the understanding of morphogenesis? Available at: https://tgdtheory.fi/public_html/articles/godin.pdf., 2016.

[L53] Pitkänen M. Are Bio-catalysis and Morphogenesis Possible via Generalized Chladni Mechanism and Bio-harmonies? *DNA Decipher Journal*, 6(3), 2016. See also https://tgtheory.fi/public_html/articles/chladnicata.pdf.

[L54] Pitkänen M. On the Representations of Genetic Code by Dark Nuclear Strings in TGD Framework. *DNA Decipher Journal*, 6(2), 2016. See also https://tgtheory.fi/public_html/articles/genecodemodels.pdf.

[L55] Pitkänen M. TGD Perspectives of Nonlocality in Quantum theory, Biology, Neuroscience and Remote Mental Interactions (Part I). *Journal of Consciousness Exploration and Research*, 7(6), 2016. See also https://tgtheory.fi/public_html/articles/nonlocal.pdf.

[L56] Pitkänen M. TGD Perspectives of Nonlocality in Quantum theory, Biology, Neuroscience and Remote Mental Interactions (Part II). *Journal of Consciousness Exploration and Research*, 7(6), 2016. See also https://tgtheory.fi/public_html/articles/nonlocal.pdf.

[L57] Pitkänen M. Twistorial Lift of Kahler Action. *Pre-Space-Time Journal*, 7(7), 2016. See also `https://tgtheory.fi/public_html/articles/twistquestions.pdf`.

[L58] Pitkänen M. About $h_{eff}/h = n$ as the number of sheets of space-time surface as Galois covering. Available at: `https://tgdtheory.fi/public_html/articles/Galoisext.pdf`., 2017.

[L59] Pitkänen M. Artificial Intelligence, Natural Intelligence, and TGD. Available at: `https://tgdtheory.fi/public_html/articles/AITGD.pdf`., 2017.

[L60] Pitkänen M. DMT, pineal gland, and the new view about sensory perception. Available at: `https://tgdtheory.fi/public_html/articles/dmtpineal.pdf`., 2017.

[L61] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry? Available at: `https://tgdtheory.fi/public_html/articles/ratpoints.pdf`., 2017.

[L62] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry?: part I. Available at: `https://tgdtheory.fi/public_html/articles/ratpoints1.pdf`., 2017.

[L63] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry?: part II. Available at: `https://tgdtheory.fi/public_html/articles/ratpoints2.pdf`., 2017.

[L64] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry?: part III. Available at: `https://tgdtheory.fi/public_html/articles/ratpoints3.pdf`., 2017.

[L65] Pitkänen M. Does valence bond theory relate to the hierarchy of Planck constants? Available at: `https://tgdtheory.fi/public_html/articles/valenceheff.pdf`., 2017.

[L66] Pitkänen M. Life-like properties observed in a very simple system. Available at: `https://tgdtheory.fi/public_html/articles/plasticballs.pdf`., 2017.

[L67] Pitkänen M. Mysteriously disappearing valence electrons of rare Earth metals and hierarchy of Planck constants. Available at: `https://tgdtheory.fi/public_html/articles/rareearth.pdf`., 2017.

[L68] Pitkänen M. p-Adicization and adelic physics. Available at: `https://tgdtheory.fi/public_html/articles/adelicphysics.pdf`., 2017.

[L69] Pitkänen M. Philosophy of Adelic Physics. In *Trends and Mathematical Methods in Interdisciplinary Mathematical Sciences*, pages 241–319. Springer.Available at: `https://link.springer.com/chapter/10.1007/978-3-319-55612-3_11`, 2017.

[L70] Pitkänen M. Philosophy of Adelic Physics. Available at: `https://tgdtheory.fi/public_html/articles/adelephysics.pdf`., 2017.

[L71] Pitkänen M. Questions about twistor lift of TGD. Available at: `https://tgdtheory.fi/public_html/articles/twistquestions.pdf`., 2017.

[L72] Pitkänen M. Re-examination of the basic notions of TGD inspired theory of consciousness. Available at: `https://tgdtheory.fi/public_html/articles/conscrit.pdf`., 2017.

[L73] Pitkänen M. p-Adicization and Adelic Physics. *Pre-Space-Time Journal.*, 8(3), 2017. See also `https://tgtheory.fi/public_html/articles/adelicphysics.pdf`.

[L74] Pitkänen M. Re-examination of the Basic Notions of TGD-inspired Theory of Consciousness. *Journal of Consciousness Exploration and Research*, 8(3), 2017. See also `https://tgtheory.fi/public_html/articles/conscrit.pdf`.

[L75] Pitkänen M. On Hydrinos Again. *Pre-Space-Time Journal*, 8(1), 2017. See also `https://tgtheory.fi/public_html/articles/Millsagain.pdf`.

[L76] Pitkänen M. On the Mysteriously Disappearing Valence Electrons of Rare Earth Metals & Hierarchy of Planck Constants. *Pre-Space-Time Journal*, 8(13), 2017. See also https://tgtheory.fi/public_html/articles/rareearth.pdf.

[L77] Pitkänen M. Does $M^8 - H$ Duality Reduce Classical TGD to Octonionic Algebraic Geometry? (Part I). *Pre-Space-Time Journal*, 8(8), 2017. See also https://tgtheory.fi/public_html/articles/ratpoints1.pdf.

[L78] Pitkänen M. Does $M^8 - H$ Duality Reduce Classical TGD to Octonionic Algebraic Geometry? (Part II). *Pre-Space-Time Journal*, 8(8), 2017. See also https://tgtheory.fi/public_html/articles/ratpoints2.pdf and https://tgtheory.fi/public_html/articles/ratpoints3.pdf.

[L79] Pitkänen M. The Anomalies of Water as Evidence for the Existence of Dark Matter in TGD Framework. *Pre-Space-Time Journal*, 8(3), 2017. See also https://tgtheory.fi/public_html/articles/wateranomalies.pdf.

[L80] Pitkänen M. About the Correspondence of Dark Nuclear Genetic Code and Ordinary Genetic Code. Available at: https://tgdtheory.fi/public_html/articles/codedarkcode.pdf., 2018.

[L81] Pitkänen M. Could cancer be a disease of magnetic body? Available at: https://tgdtheory.fi/public_html/articles/nanotesla.pdf., 2018.

[L82] Pitkänen M. Dance of the honeybee and New Physics. Available at: https://tgdtheory.fi/public_html/articles/Shipmanagain.pdf., 2018.

[L83] Pitkänen M. Dark valence electrons and color vision. Available at: https://tgdtheory.fi/public_html/articles/colorvision.pdf., 2018.

[L84] Pitkänen M. Getting philosophical: some comments about the problems of physics, neuroscience, and biology. Available at: https://tgdtheory.fi/public_html/articles/philosophic.pdf., 2018.

[L85] Pitkänen M. Morphogenesis in TGD Universe. Available at: https://tgdtheory.fi/public_html/articles/morphoTGD.pdf., 2018.

[L86] Pitkänen M. Sensory perception and motor action as time reversals of each other: a royal road to the understanding of other minds? Available at: https://tgdtheory.fi/public_html/articles/timemirror.pdf., 2018.

[L87] Pitkänen M. TGD view about coupling constant evolution. Available at: https://tgdtheory.fi/public_html/articles/ccevolution.pdf., 2018.

[L88] Pitkänen M. The Recent View about Twistorialization in TGD Framework. Available at: https://tgdtheory.fi/public_html/articles/smatrix.pdf., 2018.

[L89] Pitkänen M. On the Correspondence of Dark Nuclear Genetic Code & Ordinary Genetic Code. *DNA Decipher Journal*, 8(1), 2018. See also https://tgtheory.fi/public_html/articles/codedarkcode.pdf.

[L90] Pitkänen M. DMT, Pineal Gland & the New View on Sensory Perception. *Journal of Consciousness Exploration and Research*, 9(3), 2018. See also https://tgtheory.fi/public_html/articles/dmtpineal.pdf.

[L91] Pitkänen M. Two Poorly understood Phenomena: Maxwell's Lever Rule Expansion of Freezing Water. *Pre-Space-Time Journal*, 9(5), 2018. See also https://tgtheory.fi/public_html/articles/leverule.pdf.

[L92] Pitkänen M. How Molecules in Cells Find Each Other & Organize into Structures? *DNA Decipher Journal*, 8(1), 2018. See also https://tgtheory.fi/public_html/articles/moleculefind.pdf.

[L93] Pitkänen M. Morphogenesis in TGD Universe. *DNA Decipher Journal*, 8(2), 2018. See also `https://tgtheory.fi/public_html/articles/morphoTGD.pdf`.

[L94] Pitkänen M. Getting Philosophical: On the Problems in Physics, Neuroscience & Biology. *DNA Decipher Journal*, 8(2), 2018. See also `https://tgtheory.fi/public_html/articles/philosophic.pdf`.

[L95] Pitkänen M. Expanding Earth Hypothesis, Platonic Solids, & Plate Tectonics as a Symplectic Flow. *Pre-Space-Time Journal*, 9(7), 2018. See also `https://tgtheory.fi/public_html/articles/platoplate.pdf`.

[L96] Pitkänen M. On the Physical Interpretation of the Velocity Parameter in the Formula for Gravitational Planck Constant. *Pre-Space-Time Journal*, 9(7), 2018. See also `https://tgtheory.fi/public_html/articles/vzero.pdf`.

[L97] Pitkänen M. About a model for the control of biological body by magnetic body. Available at: `https://tgdtheory.fi/public_html/articles/rotcyclo.pdf`., 2019.

[L98] Pitkänen M. An overall view about models of genetic code and bio-harmony. Available at: `https://tgdtheory.fi/public_html/articles/gcharm.pdf`., 2019.

[L99] Pitkänen M. Copenhagen interpretation dead: long live ZEO based quantum measurement theory! Available at: `https://tgdtheory.fi/public_html/articles/Bohrdead.pdf`., 2019.

[L100] Pitkänen M. Cosmic string model for the formation of galaxies and stars. Available at: `https://tgdtheory.fi/public_html/articles/galaxystars.pdf`., 2019.

[L101] Pitkänen M. Earhquakes and volcanic eruptions as macroscopic quantum jumps in zero energy ontology. Available at: `https://tgdtheory.fi/public_html/articles/earthquakes.pdf`., 2019.

[L102] Pitkänen M. $M^8 - H$ duality and consciousness. Available at: `https://tgdtheory.fi/public_html/articles/M8Hconsc.pdf`., 2019.

[L103] Pitkänen M. New results related to $M^8 - H$ duality. Available at: `https://tgdtheory.fi/public_html/articles/M8Hduality.pdf`., 2019.

[L104] Pitkänen M. Quantum self-organization by h_{eff} changing phase transitions. Available at: `https://tgdtheory.fi/public_html/articles/heffselforg.pdf`., 2019.

[L105] Pitkänen M. Scattering amplitudes and orbits of cognitive representations under subgroup of symplectic group respecting the extension of rationals . Available at: `https://tgdtheory.fi/public_html/articles/symplorbsm.pdf`., 2019.

[L106] Pitkänen M. Secret Link Uncovered Between Pure Math and Physics. Available at: `https://tgdtheory.fi/public_html/articles/KimTGD.pdf`., 2019.

[L107] Pitkänen M. Some applications of TGD inspired quantum biology: bio-chemistry, metabolism, replication. Available at: `https://tgdtheory.fi/public_html/articles/bioexamples.pdf`., 2019.

[L108] Pitkänen M. Some comments related to Zero Energy Ontology (ZEO). Available at: `https://tgdtheory.fi/public_html/articles/zeoquestions.pdf`., 2019.

[L109] Pitkänen M. SUSY in TGD Universe. Available at: `https://tgdtheory.fi/public_html/articles/susyTGD.pdf`., 2019.

[L110] Pitkänen M. Tesla still inspires. Available at: `https://tgdtheory.fi/public_html/articles/teslastill.pdf`., 2019.

[L111] Pitkänen M. TGD inspired theory of consciousness and living systems. Available at: `https://tgdtheory.fi/public_html/articles/badenbaden.pdf`., 2019.

[L112] Pitkänen M. TGD view about McKay Correspondence, ADE Hierarchy, Inclusions of Hyperfinite Factors, $M^8 - H$ Duality, SUSY, and Twistors. Available at: https://tgdtheory.fi/public_html/articles/McKaygeneral.pdf., 2019.

[L113] Pitkänen M. The TGD Perspective of SUSY after LHC. *Pre-Space-Time Journal*, 10(3), 2019.

[L114] Pitkänen M. Three findings about memory recall and TGD based view about memory retrieval. Available at: https://tgdtheory.fi/public_html/articles/memoryrecall.pdf., 2019.

[L115] Pitkänen M. Copenhagen Interpretation & ZEO Based Quantum Measurement Theory. *Pre-Space-Time Journal*, 10(6), 2019. See also https://tgtheory.fi/public_html/articles/Bohrdead.pdf.

[L116] Pitkänen M. Earthquakes & Volcanic Eruptions as Macroscopic Quantum Jumps in Zero Energy Ontology. *Pre-Space-Time Journal*, 10(8), 2019. See also https://tgtheory.fi/public_html/articles/earthquakes.pdf.

[L117] Pitkänen M. Cosmic String Model for the Formation of Galaxies & Stars. *Pre-Space-Time Journal*, 10(8), 2019. See also https://tgtheory.fi/public_html/articles/galaxystars.pdf.

[L118] Pitkänen M. An Overall View about Models of Genetic Code & Bio-harmony. *DNA Decipher Journal*, 9(2), 2019. See also https://tgtheory.fi/public_html/articles/gcharm.pdf.

[L119] Pitkänen M. Self-organization by h_{eff} Changing Phase Transitions. *Pre-Space-Time Journal*, 10(7), 2019. See also https://tgtheory.fi/public_html/articles/heffselforg.pdf.

[L120] Pitkänen M. New Aspects of $M^8 - H$ Duality. *Pre-Space-Time Journal*, 10(6), 2019. See also https://tgtheory.fi/public_html/articles/M8Hduality.pdf.

[L121] Pitkänen M. TGD View about Quasars. *Pre-Space-Time Journal*, 10(1), 2019. See also https://tgtheory.fi/public_html/articles/meco.pdf.

[L122] Pitkänen M. SUSY in TGD Universe (Part II). *Pre-Space-Time Journal*, 10(7), 2019. See also https://tgtheory.fi/public_html/articles/susyTGD.pdf.

[L123] Pitkänen M. SUSY in TGD Universe (Part I). *Pre-Space-Time Journal*, 10(4), 2019. See also https://tgtheory.fi/public_html/articles/susyTGD.pdf.

[L124] Pitkänen M. Twistors in TGD (Part I). *Pre-Space-Time Journal*, 10(7), 2019. See also https://tgtheory.fi/public_html/articles/twistorTGD.pdf.

[L125] Pitkänen M. Twistors in TGD (Part II) . *Pre-Space-Time Journal*, 10(7), 2019. See also https://tgtheory.fi/public_html/articles/twistorTGD.pdf.

[L126] Pitkänen M. Twistor Lift of TGD & WCW Geometry. *Pre-Space-Time Journal*, 10(4), 2019. See also https://tgtheory.fi/public_html/articles/wcwnew.pdf.

[L127] Pitkänen M. A critical re-examination of $M^8 - H$ duality hypothesis: part I. Available at: https://tgdtheory.fi/public_html/articles/M8H1.pdf., 2020.

[L128] Pitkänen M. A critical re-examination of $M^8 - H$ duality hypothesis: part II. Available at: https://tgdtheory.fi/public_html/articles/M8H2.pdf., 2020.

[L129] Pitkänen M. Could brain be represented as a hyperbolic geometry? Available at: https://tgdtheory.fi/public_html/articles/hyperbolicbrain.pdf., 2020.

[L130] Pitkänen M. Could quantum randomness have something to do with classical chaos? Available at: https://tgdtheory.fi/public_html/articles/chaostgd.pdf., 2020.

[L131] Pitkänen M. How to compose beautiful music of light in bio-harmony? Research Gate: https://www.researchgate.net/publication/344623253_How_to_compose_beautiful_music_of_light_in_bio-harmony., 2020.

[L132] Pitkänen M. How to compose beautiful music of light in bio-harmony? https://tgdtheory.fi/public_html/articles/bioharmony2020.pdf., 2020.

[L133] Pitkänen M. Summary of Topological Geometrodynamics. https://tgdtheory.fi/public_html/articles/tgdarticle.pdf., 2020.

[L134] Pitkänen M. The dynamics of SSFRs as quantum measurement cascades in the group algebra of Galois group. Available at: https://tgdtheory.fi/public_html/articles/SSFRGalois.pdf., 2020.

[L135] Pitkänen M. Zero energy ontology, hierarchy of Planck constants, and Kähler metric replacing unitary S-matrix: three pillars of new quantum theory (short version). Available at: https://tgdtheory.fi/public_html/articles/kahlersm.pdf., 2020.

[L136] Pitkänen M. How to Compose Beautiful Music of Light in Bio-harmony? *DNA Decipher Journal*, 10(2), 2020. See also https://tgtheory.fi/public_html/articles/bioharmony2020.pdf.

[L137] Pitkänen M. Maintenance problem for Earth's magnetic field. *Pre-Space-Time Journal*, 11(8), 2020. See also https://tgtheory.fi/public_html/articles/Bmaintenance.pdf.

[L138] Pitkänen M. Results about Dark DNA & Remote DNA Replication. *DNA Decipher Journal*, 10(1), 2020. See also https://tgtheory.fi/public_html/articles/darkdnanew.pdf.

[L139] Pitkänen M. Could brain be represented by hyperbolic geometry. *Journal of Consciousness Exploration & Research*, 11(4), 2020. See also https://tgtheory.fi/public_html/articles/hyperbolicbrain.pdf.

[L140] Pitkänen M. Zero Energy Ontology, Hierarchy of Planck Constants, and Kahler Metric Replacing Unitary S-matrix: Three Pillars of New Quantum Theory. *Pre-Space-Time Journal*, 11(8), 2020. See also https://tgtheory.fi/public_html/articles/kahlersmshort.pdf.

[L141] Pitkänen M. A Critical Re-examination of M8–H Duality: Part I. *Pre-Space-Time Journal*, 11(8), 2020. See also https://tgtheory.fi/public_html/articles/M8H1.pdf.

[L142] Pitkänen M. A Critical Re-examination of M8–H Duality: Part II. *Pre-Space-Time Journal*, 11(8), 2020. See also https://tgtheory.fi/public_html/articles/M8H2.pdf.

[L143] Pitkänen M. Arrow of Time & Neuroscience: TGD-based View (Part I). *Journal of Consciousness Exploration & Research*, 11(7), 2020. See also https://tgtheory.fi/public_html/articles/precognize.pdf.

[L144] Pitkänen M. Arrow of Time & Neuroscience: TGD-based View (Part II). *Journal of Consciousness Exploration & Research*, 11(7), 2020. See also https://tgtheory.fi/public_html/articles/precognize.pdf.

[L145] Pitkänen M. The Dynamics of State Function Reductions as Quantum Measurement Cascades. *Pre-Space-Time Journal*, 11(2), 2020. See also https://tgtheory.fi/public_html/articles/SSFRGalois.pdf.

[L146] Pitkänen M. Summary of Topological Geometrodynamics. *Pre-Space-Time Journal*, 11(8), 2020. See also https://tgtheory.fi/public_html/articles/tgdarticle.pdf.

[L147] Pitkänen M. Does Valence Bond Theory Relate to the Hierarchy of Planck Constants? *Pre-Space-Time Journal*, 11(8), 2020. See also https://tgtheory.fi/public_html/articles/valenceheff.pdf.

[L148] Pitkänen M. When does "big" state function reduction & reversed arrow of time take place? *Journal of Consciousness Exploration & Research*, 11(4), 2020. See also https://tgtheory.fi/public_html/articles/whendeath.pdf.

[L149] Pitkänen M. Zero Energy Ontology & Consciousness. *Journal of Consciousness Exploration & Research*, 11(1), 2020. See also https://tgtheory.fi/public_html/articles/zeoquestions.pdf.

[L150] Pitkänen M. About the role of Galois groups in TGD framework. https://tgdtheory.fi/public_html/articles/GaloisTGD.pdf., 2021.

[L151] Pitkänen M. Can one regard leptons as effectively local 3-quark composites? https://tgdtheory.fi/public_html/articles/leptoDelta.pdf., 2021.

[L152] Pitkänen M. Does Consciousness Survive Bodily Death? https://tgdtheory.fi/public_html/articles/BICS.pdf., 2021.

[L153] Pitkänen M. EEG and the structure of magnetosphere. https://tgdtheory.fi/public_html/articles/mseeg.pdf., 2021.

[L154] Pitkänen M. Is genetic code part of fundamental physics in TGD framework? Available at: https://tgdtheory.fi/public_html/articles/TIH.pdf., 2021.

[L155] Pitkänen M. Is $M^8 - H$ duality consistent with Fourier analysis at the level of $M^4 \times CP_2$? https://tgdtheory.fi/public_html/articles/M8Hperiodic.pdf., 2021.

[L156] Pitkänen M. MeshCODE theory from TGD point of view. https://tgdtheory.fi/public_html/articles/talin.pdf., 2021.

[L157] Pitkänen M. Negentropy Maximization Principle and Second Law. Available at: https://tgdtheory.fi/public_html/articles/nmpsecondlaw.pdf., 2021.

[L158] Pitkänen M. Some questions concerning zero energy ontology. https://tgdtheory.fi/public_html/articles/zeonew.pdf., 2021.

[L159] Pitkänen M. TGD as it is towards the end of 2021. https://tgdtheory.fi/public_html/articles/TGD2021.pdf., 2021.

[L160] Pitkänen M. Three alternative generalizations of Nottale's hypothesis in TGD framework. https://tgdtheory.fi/public_html/articles/MDMdistance.pdf., 2021.

[L161] Pitkänen M. Time reversal and the anomalies of rotating magnetic systems. Available at: https://tgdtheory.fi/public_html/articles/freereverse.pdf., 2021.

[L162] Pitkänen M. What could 2-D minimal surfaces teach about TGD? https://tgdtheory.fi/public_html/articles/minimal.pdf., 2021.

[L163] Pitkänen M. About TGD counterparts of twistor amplitudes: part I. https://tgdtheory.fi/public_html/articles/twisttgd1.pdf., 2022.

[L164] Pitkänen M. About TGD counterparts of twistor amplitudes: part II. https://tgdtheory.fi/public_html/articles/twisttgd2.pdf., 2022.

[L165] Pitkänen M. About the number theoretic aspects of zero energy ontology. https://tgdtheory.fi/public_html/articles/ZEOnumber.pdf., 2022.

[L166] Pitkänen M. Comparison of Orch-OR hypothesis with the TGD point of view. https://tgdtheory.fi/public_html/articles/penrose.pdf., 2022.

[L167] Pitkänen M. Finite Fields and TGD. https://tgdtheory.fi/public_html/articles/finitefieldsTGD.pdf., 2022.

[L168] Pitkänen M. How animals without brain can behave as if they had brain. https://tgdtheory.fi/public_html/articles/precns.pdf., 2022.

[L169] Pitkänen M. Intersection form for 4-manifolds, knots and 2-knots, smooth exotics, and TGD. https://tgdtheory.fi/public_html/articles/finitefieldsTGD.pdf., 2022.

[L170] Pitkänen M. Some New Ideas Related to Langlands Program *viz.* TGD. https://tgdtheory.fi/public_html/articles/Langlands2022.pdf., 2022.

[L171] Pitkänen M. Trying to fuse the basic mathematical ideas of quantum TGD to a single coherent whole. https://tgdtheory.fi/public_html/articles/fusionTGD.pdf., 2022.

[L172] Pitkänen M. Two objections against p-adic thermodynamics and their resolution. https://tgdtheory.fi/public_html/articles/padmass2022.pdf., 2022.

[L173] Pitkänen M. About tessellations in hyperbolic 3-space and their relation to the genetic code . https://tgdtheory.fi/public_html/articles/tessellationH3.pdf., 2023.

[L174] Pitkänen M. A TGD Inspired Model for Solar Flares. https://tgdtheory.fi/public_html/articles/solarflares.pdf., 2023.

[L175] Pitkänen M. About long range electromagnetic quantum coherence in TGD Universe. https://tgdtheory.fi/public_html/articles/hem.pdf., 2023.

[L176] Pitkänen M. Are Conscious Computers Possible in TGD Universe? https://tgdtheory.fi/public_html/articles/tgdcomp.pdf., 2023.

[L177] Pitkänen M. Holography and Hamilton-Jacobi Structure as 4-D generalization of 2-D complex structure. https://tgdtheory.fi/public_html/articles/HJ.pdf., 2023.

[L178] Pitkänen M. Is Negentropy Maximization Principle needed as an independent principle? https://tgdtheory.fi/public_html/articles/NMPcrit.pdf., 2023.

[L179] Pitkänen M. Magnetic Bubbles in TGD Universe. https://tgdtheory.fi/public_html/articles/magnbubble.pdf., 2023.

[L180] Pitkänen M. New result about causal diamonds from the TGD view point of view. https://tgdtheory.fi/public_html/articles/CDconformal.pdf., 2023.

[L181] Pitkänen M. Reduction of standard model structure to CP_2 geometry and other key ideas of TGD. https://tgdtheory.fi/public_html/articles/cp2etc.pdf., 2023.

[L182] Pitkänen M. Symmetries and Geometry of the "World of Classical Worlds" . https://tgdtheory.fi/public_html/articles/wcwsymm.pdf., 2023.

[L183] Pitkänen M. A fresh look at M^8-H duality and Poincare invariance. https://tgdtheory.fi/public_html/articles/TGDcritics.pdf., 2024.

[L184] Pitkänen M. About Langlands correspondence in the TGD framework. https://tgdtheory.fi/public_html/articles/Frenkel.pdf., 2024.

[L185] Pitkänen M. About the Biefeld Brown effect. https://tgdtheory.fi/public_html/articles/BB.pdf., 2024.

[L186] Pitkänen M. How subjective memories are realized in TGD inspired theory of consciousness? https://tgdtheory.fi/public_html/articles/memorytgd.pdf., 2024.

[L187] Pitkänen M. Quartz crystals as a life form and ordinary computers as an interface between quartz life and ordinary life? https://tgdtheory.fi/public_html/articles/QCs.pdf., 2024.

[L188] Pitkänen M. Some solar mysteries. https://tgdtheory.fi/public_html/articles/Haramein.pdf., 2024.

[L189] Pitkänen M. TGD as it is towards the end of 2024: part II. https://tgdtheory.fi/public_html/articles/TGD2024II.pdf., 2024.

[L190] Pitkänen M. What gravitons are and could one detect them in TGD Universe? https://tgdtheory.fi/public_html/articles/whatgravitons.pdf., 2024.

[L191] Pitkänen M and Rastmanesh R. Arrow of time and neuroscience: TGD based view. Available at: https://tgdtheory.fi/public_html/articles/precognize.pdf., 2020.

[L192] Pitkänen M and Rastmanesh R. DNA and Time Reversal. Research Gate: https://www.researchgate.net/publication/344637491_DNA_and_Time_Reversal_immediate_October_12_2020., 2020.

[L193] Pitkänen M and Rastmanesh R. DNA and Time Reversal. Available at: https://tgdtheory.fi/public_html/articles/DNAtimereversal., 2020.

[L194] Pitkänen M and Rastmanesh R. Homeostasis as self-organized quantum criticality. Available at: https://tgdtheory.fi/public_html/articles/SP.pdf., 2020.

[L195] Pitkänen M and Rastmanesh R. New Physics View about Language: part I. Available at: https://tgdtheory.fi/public_html/articles/languageTGD1.pdf., 2020.

[L196] Pitkänen M and Rastmanesh R. New Physics View about Language: part II. Available at: https://tgdtheory.fi/public_html/articles/languageTGD2.pdf., 2020.

[L197] Pitkänen M and Rastmanesh R. The based view about dark matter at the level of molecular biology. Available at: https://tgdtheory.fi/public_html/articles/darkchemi.pdf., 2020.

[L198] Pitkänen M and Rastmanesh R. Aging from TGD point of view. https://tgdtheory.fi/public_html/articles/aging.pdf., 2021.

[L199] Pitkänen M and Rastmanesh R. Why the outcome of an event would be more predictable if it is known to occur? https://tgdtheory.fi/public_html/articles/scavhunt.pdf., 2021.

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