TGD INSPIRED THEORY OF CONSCIOUSNESS: PART II

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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. 23**). 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 $H = M^4 \times CP_2$ [L67]. 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 [L28, L37](see **Fig. 24**). 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. 25**). The mere mathematical existence of WCW geometry requires that it has maximal isometries, which together twistor lift and number theoretic vision fixes it uniquely [L68].

- 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 [K100, L46].

- 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 [K14, K41] [L62].

- 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 [L65]. 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 [L70].

- 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 [L26, L27] 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. 26**). 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 [L69]. 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. 27**). 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. 28**), 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. 29**).

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. 31** and **Fig. 32**). 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. 33**). 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 [L59], 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 [A12]. I have proposed [K36, K17, K97, K73, L68] 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 [K100, L46] 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 [L66]. 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 [L56, L57] 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 [L70].

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 [L63]. 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.

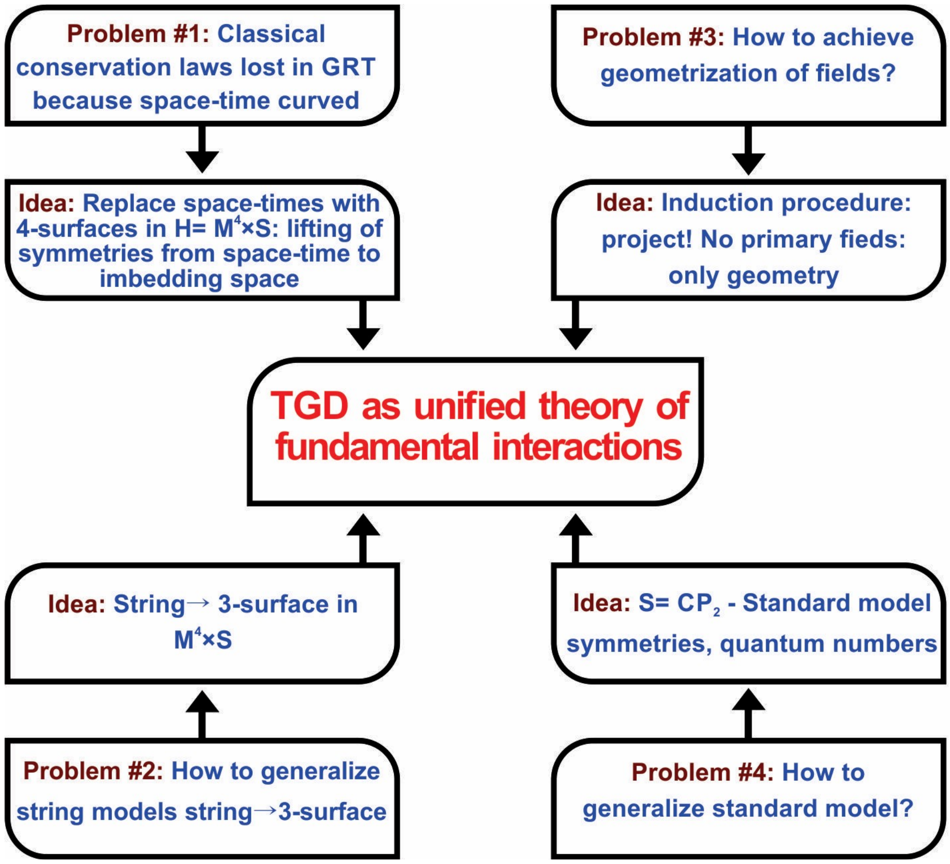

Figure 1: The problems leading to TGD as their solution.

- 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.

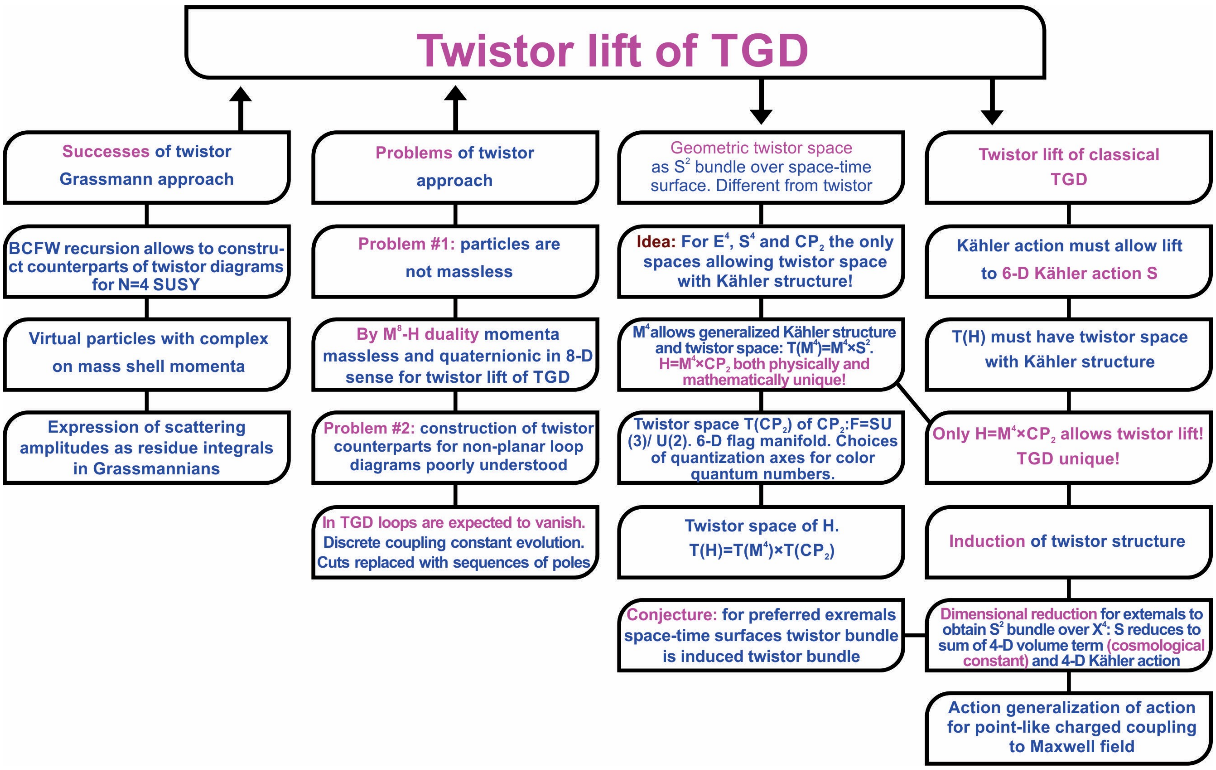

Figure 2: Twistor lift

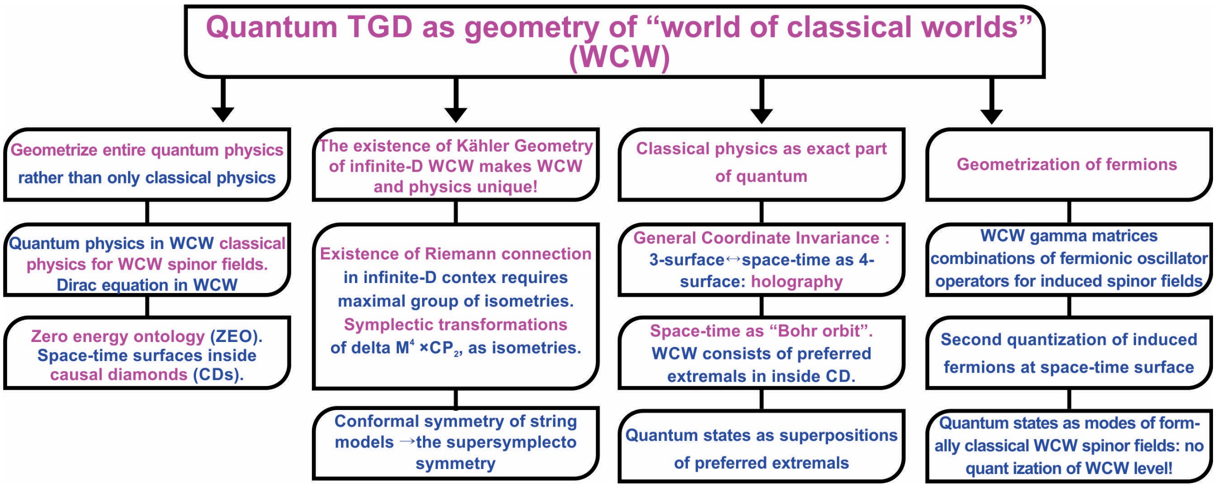

Figure 3: Geometrization of quantum physics in terms of WCW

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

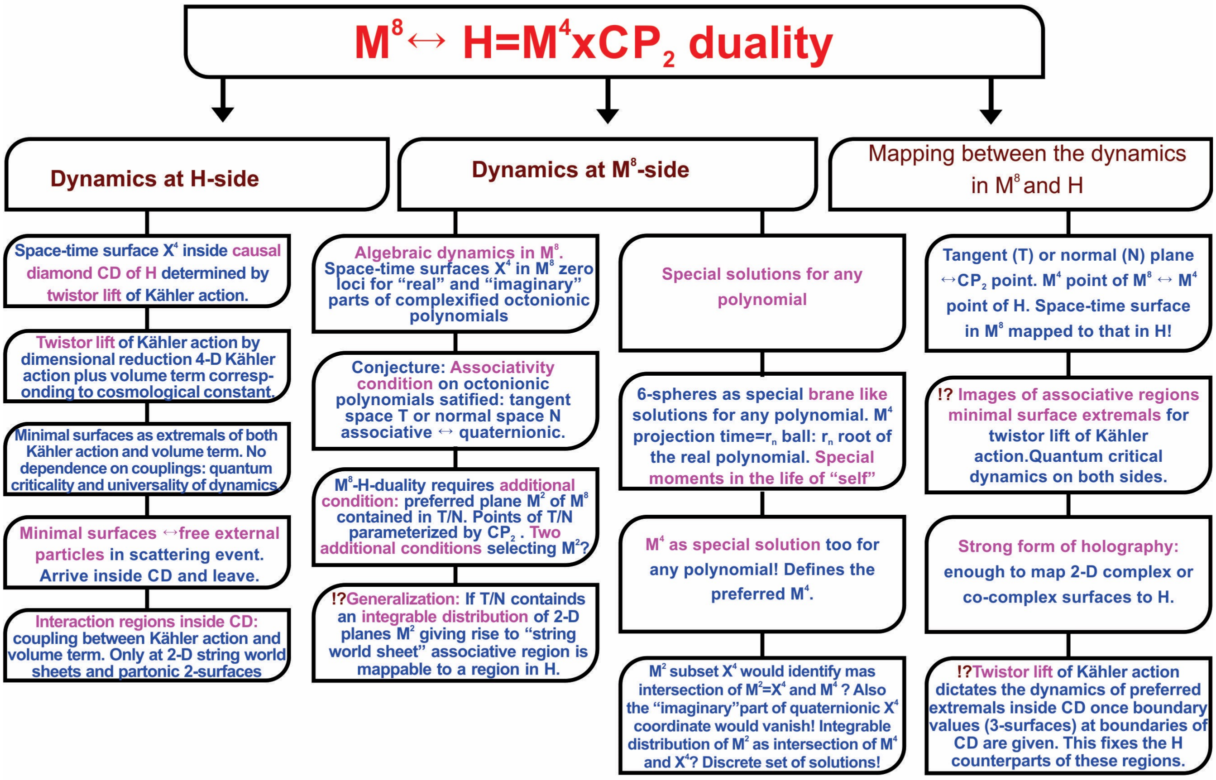

Figure 4: $M^8 - H$ duality

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

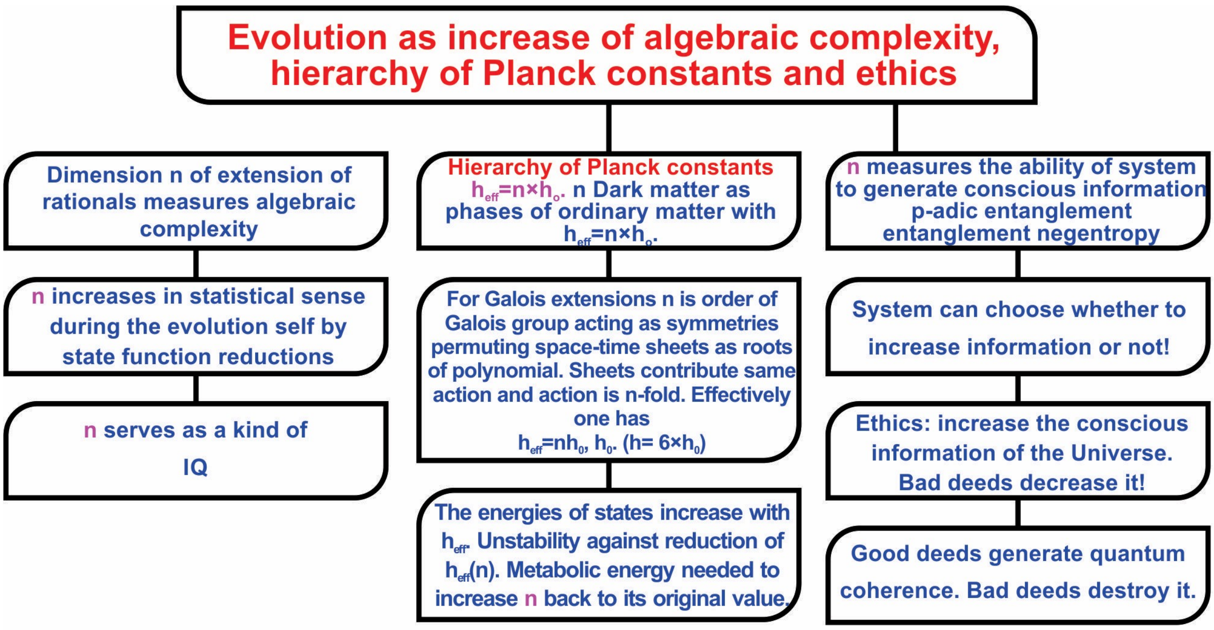

Figure 5: Number theoretic view of evolution

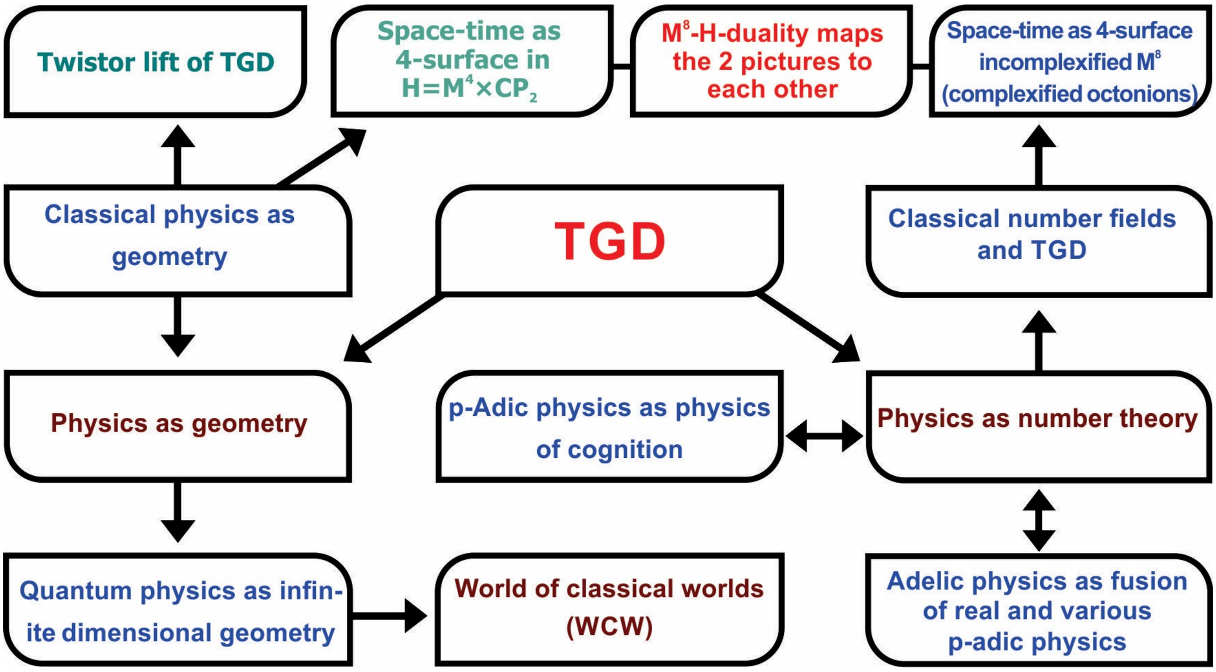

Figure 6: TGD is based on two complementary visions: physics as geometry and physics as number theory.

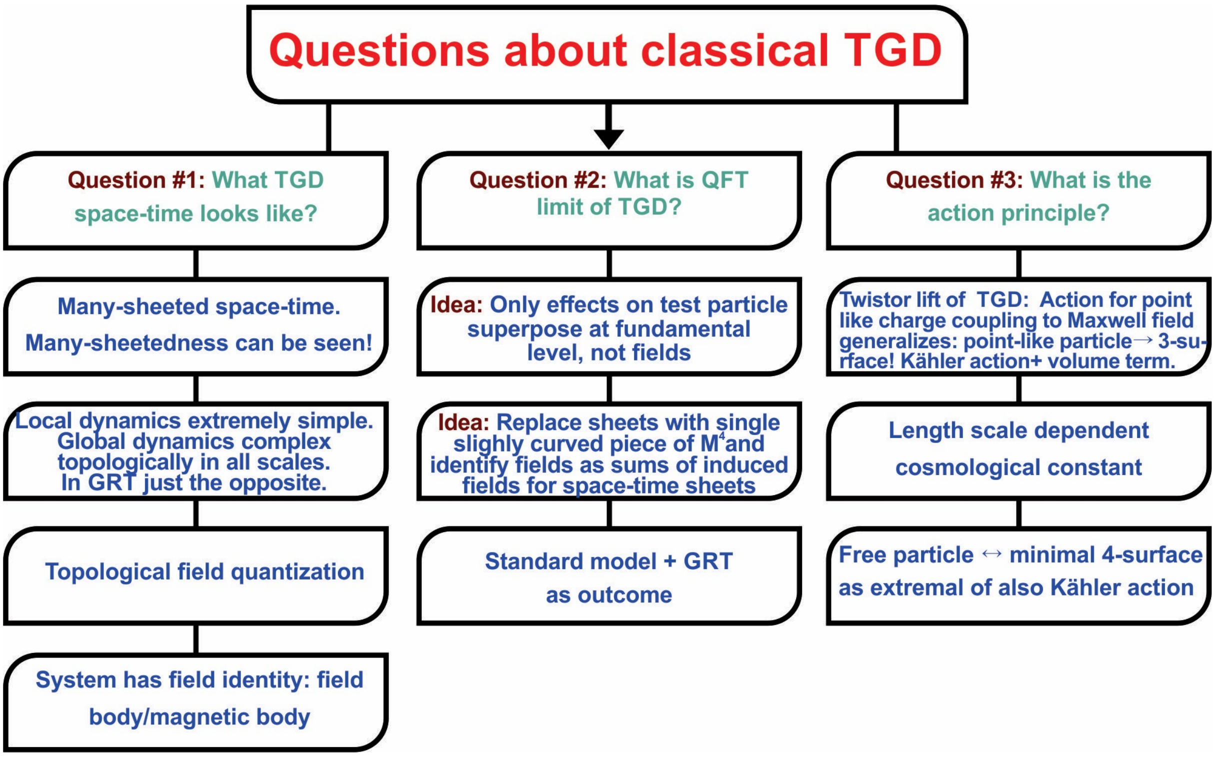

Figure 7: Questions about classical TGD.

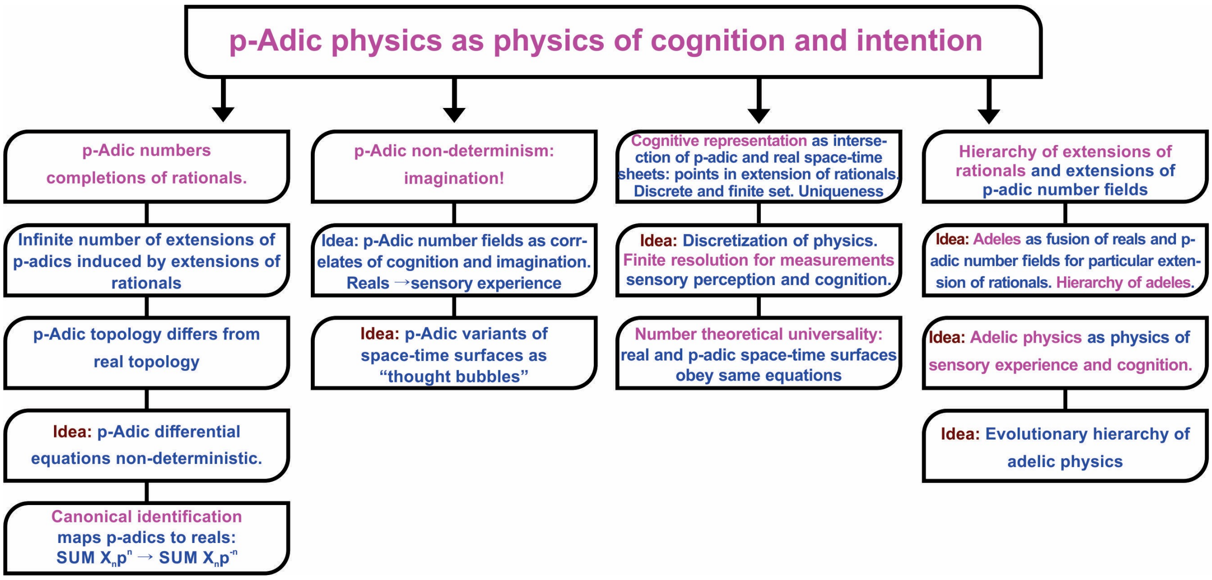

Figure 8: p-Adic physics as physics of cognition and imagination.

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.

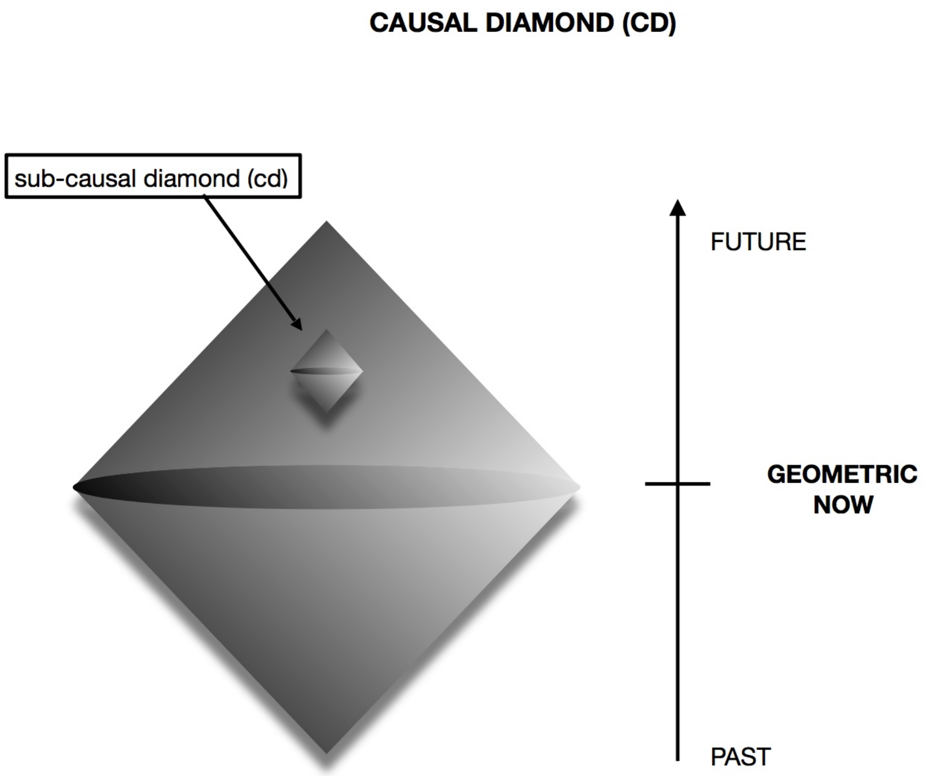

Figure 9: Causal diamond

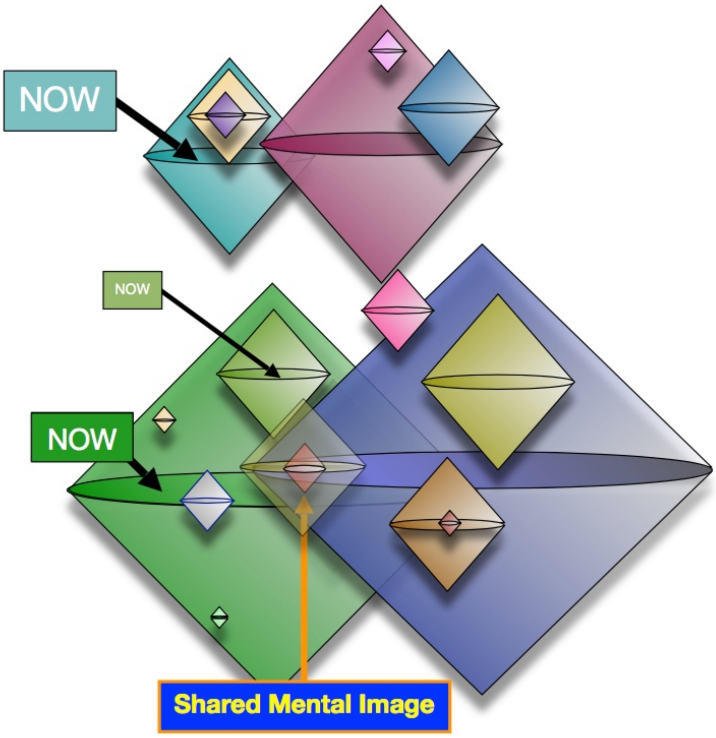

Figure 10: CDs define a fractal "conscious atlas"

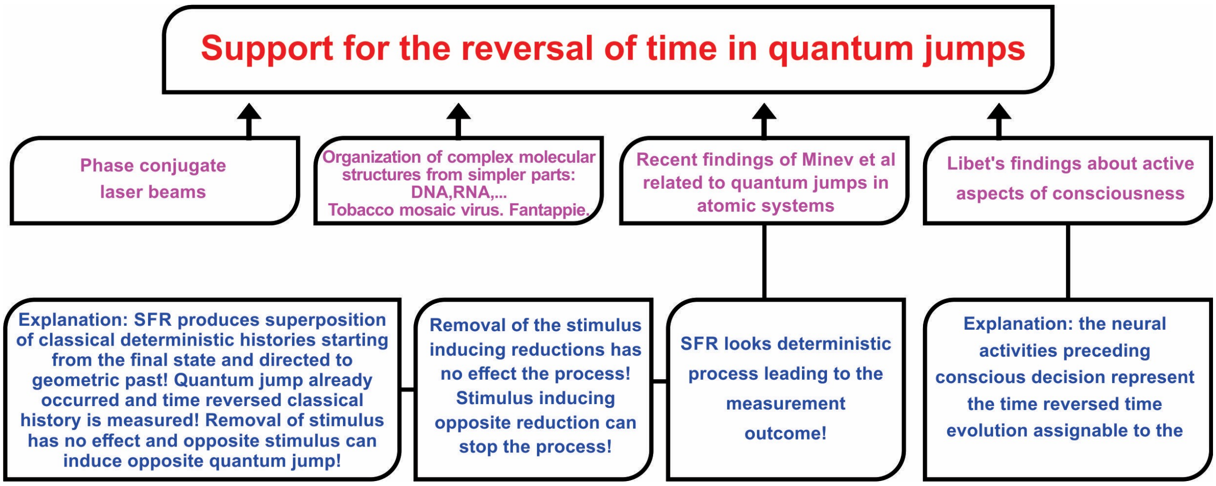

Figure 11: Time reversal occurs in BSFR

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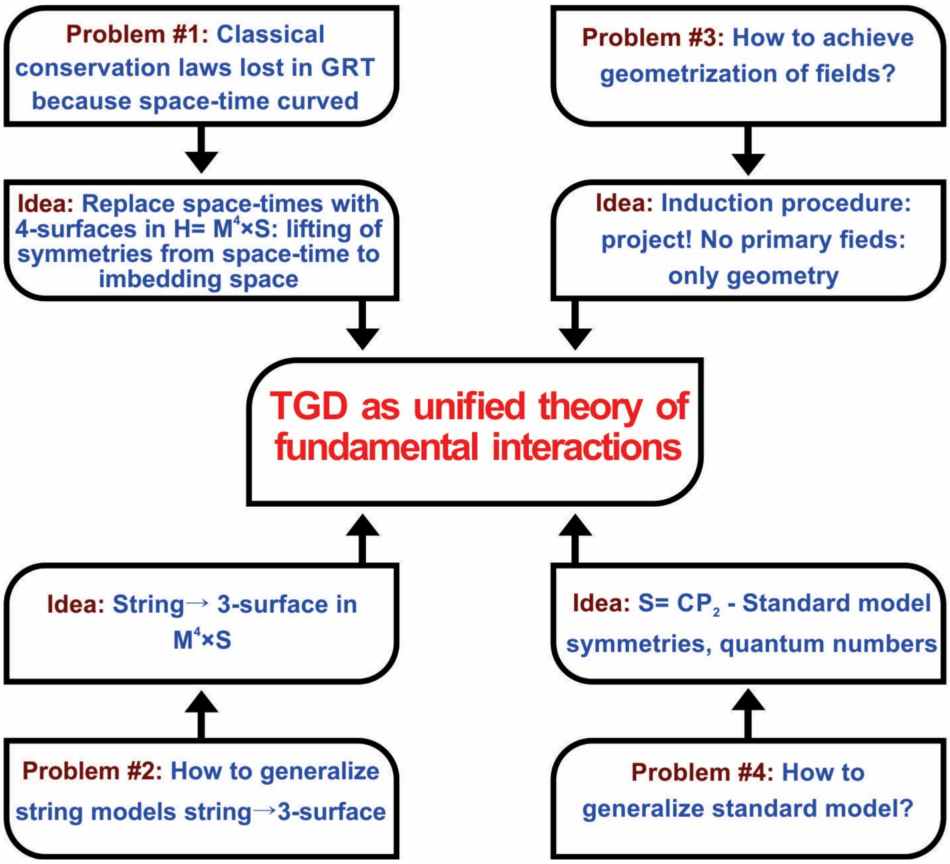


Figure 12: The problems leading to TGD as their solution.

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

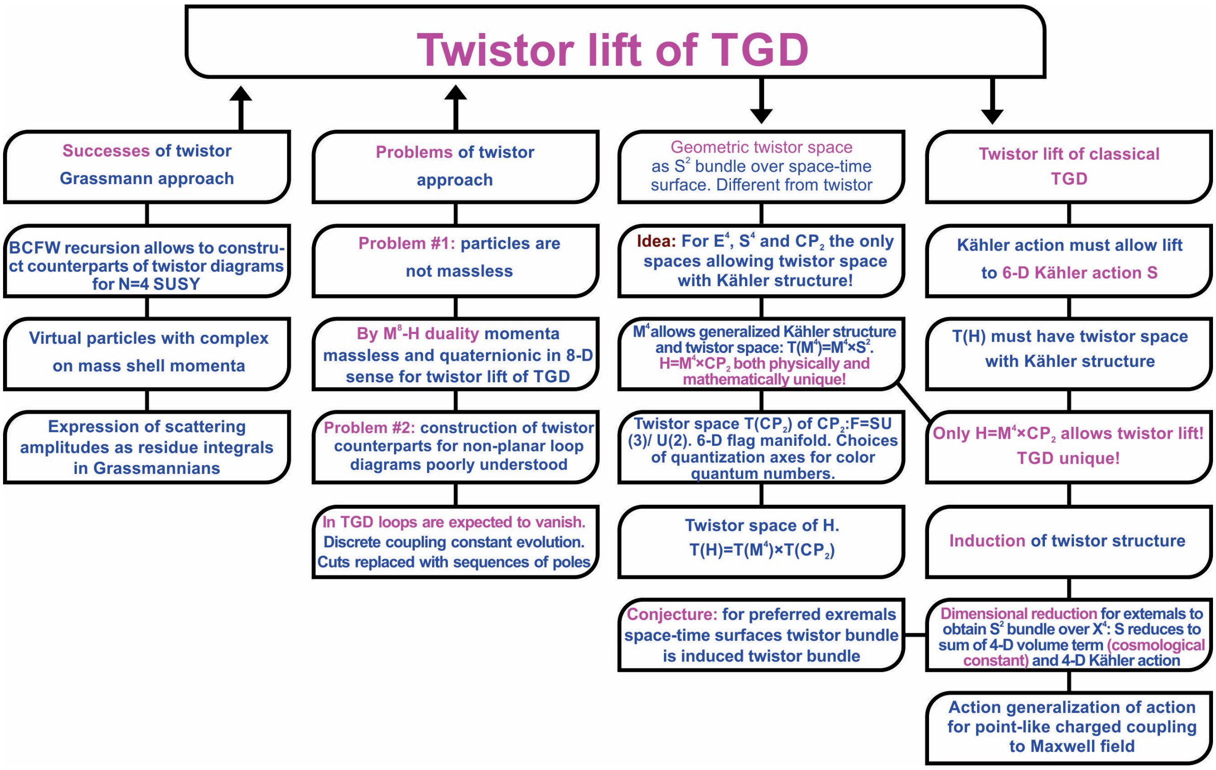


Figure 13: Twistor lift

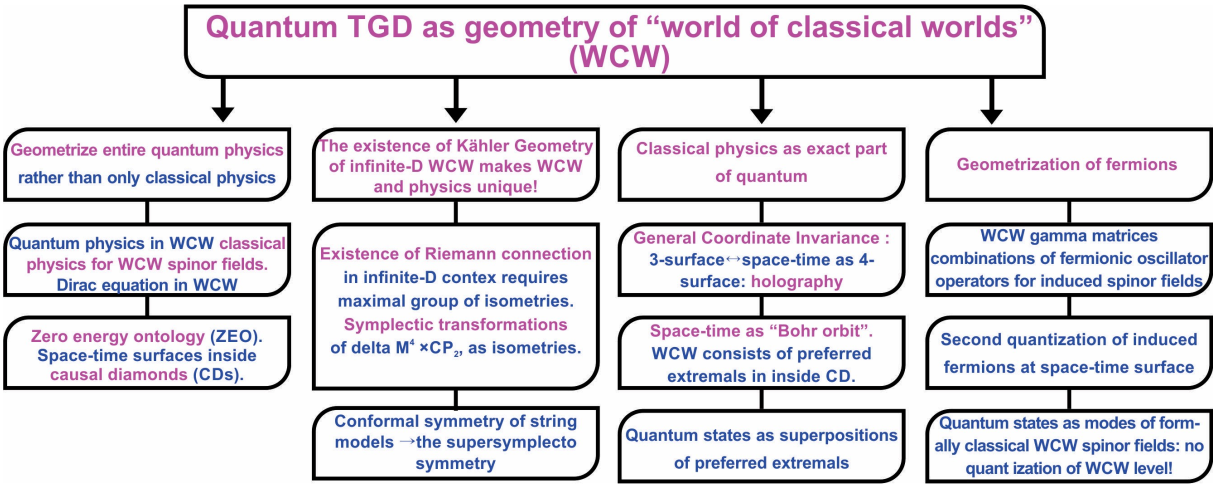


Figure 14: Geometrization of quantum physics in terms of WCW

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

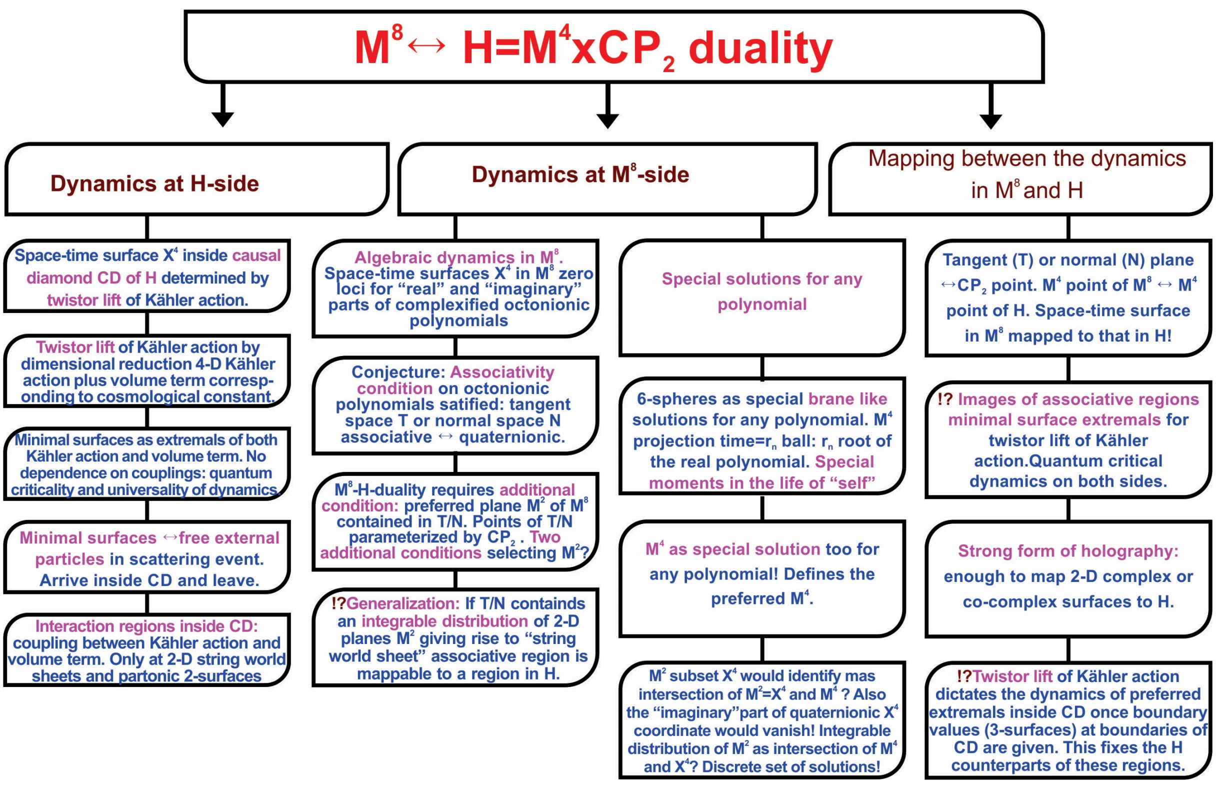


Figure 15: $M^8 - H$ duality

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

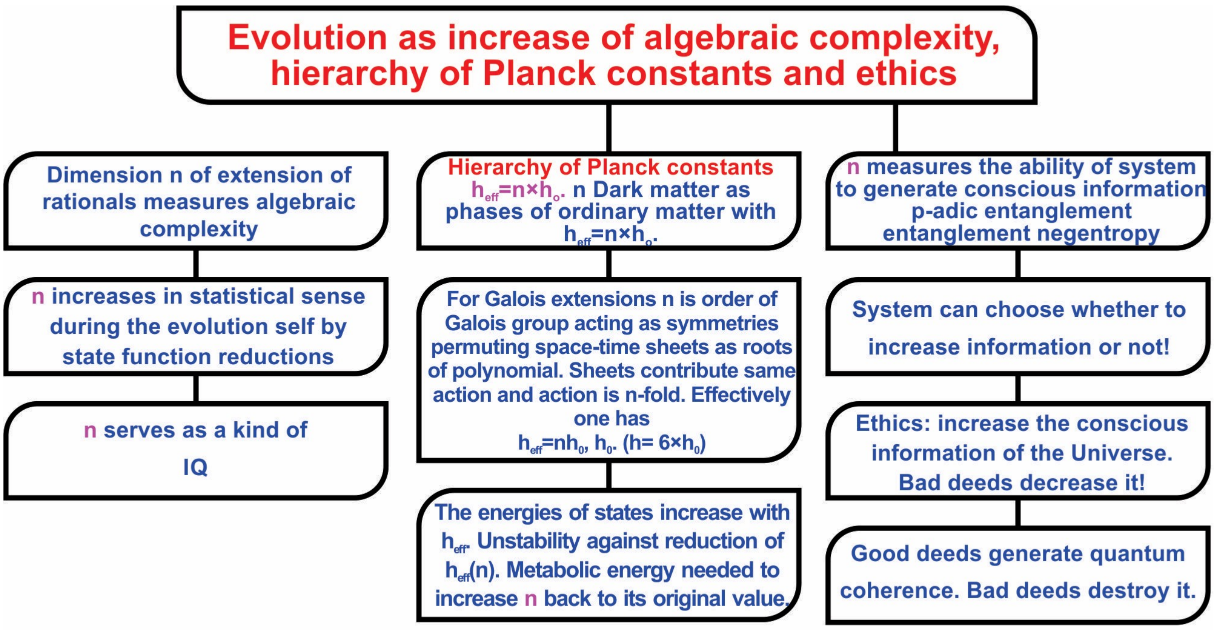


Figure 16: Number theoretic view of evolution

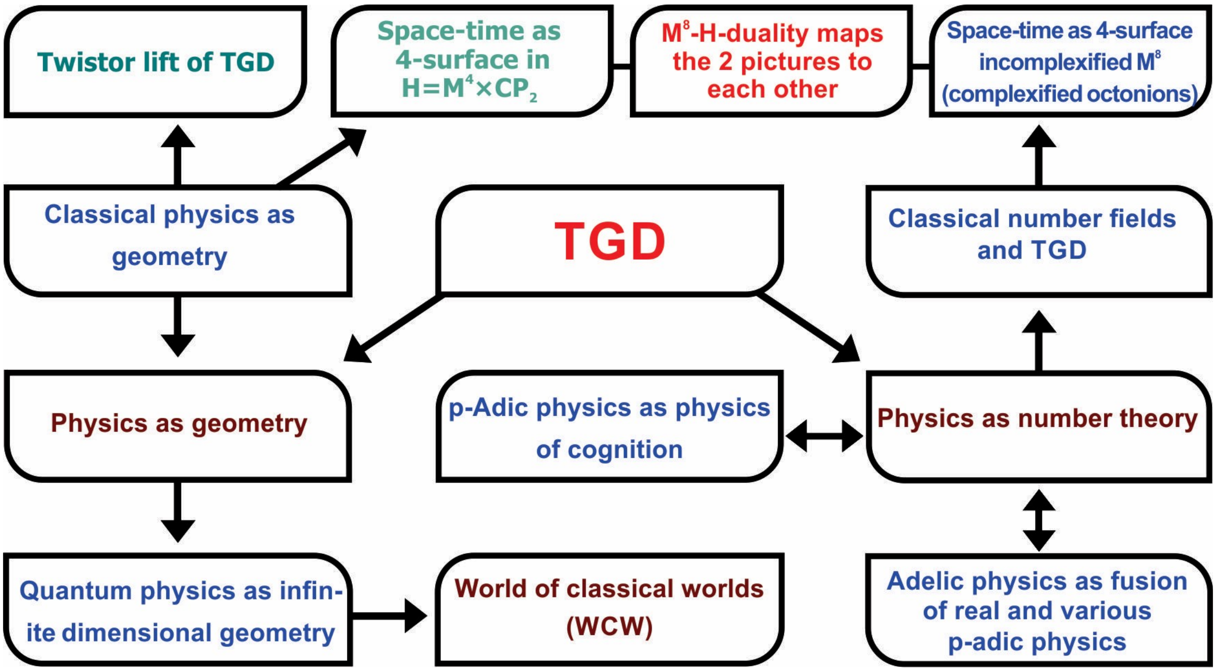
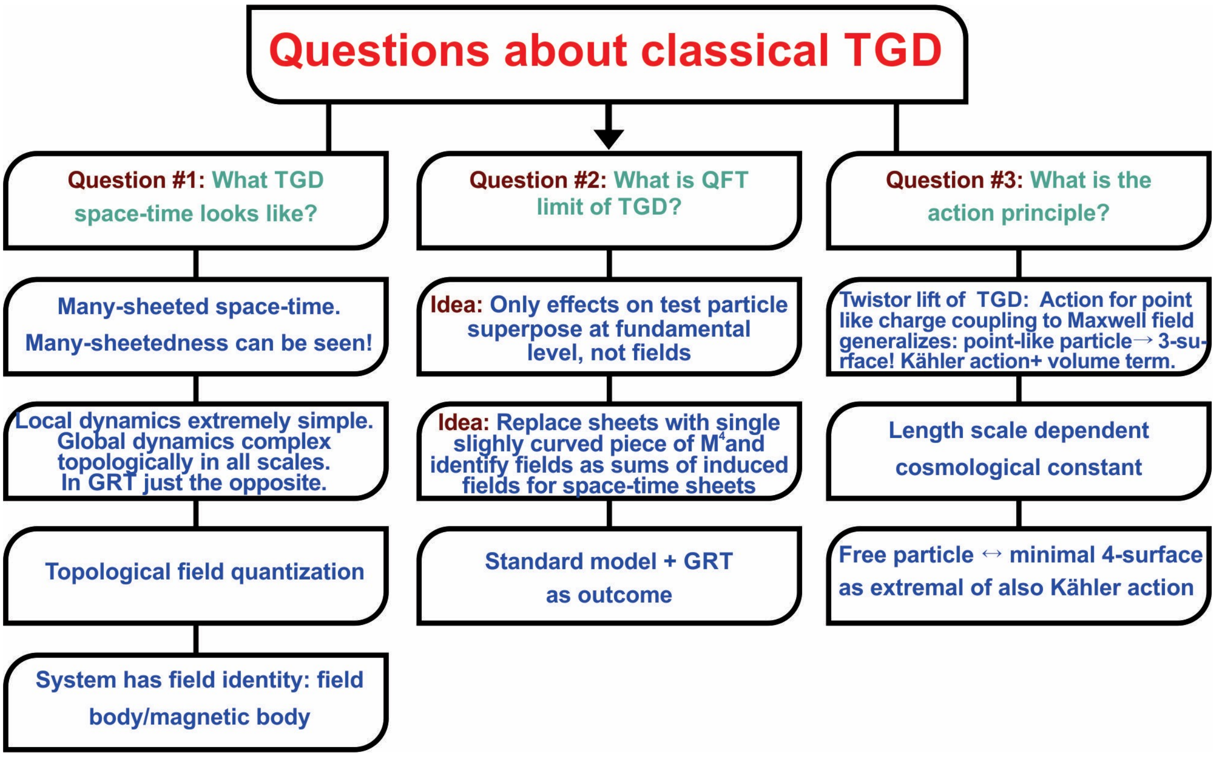


Figure 17: TGD is based on two complementary visions: physics as geometry and physics as number theory.



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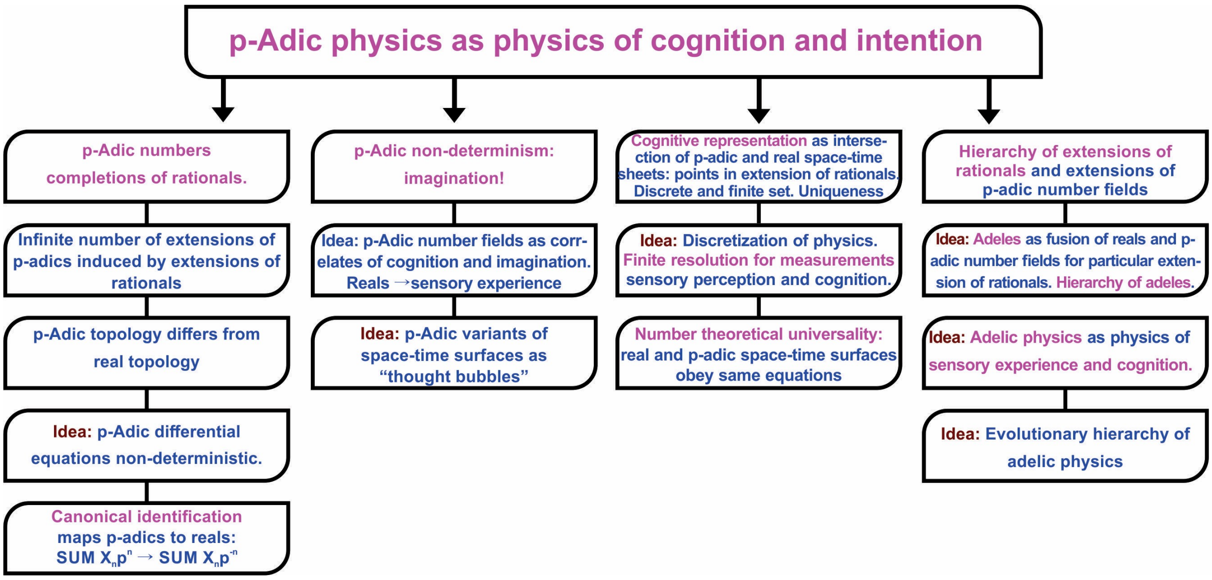


Figure 19: p-Adic physics as physics of cognition and imagination.

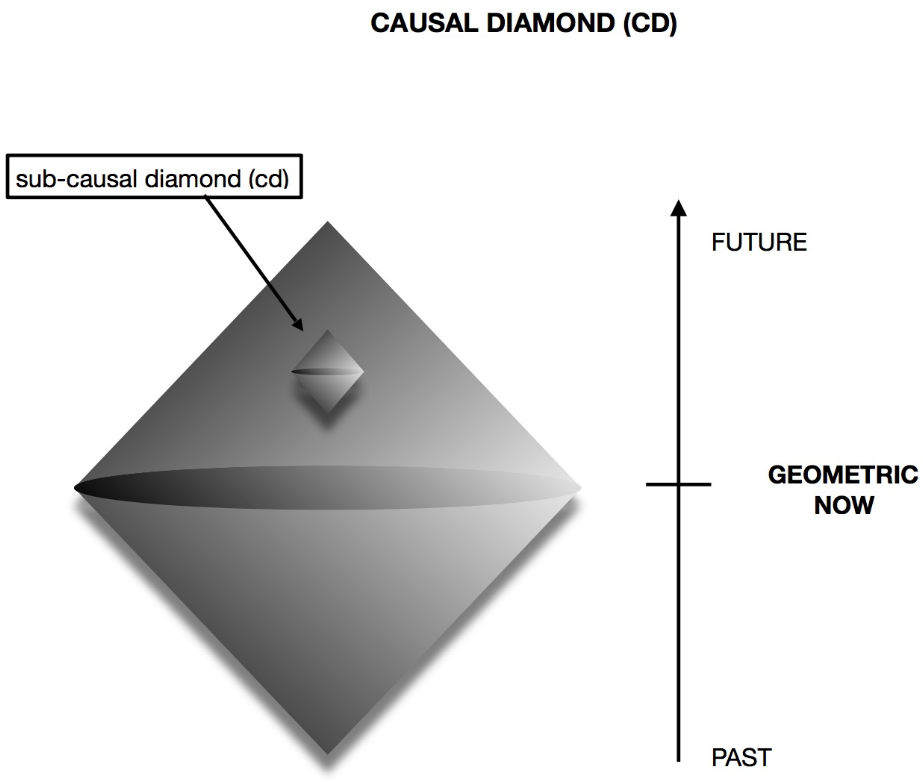


Figure 20: Causal diamond

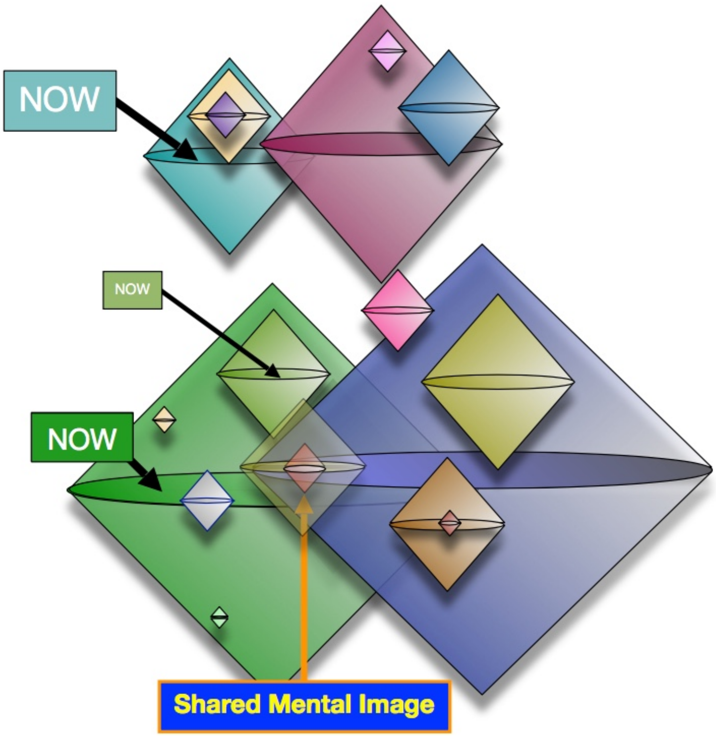


Figure 21: CDs define a fractal “conscious atlas”

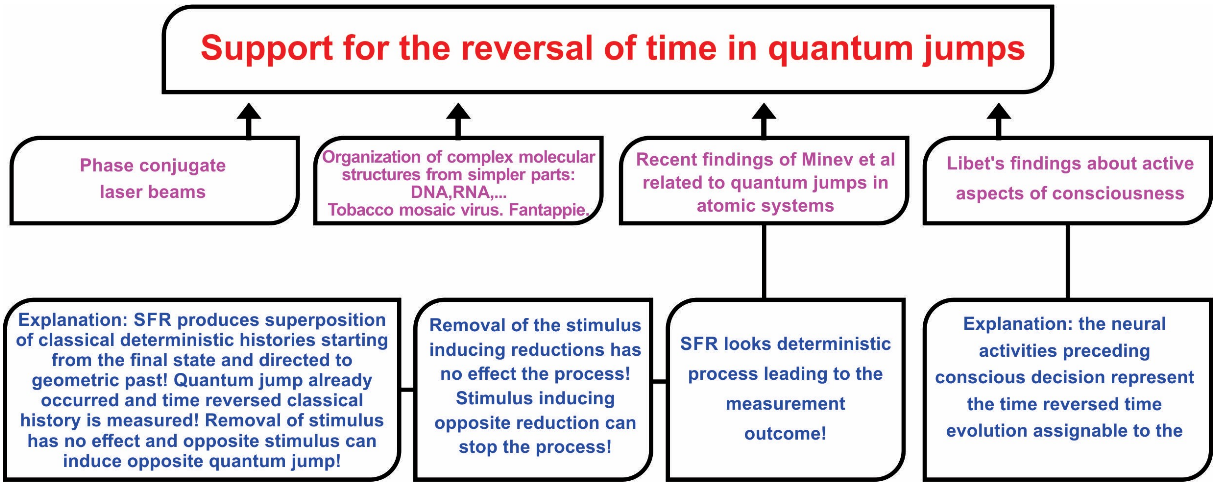
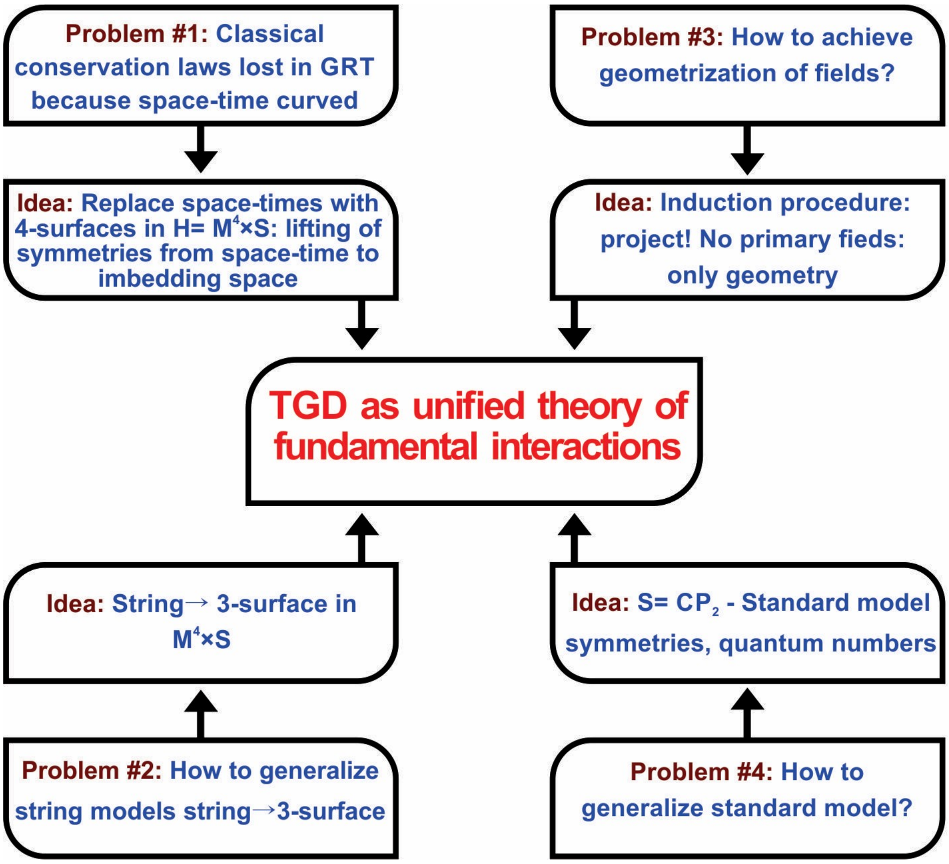


Figure 22: Time reversal occurs in BSFR



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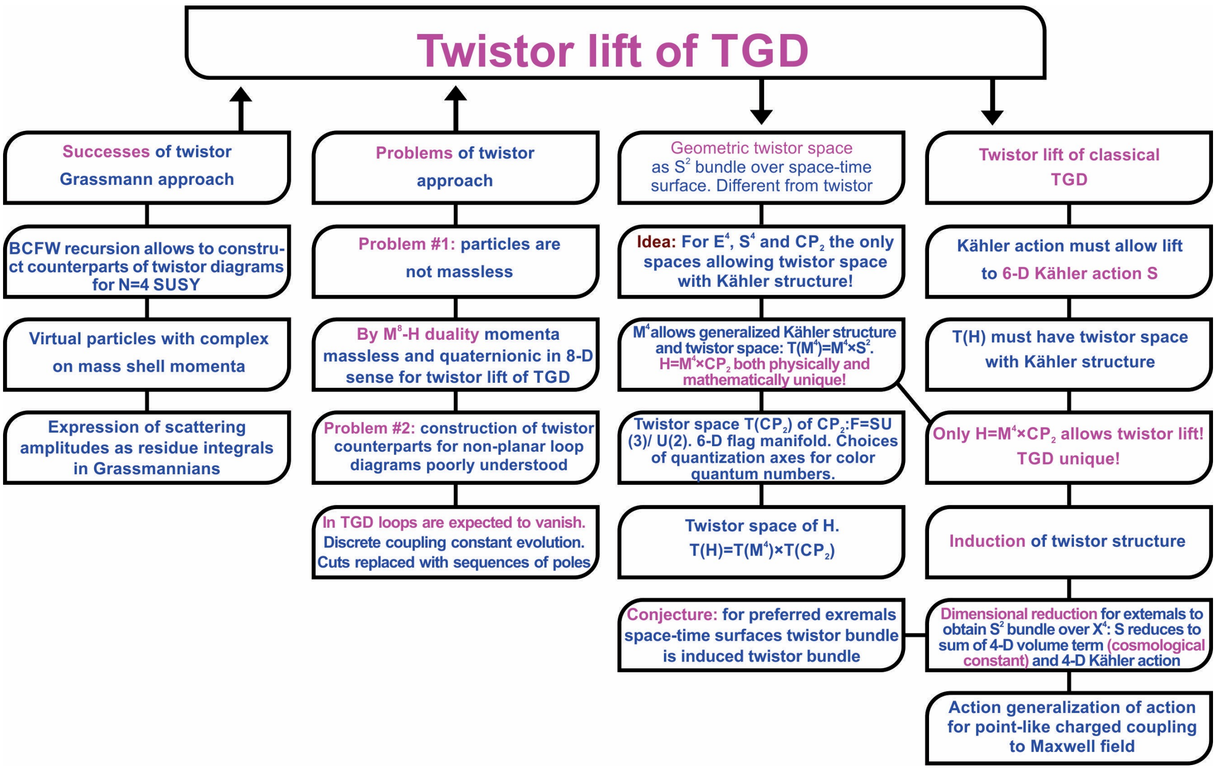


Figure 24: Twistor lift

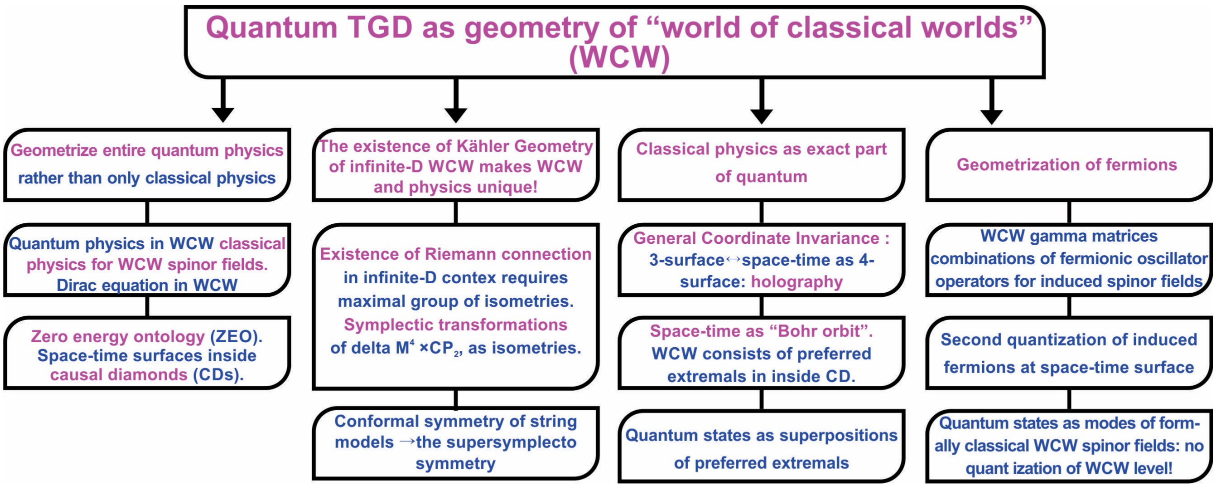


Figure 25: Geometrization of quantum physics in terms of WCW

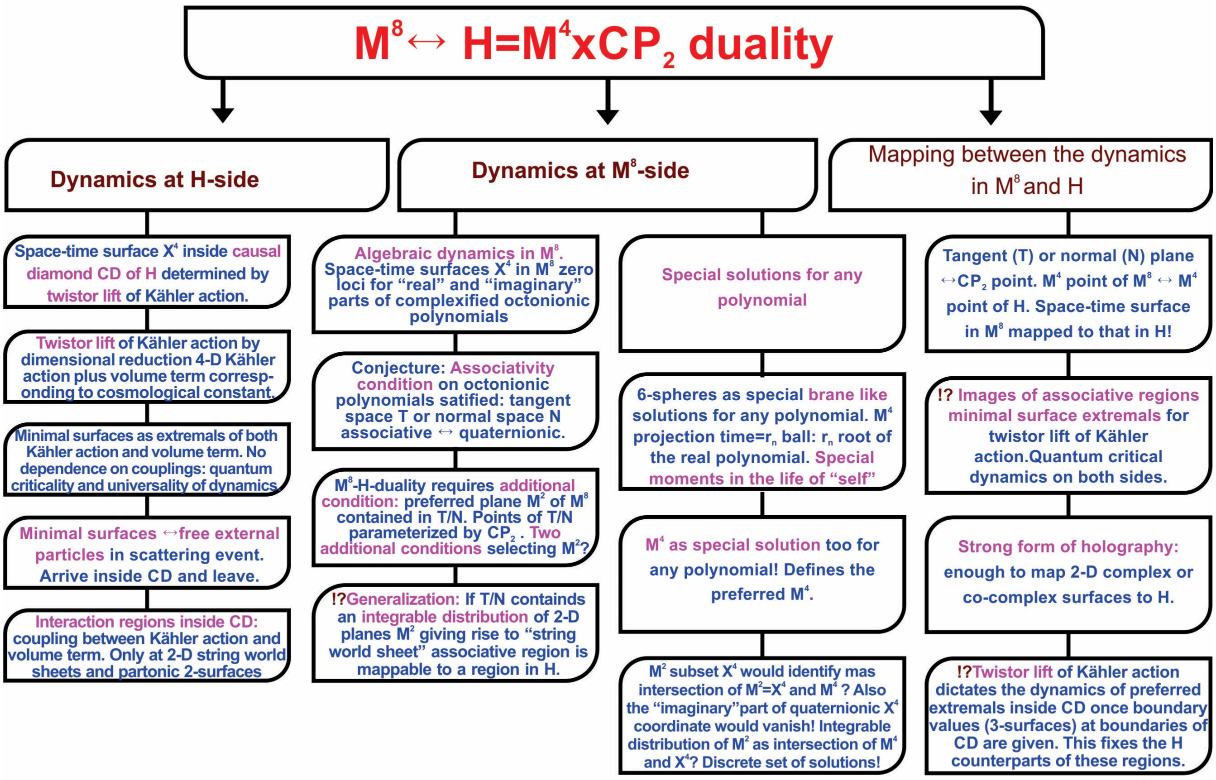
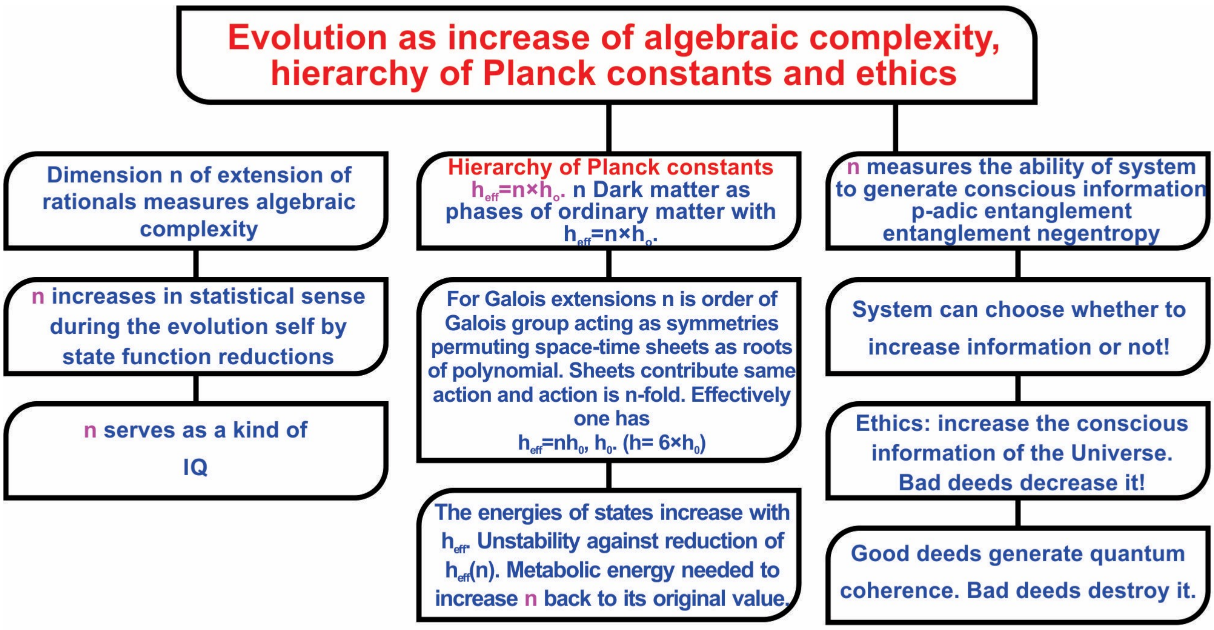


Figure 26: $M^8 - H$ duality



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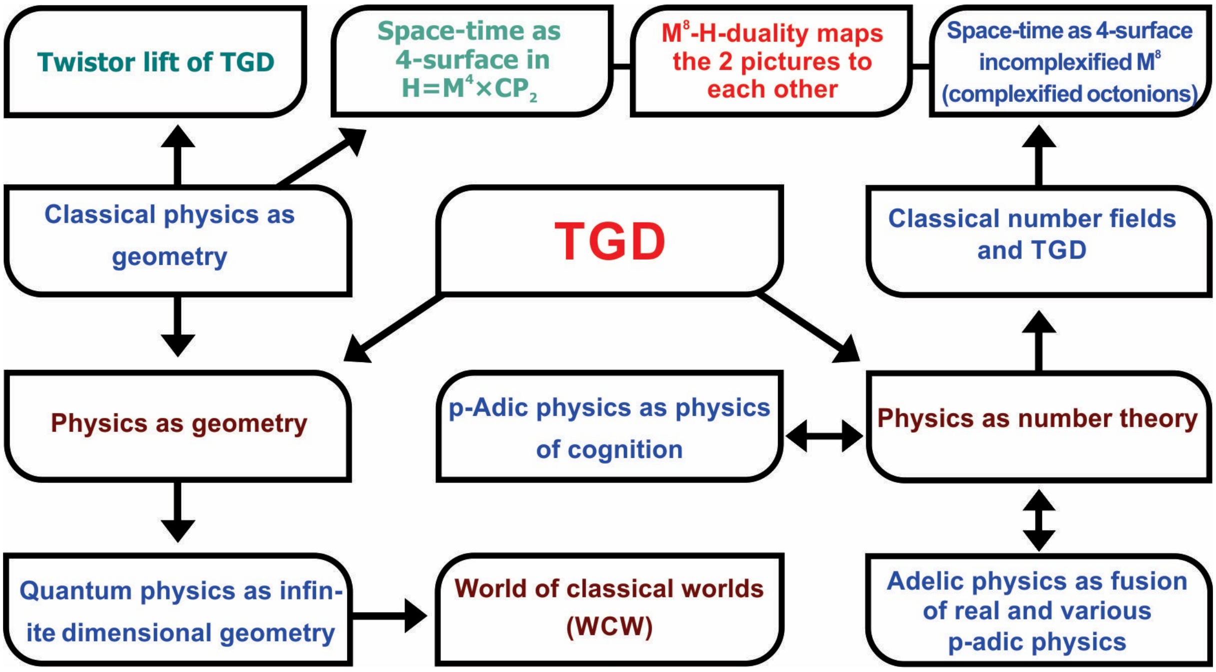

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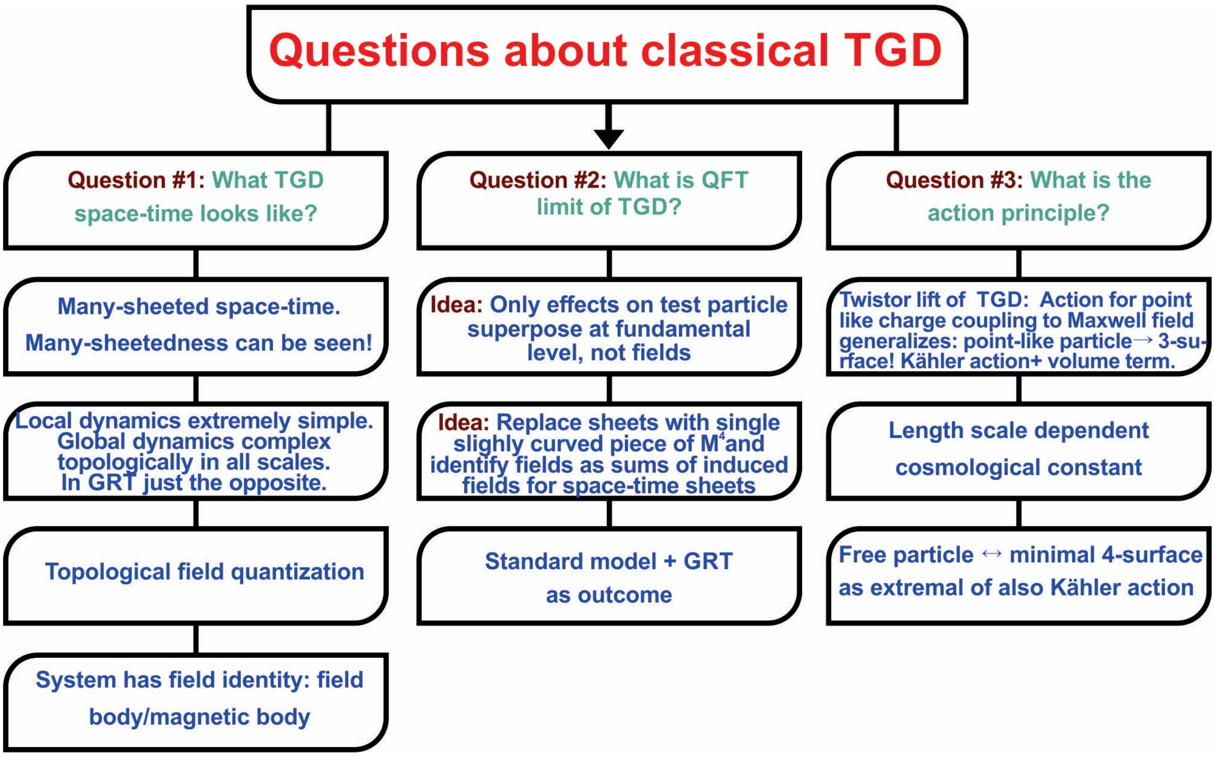

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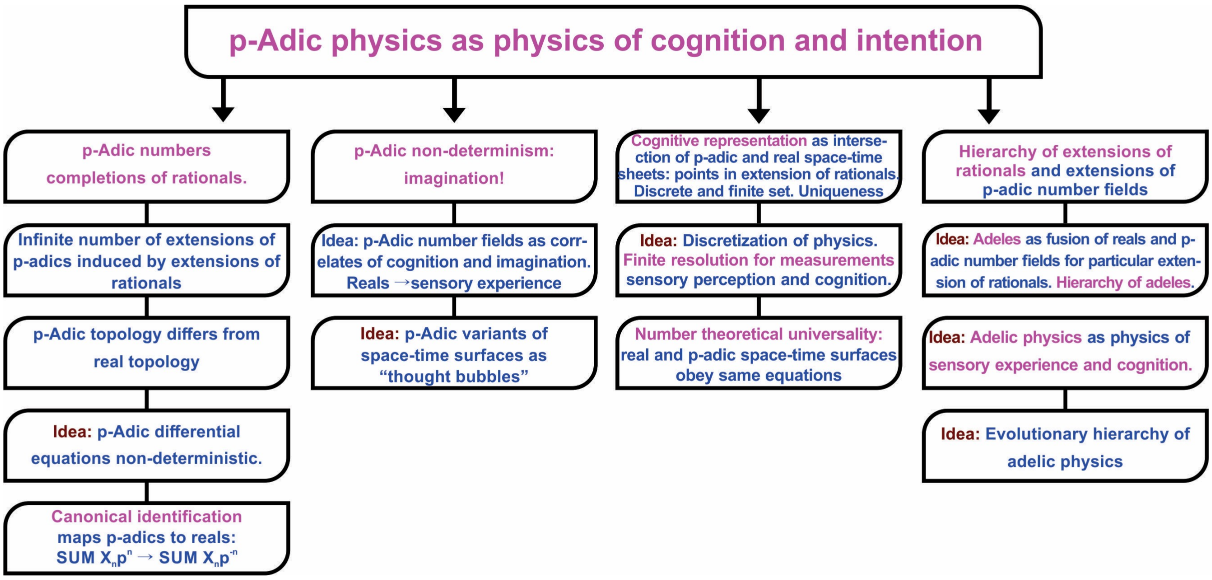

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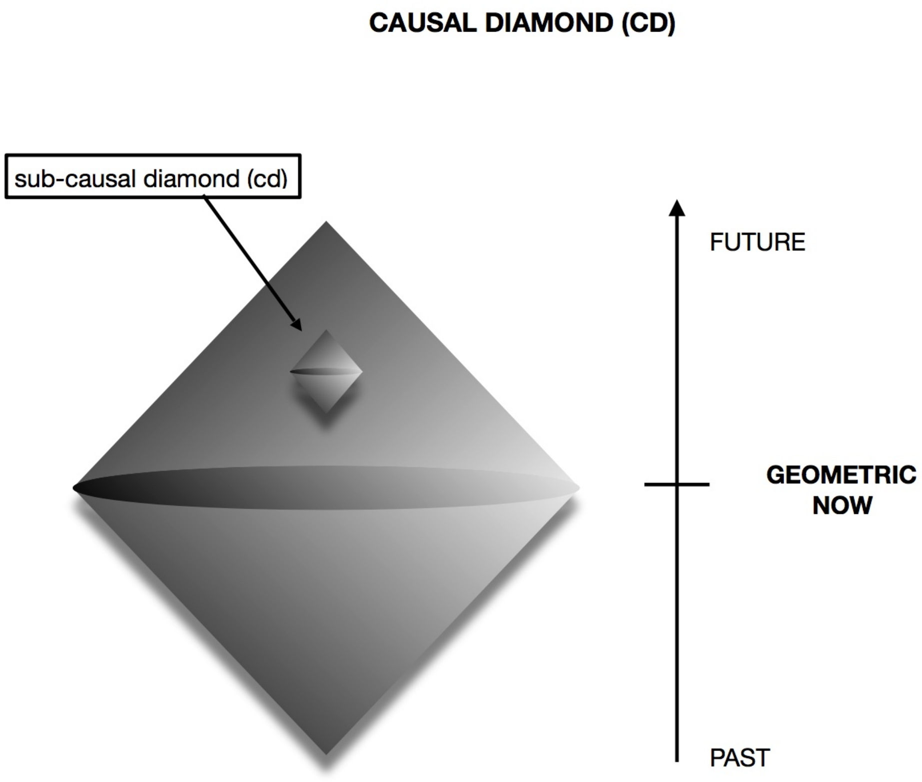
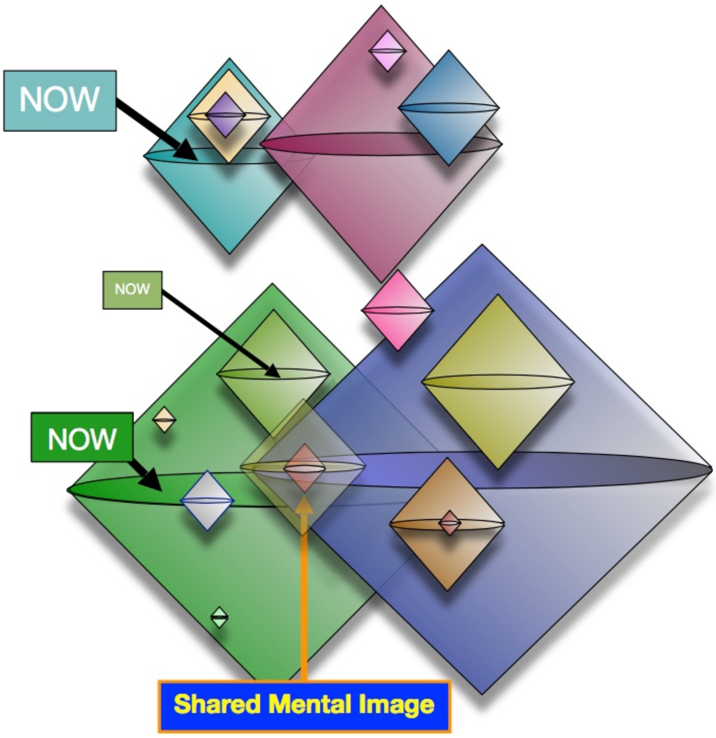


Figure 31: Causal diamond



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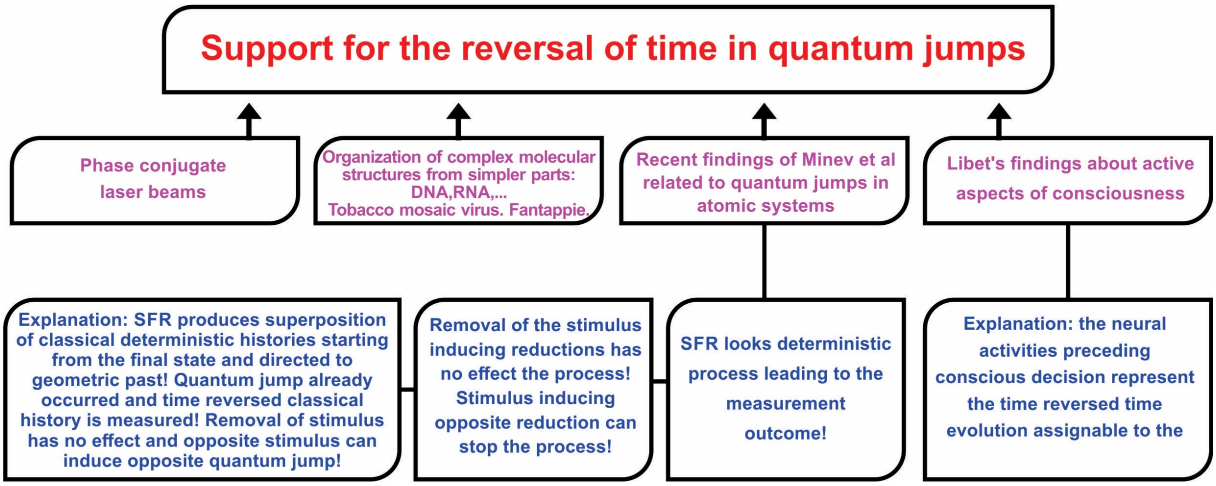

Figure 33: Time reversal occurs in BSFR

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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Chapter 1

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 [A18]. 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 non-vanishing 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 [A3] [B9, B7, B8]), 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 [B5]) 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 [A13, A17, A11, A16].

The identification of the space-time as a sub-manifold [A14, A20] 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. ??** 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 [A19, A21, A25]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. 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 [K49]. 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^8_c 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 $Y^4 \subset M^8_c$ 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 [K45].

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^8_c

$Y^4 \subset M^8_c$ 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^4_c 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 $M^4_c \subset M^8_c$, 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 $Re(E)^2$.

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

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 $Y^4 \subset M^8_c$ 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 $M^4_c \to SU(3)_c \subset G_{2,c}$, 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 $SU(3) \rightarrow CP_2$ 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^8_c 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 $H^3 \subset M^8_c$ and its image $H^3 \subset H$ vanish. One would have color confinement at the mass shells H^3_i, 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^3_i.

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 [K79].

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 [K63, K64, K61]) 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 [K90]. 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 [A18]. 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 [L35].

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 [L27]. 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 [K89, K9, K60, K7, K31, K39, K42, K81, K87].

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

$$\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f \ \ ,$$

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 [J54] 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) [K45] 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 [K72]. 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 [K84] . 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 [K23].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [K23]. 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 [K23]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K40, K23]. 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 [K23].

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 [K22, K23]. 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 [K23]. 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 [K40, K23]. 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 $A \rightarrow B$ 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 [K94, K91, K71, K53, K12, K50, K34, K82] and nine online books about TGD inspired theory of consciousness and quantum biology [K89, K9, K60, K7, K31, K39, K42, K81, K87] 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 $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f$ 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

INTELLIGENCE, INFORMATION, AND COGNITION

Chapter 2

Conscious Information and Intelligence

2.1 Introduction

This chapter is a fusion of two separate parts, the first one devoted to information measures for conscious experience and second summarizing a quantum model for intelligent systems. This reflects in its own way the fact that the development of the related ideas has not been a linear process and has involved many weird twists typical for a mathematical thinking without strong connection with empiria.

The motivation for the recent updating are the developments in basic quantum TGD and in TGD inspired theory of consciousness (I am writing this towards the end of March, 2015). In the following I try to summarize TGD inspired view about information, intelligence and consciousness. Some of the memes of the previous updated version prepared around 2003 have lost the game and new memes - or rather an overall vision about conscious intelligence - has emerged. This is also due to the unification of about decade old ideas related to TGD proper to form single coherent whole.

One of the most notable losers is the hypothesis about the quantum jump replacing p-adic space-time sheet with a real one as a realization of intentional action. The hypothesis was inspired by the idea that p-adic space-time sheets are correlates for both cognition and intentionality. In adelic vision about TGD space-time surfaces are correlates both for the sensory and cognitive aspects and intentional action are assigned state function reduction. Intention is assigned with the sequence of repeated state functions defining self and subselves as mental images of self. Quite generally, p-adic and real aspects integrate to form an adelic view at all levels rather than being thought to be something separate.

The earlier vision identifying evolution at basic as a generation of number theoretic complexity of algebraic extensions of rationals becomes rather concrete in the adelic vision about TGD, and the strong form of holography leads to an elegant unification of real and p-adic physics in terms of number theoretic universality in the intersection of real and p-adic worlds defined by string world sheets and partonic 2-surfaces and serving as the seat of life. This intersection carries also the cognitive and sensory representations and for the parameters characterizing extension take physical meaning.

The new elements relate to the progress in the understanding of the notion of self implied by a generalization of quantum measurement theory based on Zero Energy Ontology (ZEO). In particular, the precise definition of Negentropy Maximization Principle and role of negentropic entanglement (NE) leads to powerful predictions consistent with what is known about biology and consciousness and very relevant for the notion of evolution of conscious intelligence. Also the realization that the hierarchy of Planck constants corresponds to a hierarchy of quantum criticalities realized in terms of symmetry breakings has strong implications central for understanding evolution and intelligence.

2.1.1 Magnetic Body As Intentional Agent And Experiencer

The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion-like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism [K23].

The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

Magnetic flux tubes and flux sheets are basic building bricks of the magnetic body and DNA as topological quantum computer hypothesis assumes that DNA nucleotides are connected to cell membrane by flux tubes defining braids playing a key role in topological quantum computation [K2]. Therefore magnetic body is essential for realizing the software of biological intelligence. The essential assumption is that magnetic body carries dark matter consisting of ordinary with a non-standard value of Planck constant. The phase transition changing the value of Planck constant change the size scale of the flux tube and this process together with reconnection of the flux tubes would define mechanisms of bio-catalysis.

Magnetic bodies - or rather their time evolutions connecting two space-like 3-surfaces at the opposite boundaries of causal diamond (CD) in ZEO - are natural space-time correlates for memes and the replication of magnetic bodies completely analogous to what happens in 3-particle vertex makes possible the replication of memes and is assumed to induce biological replication. 4-D character of the quantum self-organization and of the space-time correlates of zero energy states can be seen as an essentially new element allowing to understand how behaviors and function emerge.

2.1.2 What Is Conscious Intelligence

The following summary tries to give a brief summary about how conscious intelligence could be understood in TGD Universe. The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is certainly the most important aspect in this respect. ZEO (ZEO) and the notion of causal diamond (CD) lead to the modification of quantum measurement theory allowing to define the notion of self and explaining basic aspects of consciousness. 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.

Zero energy ontology and intelligence

In zero energy ontology (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 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.

ZEO combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of the 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 [K96]. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD in terms of the Kähler-Dirac action.

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.

ZEO implies that 3-D objects are replaced by pairs of space-like 3-surfaces at opposite boundaries of CD and holography implies that space-time surfaces replace 3-D objects. Spatiotemporal patterns or actually their quantum superpositions become the basic objects. Behavior and function matter rather than the state of system, say brain, at given moment. This has important implications for the view about morphogenesis in biology and behavior in neuroscience. Self-organization becomes evolution of 4-D rather than 3-D patterns. Identifying magnetic bodies as counterparts of memes, one can even speak about replication of memes inducing that of living matter. Obviously these aspects are central also for understanding of intelligence.

The original interpretation of the space-time correlates of mental images was as mind-like space-time sheets identified as space-time sheets with a finite temporal size. In ZEO all space-time sheets have a finite size and serve as correlates for zero energy states, which could be interpreted as representations of laws of physics as superpositions of pairs of initial and final states given by M-matrix. In state function reduction process these states are reduced to states for which only negentropic time-like entanglement is possible and one might say that the negentropy measures the conscious information associated with the final state of the reduction process. One can interpret negentropic quantum states as memes or morphogenetic fields [K72] [I15].

ZEO based quantum measurement theory leads automatically to the notion of self predicting that self has a finite life-time [K43, K74]. The highly non-trivial prediction is that in death caused by a state function reduction to the opposite boundary of CD self re-incarnates at the opposite boundary of CD as a time-time reversed version: at the level of sub-selves this means replacement of mental image with its time-reversed mental image. The experience flow of subjective time finds a simple explanation and the question why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD) [K93, K4].

The decomposition of contents of consciousness of self to a static part coming from the passive boundary of CD at which state function reduction sequences has no effect and to part coming from the active boundary of CD, which changes and for which the state changes suggest interpretation as an analog of figure-background or experiencer-experienced division. The time reversal would change the roles of figure and background and vase-faces illusion could be an example about time reversal of mental image. Time reversed writing and time-reversed speech [K74] could be also examples about directly experienced time reversal of mental images. This aspect of selfness is certainly crucial for understanding intelligence: since figure back-ground divisions is what intelligent systems perform routinely. For instance, right and left brain might be specialized to produce time reversed views about same sensory input.

Also first and third person views might correspond to time reversed mental images. In near death experiences person sees himself as an outsider: could this be interpreted as the change of the roles of figure and background interpreted as first and third person perspectives?

Weak form of NMP

The precise form of NMP has chrystallized only gradually. The strong form of NMP states that negentropy gain in state function reduction is maximal. This would fix completely the sub-system complement pair of system for which the reduction takes place and if negentropic entanglement is present also the final state as negentropically entangled state with density matrix which is projector to subspace which has dimension which can be also higher than $d = 1$. In standard quantum theory one has $n = 1$ and one can argue that the density matrix in practices has only non-degenerate eigenvalues in real context. In TGD framework quantum criticality changes the situation and quantum critical states have the property that $d > 1$ is possible.

It has however turned out that strong form of NMP does not allow genuine morally responsible free will. We would live in best possible world which does not seem to be the case. This leads to the proposal that weak form of NMP is more appropriate formulation. Again NMP would select the sub-system-complement pair which can produce the maximal negentropy gain but the continuation is different.

1. Suppose that $n > 1$-dimensional projector would produce maximum negentropy gain and would be thus forced by strong form of NMP. The weak form of NMP allows self associated with the CD containing the CD of self as sub-CD to choose also lower-dimensional subspace of sub-space of dimension $n-k$, $0 \leq k < n$.

   For $k = n-1$ one has ordinary state function reduction destroying NE and isolating the self from the rest of the world. This means free will. Note that self does not itself decide what as it dies and reincarnates: it is self above who decides! One can also understand the quantum correlates of ethics and moral if the generation of NE is what good deed means. The death of self is like picking a fruit from tree and the self picking it decides how much NE is created.

2. If one has fixed base for n-dimensional sub-space (this might be questioned) one the resulting subspaces have dimension in the range $1, ..., n$ and their number is $2^k - 1$: this like putting $n-k$ balls in distinct boxes in all possible way and the number is given by binomial coefficient: the 0-dimensional final state space is not allowed. This would suggest that the choices are in 1-1 correspondence with the basis of Boolean algebra of k bits. Since the amount of negentropy generated should measure the degree of positive emotional coloring of the choice, it is possible that one has kind of emotional realization of of Boolean logic with one statement thrown away (in set theoretic realization this would be the statement represented by an empty set). Since the p-adic prime appearing in the definition of number theoretic negentropy is a factor of $n-k$, those values of $n-k$ near to n, which correspond to powers of single prime produce largest negentropy gain and would be favored so that powers of prime are favored by selection implied by weak form of NMP.

3. An interesting question is whether this "emotional" realization of logic can be mapped naturally to the realization of Boolean logic by many-fermion states in ZEO (many-fermion state and its counterpart with opposite quantum numbers at opposite boundary of CD in a fixed basis realize the Boolean statement). This realization could be fundamental for understanding the correlates of emotional intelligence at quantum level.

One can represent an objection against the proposed emotional realization of Boolean logic. One is choosing from the discrete set of sub-set of a fixed basis for n-dimensional space. Why not to choose from the continuous set of sub-spaces? This would be the classical option. There is a continuum of choices for $n-k$-dimensional sub-space and the choices are parameterized by complex Grassmannian $G(n,k)$ (appearing in twistor Grassmann approach to scattering amplitudes!) and now one can talk about probabilities only. The probability for a choice of $n-k$-dimensional subspace would be naturally proportional to the volume of Grassmannian $G(n,k)$. The first problem is that this volume is vanishing for $k = 0$ so that the choice with maximal dimension would have zero probability. The second problem is that volume of $G(n,k)$ is proportional to a scale parameter R raised to the dimension $d(k) = k(n-k)$ of $G(n,k)$ and the condition that probabilities for various choices depend on the choice of R. It seems that the classical option cannot make sense and will not be discussed in the sequel.

Boolean mind and fermions

The connection of fermionic Fock space basis with Boolean algebra was one of the first ideas related to the quantum modelling of intelligent systems. The state basis for the fermionic Fock space has a natural interpretation as Boolean algebra (fermion number $=1/0 \leftrightarrow$ yes/no). In this way ordinary Boolean algebra is extended to a vector space spanned by fermionic states. Fermion number conservation poses an obvious problem for this scenario in positive energy ontology. ZEO resolves this problem quite generally and zero energy states resulting as an outcome of state function reduction process represent Boolean statements of type A$\rightarrow$ B in terms of time-like NE in fermionic degrees of freedom.

The original proposal was to use cognitive fermion pairs instead of fermions with fermion and anti-fermion located at the opposite throats of wormhole contact. In the recent formulation of quantum TGD bosons and their super counterparts correspond to wormhole contacts. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic and whether our logical mind could have something to do with Boolean algebra. For instance, could primary "this is true" experiences correspond to Boolean qualia having increments of fermionic quantum numbers as physical correlates. Boolean truth values could also correspond to spin directions of fermions. In this case fermion number conservation does not pose any constraints and the macroscopic realization replacing single spin as a representative of bit with a magnetized ensemble of fermions, makes the realization robust.

Negentropic entanglement (NE) means that qubits are always fuzzy and the fuzziness depends on the situation. The positive aspect is that the quantum superposition gives rise to an abstraction, rule about pairing of say initial and final states represented as positive and negative energy parts of zero energy state with the pairs of superposition representing the instances of the rule. p-Adic-real entanglement with positive definite number theoretical entanglement entropy in the intersection of real and p-adic worlds could give rise the experience of understanding and makes possible cognitive quantum computation like processes.

A new element is the realization that spinor modes and thus fermions are localized to string world sheets and partonic 2-surfaces by the condition that em charge is well-defined. There are many other reasons for this localization. By strong form of holography these 2-surfaces define kind of space-time genes. The natural assumption is that they are in the intersection of reality and various p-adicities in the sense that the parameters characterizing them belong to an algebraic extension of rationals and are therefore discretized.

This makes possible an elegant correspondence between real and p-adic space-time sheets. They are not mapped to each other directly but obtained by holography from the fundamental 2-surfaces in the intersection by the condition that they are preferred extremals of Kähler action for which the classical Noether charges for a sub-algebra of super-symplectic algebra with conformal weights coming as n-ples of those for the full algebra vanish. No discretization at space-time level is required and problems with the general coordinate invariance (GCI) are avoided. By conformal invariance the parameters in question are general coordinate invariant conformal moduli. The vanishing of classical Noether charges for the sub-algebra of super-symplectic algebra characterizes partially the preferred extremals.

Fermions would reside in the intersection and be number theoretically universal. Indeed, the anticommutations relations are number theoretically universal, even in the case that they involve quantum group phase.

The hierarchy of algebraic extensions of rationals defines the fundamental hierarchy defining also evolutionary hierarchy. The higher the complexity of the extension, the higher the level in the evolutionary hierarchy. p-Adic primes are identified as ramified primes of algebraic extension and the large the p-adic prime the higher the level of cognition. The higher the dimension $n = h_{eff}/h$ of extension, the longer the scale of quantum coherence, and the higher the intelligence of the system. What distinguishes ramified p-adic primes from the others that the prime ideals of of integers of extension define by ramified primes are such that the action of Galois group is trivial. The interpretation is that for ramified primes n space-time sheets co-incide at their ends at boundaries of CD. This would be one way to interpret quantum criticality and consistent with the adopted interpretation. This brings in n "dark" discrete degrees of freedom which are crucial for intelligence and this is what makes corresponding p-adic primes so special.

Weak NMP supports the generalization of p-adic length scale hypothesis stating that ramified/p-adic primes near but below powers or primes are of special importance. Primes near powers of 2 appear in the original form of p-adic length scale hypothesis and should be central for understanding intelligence in TGD Universe. Finite fields associated with $p = 2, 3, 5$ can be realized as finite geometries representable by Platonic solids. Also other finite fields can be realized as finite geometries realized as regular polygons. This suggests that powers of primes near but below p^k, $p = 2, 3, 5$ are of special importance. The model of music harmony and genetic code based on icosahedral geometry supports this view: icosahedron corresponds to $p = 5$ finite projective geometry [K65]. Music scales involve both 2-adicity (octave equivalence) and 3-adicity (quint cycle) and the finding that powers of 3 define time scales at which sudden jumps in biological evolution have occurred [I9] support this view. Cyclic group Z_5 defines one particular Galois group with 5 elements and corresponds to angle $2\pi/5$,whose cosine involves $\sqrt{5}$ defining an algebraic extension containing $\sqrt{5}$ and appearing in Golden Mean, which is fundamental in biology.

String world sheets and partonic 2-surfaces would be characterized by $n = h_{eff}/h$ and the ramified primes. Number theory alone does not predict any correlations between them. The generalization of AdS/CFT correspondence to TGD framework realizes quantum classical correspondence and suggests that the p-adic primes identified as ramified primes must divide n. This assumption would mean that even elementary particles would carry surprisingly large number of discrete dark degrees of freedom. For instance, electron would correspond to $n = M_{127} = 2^{127} - 1$ and carry 126 bits of information, and would be ideal for realizing memetic code that I proposed for two decades ago with inspiration coming from Combinatorial Hierarchy [K32]. The secondary p-adic time scale of electron is .1 seconds and corresponds to a fundamental bio-rhythm. The corresponding p-adic length scale corresponds to the size of Earth. Hence - in sharp contrast with standard physics expectations - elementary particles -also quarks - could be crucial for understanding conscious intelligence. Neutrinos correspond to p-adic length scale possibly longer than that associated with Gaussian Mersenne $M_{G,127} = (1 + i)^{167} - 1$. There are actually 4 Gaussian Mersennes in biologically relevant length scale range 10 nm- 2.5 μ m corresponding to $k = 151, 157, 163, 167$. This number theoretical miracle must have some deep meaning. That Gaussian Mersennes are in question might have some deep meaning. They represent primes of algebraic extension containing i possible for primes $p = 3 \ \ mod3$. Do

p-Adic physics as physics of cognition and imagination

The vision about p-adic physics as physics of cognition has gradually established itself as one of the key idea of TGD inspired theory of consciousness. There are several motivations for this idea.

The strongest motivation is the vision about living matter as something residing in the intersection of real and p-adic worlds. One of the earliest motivations was p-adic non-determinism identified tentatively as a space-time correlate for the non-determinism of imagination. 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 the 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 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 some unique 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. p-Adic reality is much like the dream reality consisting of rational fragments glued together in illogical way or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious looking interpretation for the solutions of the p-adic field equations would be as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general could have p-adic space-time sheets as their geometric correlates. A deep principle could 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.

The original idea was that p-adic space-time regions can suffer topological phase transitions to real topology and vice versa in quantum jumps replacing space-time surface with a new one is given up as mathematically awkward: quantum jumps between different number fields do not make sense. The new adelic view states that both real and p-adic space-time sheets are obtained by continuation of string world sheets and partonic 2-surfaces to various number fields by strong form of holography.

The idea about p-adic pseudo constants as correlates of imagination is however too nice to be thrown away without trying to find an alternative interpretation consistent with strong form of holography. Could the following argument allow to save p-adic view about imagination in a mathematically respectable way?

1. Construction of preferred extremals from data at 2-surfaces is like boundary value problem. Integration constants are replaced with pseudo-constants depending on finite number pinary

digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces.

2. Preferred extremal 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. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets and partonic 2-surfaces not allowed in real context and realizing imagination.

3. Could imagination be realized as a larger size of the p-adic sectors of WCW? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could the modes of WCW spinor fields for which 2-surfaces are extandable to space-time surfaces only in some p-adic sectors make sense? The real space-time surface for them be somehow degenerate, for instance, consisting of string world sheets only. Could imagination be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real preferred extremals? 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.

Although p-adic space-time sheets as such are not conscious, p-adic physics would provide a beautiful mathematical realization for the intuitions of Descartes. The formidable challenge is to develop experimental tests for p-adic physics. The basic problem is that we can perceive p-adic reality only as "thoughts" unlike the "real" reality, which represents itself to us as sensory experiences. Thus it would seem that we should be able generalize the physics of sensory experiences to physics of cognitive experiences.

Hierarchy of Planck constants and consciousness

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 [K26]. 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.

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 h_{eff}/g multiples of this time scale. These two hierarchies could allow to get rid of the notion of self as a primary concept by reducing it to a quantum jump at higher level of hierarchy. Self would in general consists of quantum jumps inside quantum jumps inside... and thus experience the flow of time through sub-quantum jumps.

The hierarchy of Planck constants means the possibility of temporal zooms of the event sequences of the external world making possible "stories" as either zoomed up or zoomed down versions of the actual course of events. This makes possible simulation in the time natural time scales of neuronal activity and is expected to be a key element of conscious intelligence.

The realization that dark matter hierarchy corresponds to a hierarchy of quantum criticalities leads to an understanding of general characteristics of living systems. NMP demands increase of NE and spontaneous increase of h_{eff} can occur in the first state function reduction to the opposite boundary of CD. This however means death of self and self tries to survive as long as possible by gathering NE stored to mental images so that the NE associated with mental images increases. Metabolism makes this gathering of NE possible if metabolites carry NE. Even sensory qualia would involve in the capacitor model transfer negentropic carriers of quantum numbers having interpretation as generalized metabolites so that the primary qualia would characterize metabolites. Nutrients should carry or generate NE. An open question is in what scale NE is present or is generated. In [K58] it is proposed that NE is in scale of Earth.

2.1.3 The Meanings Of Sensory, Cognitive, Symbolic

With my physicist's background I have used the attributes sensory, cognitive and symbolic somewhat sloppily and the precise meanings of these become only gradually clear. The recent view is that p-adic space-time sheets correspond to cognition and imagination and that their intersections with real space-time sheets in the intersection of real and p-adic worlds define simultaneously both sensory and cognitive representations in algebraic extension of rationals.

These representations are defined in terms of data coming from the rational and algebraic points common to real and partonic 2-surfaces with the algebraic extension in question characterized by the mathematical representation of the partonic 2-surfaces and string world sheets making sense for both real and p-adic 2-surfaces simultaneously. Lowest level corresponds to discrete points of partonic 2-surfaces which string world sheets meet them and their boundaries carrying fermions being. For string world sheets and partonic 2-surfaces discretization is at the level of conformally invariant parameters. A number theoretic variant of quantum field theory is needed in order to have a first principle description of conscious intelligence and intentionality. Strong form of holography defines representations at space-time level.

The classical non-determinism of Kähler action quite generally implies that space-time surfaces define what might be called symbolic representations realizing quantum classical correspondence. This applies irrespective of the number field used and in p-adic context p-adic non-determinism is an additional ingredient. For instance, nerve pulse patterns define symbolic real physics representations of the sensory input but do not give rise to sensory qualia which reside at the level of the primary sensory organs (contrary to the expectations raised by various findings of neuro-science). Sensory experience is always a multiverse experience since sensory qualia have quantum jump increments as quantum correlates, and is thus not reducible to the level of space-time.

2.1.4 Topics Of The Chapter

The topics of the chapter is as follows.

1. Various candidates for measures for conscious information are discussed. The basic information measure being the reduction of entanglement entropy in state function process for given subsystem as it splits to two parts. NE is also possible and this kind of systems are stable against state function reduction to a pair of unentangled states. It is tempting to characterize self by this entanglement negentropy which is well-defined and positive in the intersection of real and p-adic worlds. Strong form of holography and the appearance of algebraic extensions of rationals whose basic parameters allow information theoretic interpretation allows to assign information measure also with space-time surface as parameters of extension assignable to the string world sheets and partonic 2-surfaces.

2. Frieden's proposal that action principles, including also Maxwell action, could have information theoretic interpretation is discussed in TGD framework in the hope that this would provide additional insights about quantum classical correspondence and living matter. Frieden's

prooposal fails in Minkowskian regions but works in Euclidian regions and allows to consider the possibility that entanglement negentropy assignable to Minkowskian regions and fermionic strings equals to the Kähler function apart from a constant factor.

3. The realization of quantum variant of Boolean logic in terms of zero energy fermion states is discussed.

4. The next sections are devoted to the relationship of TGD based visions about brain as computer, hologram, and association machine. Also the connection with the neuro science view about brain is discussed.

5. The notions of meme and morphic field are discussed in TGD framework.

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` [L4].

2.2 How To Define Measures For The Information Content Of Consciousness?

In this section my aim is to discuss different approaches to the problem how to define the information contents of conscious experience rather than advocating any final truth. Of course, just at this moment the information measures based on entanglement negentropy and associated with self seem to be the most realistic ones to me personally, but during these 37 years of TGD I have learned that it it is better to tolerate all views about the solution of the problem even when their mutual consistency is not obvious.

2.2.1 Information Measures For Conscious Experience

The concepts of information, information flow and information gain of conscious experience would seem to have a natural place in theories of consciousness. It seems intuitively obvious that WCW spinor fields must contain information. WCW spinor fields have indeed interpretation as both objective realities and Platonic Ideas, the latter interpretation being suggested strongly by the possibility to interpret fermionic Fock state basis as a Boolean algebra of statements about statements. The basic statements are most naturally statements about space-time geometry since fermionic oscillator operators are determined by the second quantized free quantum field theory for the induced spinors [K43].

The condition that em charge is well-defined for the spinor modes led to realization that spinor modes must be restricted to 2-D string world sheets intersecting partonic 2-surfaces at discrete points. The result is consistent with the strong form of holography following from the strong form of GCI and implies that both space-time surfaces and scattering amplitudes can be constructed from the data at these 2-surfaces. This in turn leads to an elegant realization of number theoretic universality. The 2-surface in question are characterized by parameters, which are in some algebraic extension of rationals - all extensions are allowed - and can be therefore continued to the field of real numbers and to the induced extensions of various p-adic numbers fields. The outcome is what one could call adelic physics. Adelic space-time surfaces has a book-like structure with pages labelled by various number fields and glued together along back defined by the 2-surfaces. Same applies at the level of embedding space and WCW.

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 associated for the initial and final states of quantum jump identified as those for the state assignable to passive boundary of CD. Note that one can assigned average negentropy also to the the active boundary but it seems that this is potential information rather than actualized information.

The most plausible measure information measure is based on p-adic norm and defined by a generalization of Shannon formula for entropy by replacing 5h3 logarithm of probability with logarithm of p-adic norm of probability and finding the prime for which the resulting negative entropy identifiable as negentropy is maximal. This defies a measure for negentropic entanglement (NE) as number theoretic entropy for the largest power of prime factor dividing the dimension of the final state space resulting in state function reduction. I have discussed this measure already in the introduction and also in [K45] and there is no point repeating the discussion.

State function reduction sequence at fixed boundary of CD defines self. Self dies, when the first reduction to the opposite boundary takes place and re-incarnates as self assignable to the opposite boundary. The first state function reduction to opposite boundary reduction decomposes to a cascade of state function reduction both in zero modes and in quantum fluctuating degrees of freedom ultimately leading to a completely unentangled state decomposing to a product of un-entangled states consisting of bound states and and states for which every decomposition to a pair of subsystems is negentropically entangled. At each step system decomposes to a unique pair of unentangled subsystems. The entanglement probabilities defined by the density matrix for either subsystem characterize the probabilities for the outcomes of the self measurement. Both unentangled subsystems resulting in the first step are again subject to self measurements and the process continues until an unentangled state results.

Consider now the information measures.

1. 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.

2. 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.

3. 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 gaine 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.

4. The information content of the conscious experience associated with self is more interesting practically. If one assumes that self experiences sub-self as a statistical ensemble of sub-subselves, 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 sub-selves the information measures and they give either positive or negative contribution to the information content of self.

5. In principle this allows to define also the net information gain of state function reduction as the difference of the total negentropies of the final and initial states of state function reduction 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"). One can also assign negentropy gain with the life-cycle of self as difference of negentropies of the time reversed self resulting in the first reduction to opposite boundary of CD and self. This negentropy gain can be said to be the saldo of the life of self.

I have considered several forms for NMP starting from a form producing standard quantum measurement theory assuming that density matrix of the subsystem is the universal observable. The allowance of NE possible for entanglement probabilities in an algebraic extension of rationals was the next step. It was however realized that the condition that the outcome of reduction is eigenstate of the density matrix allows only final states for which the density matrix is projector:

unitary 2-particle entanglement corresponds to this kind of situation. Eventually I realized that weak form of NMP is the most plausible option. For strong form of NMP the final state would be essentially unique if the initial state density matrix contains a higher-dimensional projector. Weak form of NMP allows however possible to choose also lower-dimensional subspace of the sub-space giving rise to maximal negentropy gain. This option allows to derive a generalization of p-adic length scale hypothesis. It allows also free will and provides physical correlates for ethics and moral: the basic principles is that the best self can achieve is to increase negentropic resources of the Universe.

Weak form of NMP favor large prime factors in the dimension of the sub-space resulting in state function reduction, which can be any integer $n-k \geq 1$, $k=1,2...$ This does not yet imply that the integer $n = h_{eff}/h$ characterizing the super-symplectic subalgebra acting as gauge symmetries contains a large prime as a factor. The condition that the effective string tension associated with elementary particle magnetic flux tube is small is however satisfied if this is the case. For electron this would mean that $p = M_{127} = 2^{127}-1$ divides n: this suggests that the magnetic flux tube involved carries 126 bits of information. That the fundamental time scale of living matter is .1 seconds and corresponds to the secondary p-adic length scale of electron and size scale of Earth gives additional support for the speculation. This modifies completely the neuroscience based vision about intelligence as emergent phenomenon but is consistent with what is experimentally known: we are not yet able to detect dark matter and in the case of electron the dark contribution to electrons mass is of order $\Delta m/m \sim 10^{-19}$.

In TGD framework negentropy 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 [J22]). 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 analogs spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

2.2.2 Information Concept At Space-Time Level

Quantum-classical correspondence suggests that the notion of information is well defined also at the space-time level. The non-determinism of Kähler action and p-adic non-determinism plus algebraic information measures suggest a natural approach to the problem of defining the information concept. This approach provides also a new light to the problem of assigning a p-adic prime to a given real space-time sheet.

Can one assign an information measure to a space-time sheet?: the recent view

For years ago I ended up with the idea that space-time surface should somehow code for the preferred primes so that it would be a representations for an integer and considered some naïve proposals how this could be realized. Since the ramified primes identifiable as preferred p-adic primes characterize the algebraic extension of rationals - or more precisely, the ideal for algebraic extension - to which the parameters characterizing string world sheets and partonic 2-surfaces belong, they characterize by strong form of holography also the space-time region containing them. In fact, the integer defined by the product of ramified primes characterizes the space-time region.

Can one assign an information measure to a space-time sheet?: the older view

I have included also the older attempts to assign information measure to a space-time sheet. Whether they have any connection with the vision based on ramified primes of algebraic extension, remains an open question. It would however not be too surprising if the character of non-determinism of Kähler action would correlate with the properties of algebraic extension involved. Pseudo-constants belong to the algebraic extension and the dimension of the space associated with given pseudo-constant is the dimension n of extension. If one has m pseudo-constants, the dimension of corresponding space is n^m, and if p divides n, the dimension is proportional to p^m as p-adic considerations would suggest. The information measure would be naturally number theoretic entropy of system with p^m states with identical probabilities and given by $N = mlog(p)$.

Consider now the earlier argument. In the presence of the classical non-determinism of Kähler action and p-adic non-determinism one can indeed define ensembles, and therefore also probability distributions and entropies. For a given space-time sheet the natural ensemble consists of the deterministic pieces of the space-time sheet regarded as different states of the same system. The probability for the appearance of a given value of observable is of the general form $p_i = m_i/N$, $m_i < N$, where N is the number of deterministic pieces and S_p is always negative, when p divides N.

Obviously the primes dividing N define natural candidates for the information measures but the problem is which criterion selects one of them. There are three options.

1. Require that the information measure corresponds to the prime p for which S_p is smallest. Obviously p must divide N.

2. Define the information as sum

$$I = -\sum_{p|N} S_p \quad ,$$

(here $p|N$ means that p divides N) so that all contributions are positive.

3. Include all primes dividing N or m_i in $p_i = m_i/N$:

$$I = -\sum_{p|N \ or \ p|m_i} S_p \quad ,$$

In this case also negative contributions are present. This defition is actually equivalent with a definition

$$I = -\sum_{p} S_p \quad ,$$

in which the summation appears over all primes. One could say that the information decomposes into different kinds of informations labelled by primes.

What is interesting is that, the ordinary Shannon entropy S for rational probabilities can be expressed as a sum of all p-adic entropies using the adelic decomposition $|x| = \prod_p |x|_p^{-1}$:

$$S = -\sum_{p} S_p = I \quad .$$

The sum of real and p-adic entropies vanishes. Real dis-information and the p-adic information would compensate each other completely. Whether the adelic formula for information theory might have some deeper interpretation remains open.

Does classical space-time physics represent factorization of integers?

Space-time region represents factorization of integer and p-adic space-time region corresponding to ramified primes define a similar adelic factorization. The reason for the preferred character of the ramified primes is that for them n separate space-time surfaces obtained by the action of Galois group on the parameters of 2-surfaces coincide at the boundaries of CD (criticality!) so that one obtains analog of bound state [K95]. The different branches correspond to n discrete of freedom, and one can assign to them many-fermion states: at most 1 fermion at single sheet of the covering.

The following represents the older argument for factorization. Quantum-classical correspondence suggests that quantum computation processes might have counterparts at the level of space-time. An especially interesting process of this kind is the factorization of integers to prime factors. The classical cryptography relies on the fact that the factorization of large integers to prime factors is a very slow process using classical computation: the time needed to factor 100 digit number using modern computer would take more than the recent age of the universe. For quantum computers the factorization is achieved very rapidly using the famous Shor's algorithm. Does the factorization process indeed have a space-time counterpart?

Suppose that one can map the integer N to be factored to a real space-time sheet with N deterministic pieces. If one can measure the powers $p_i^{n_i}$ of primes p_i for which the fractality above the appropriate p-adic length scale looks smoothness in the p-adic topology, it is possible to deduce the factorization of N by direct physical measurements of the p-adic length scales characterizing the representative space-time sheet (say from the resonance frequencies of the radiation associated with the space-time sheet). If only the p-adic topology corresponding to the largest prime p_1 is realized in this manner, one can deduce first it, and repeat the process for N/p_1^n, and so on, until the full factorization is achieved. A possible test is to generate resonant radiation in a wave guide of having length which is an integer multiple of the fundamental p-adic length scale and to see whether frequencies which correspond to the factors of N appear spontaneously.

Seeing the prime factorization might be also possible via a direct sensory perception. Oliver Sacks tells in his book "The man who mistook his wife for a hat" [J59] about twins, John and Michael, who had a mysterious ability to "see" large numbers and their prime factorizations despite the fact that their intelligence quotient was about 60 and they did not have any idea about the notions of integer and prime. 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 sensory representation for the decomposition $111 = 3 \times 37$ of number 111 to a product of primes! The explanation of these strange feats suggested in [K74] is a less general idea about physical representation of the factorization. The proposed mechanism could indeed explain prime factorization as a sensory perception involving no algorithmic cognition at all.

2.2.3 Information Theoretic Interpretation Of Kähler Function

An important stimulus in the development of ideas was the Jan 30, 1999 issue of New Scientist [B18] in which the work of Roy Frieden [B17] about information theoretical interpretation of the variational principles of physics was discussed at popular level. The work of Frieden relies on the concept of Fisher information. One can find a precise definition of the Fisher information in Mathematical Handbooks but this definition does not help too much without any further knowledge about Frieden's work.

Although the article in New Scientist [B18] does not give any mathematical details about Frieden's work, it becomes clear that Fisher's theory as such does not apply to TGD framework. Frieden's basic idea seems however attractive. Indeed, TGD inspired theory of consciousness inspires a hypothesis concerning the information theoretic interpretation of the Kähler function.

Frieden's hypothesis inspired the idea that Kähler function (Kähler action for a preferred extremal) has information theoretic interpretation. At that time I had not realized that Kähler function comes from Euclidian space-time regions whereas Minkowskian regions give an imaginary contribution due to the presence of the metric determinant and identifiable as the counterpart of quantum field theoretic action. This allows to solve the basic problem of the Frieden's approach due to the fact that in Minkowskian realm action is not positive definite. Therefore the information theoretic interpretation of Kähler function might work but Frieden's idea does not have a feasible realization in TGD framework.

Information theoretic interpretation of action in Frieden's theory

Frieden [B17, B18] introduces two kinds of information concepts. Fisher information, usually denoted by I, is defined as the information which can extracted from a physical phenomenon by measurements of a specific type. Information J is defined as the information contained by the phenomenon and in general $J - I \geq 0$ holds true.

The action defining the dynamical equations of a physical theory decomposes into a difference $I - J$, where J is the total information contained by the state and I is the available information. I and J depend on what is measured. Minimization of $I - J$ for position measurement leads to classical Newton's equations.

In classical mechanics J corresponds typically to the integral of potential energy V and I corresponds to the integral of kinetic energy I, in accordance with the decomposition

$$S = \int L dt, \quad L = T - V \ .$$

Maxwell action is obtained by considering position measurement in presence of charge. For Maxwell action

$$S = \int (B^2 - E^2) d^4x \ ,$$

the entire integral of B^2 corresponds to I whereas total (or potential) information J is non-vanishing only provided there is coupling to external currents.

Information theoretic interpretation of Kähler function

The first thing to notice is that without further assumptions the Kähler function of the Universe should be infinite since otherwise the exponent of Kähler action becomes zero. ZEO provides the manner to escape this conclusion: each CD defines it sub-Universe and Kähler function is Kḧler action for the space-time surface inside CD.

Information theoretic interpretation of Kähler function - albeit not in the sense proposed by Frieden - might make sense in TGD framework. Quantum classical correspondence suggests that Kähler function could serve as a classical correlate for quantal information measure defined by negentropy.

It is however essential that one accepts the possibility of Euclidian space-time regions predicted by TGD to serve as space-time correlates for the lines of generalized Feynman diagram and thus representation of matter. One must accept also the number theoretic vision that conscious information is possible in the intersection of real and p-adic worlds.

1. When should one use entanglement negentropy and when entanglement entropy based on real numbers is appropriate? It seems that entanglement negentropy makes sense at the passive end of CD at which state does not change and reduction to an eigen-space of density matrix has occurred for given sub-system-complement pair.

   At the active boundary of CD situation is different since the entanglement does not reduce to this simple form and one could argue that the ordinary entanglement entropy is natural notion. After all, future is uncertain!

2. For the regions with Euclidian signature representing generalized Feynman graphs with lines represented as deformations of CP_2 type vacuum extremals one must be very careful with the sign factors. One cannot distinguish between electric and magnetic contributions and the sign of the Kähler function is positive. It would be attractive to assign entropy or negentropy with elementary particles and identify it as Kähler function apart from possible numerical factor. Whether one has entropy or negentropy seems to be a matter of convention. Strict adherence to thermodynamical analogy would suggest the interpretation as entropy.

3. Entanglement negentropy assignable to strings connecting partonic 2-surfaces in Minkowskian regions is the quantal information measure. Strings are assignable to magnetic flux tubes carrying possible monopole flux.

4. The generalization of AdS/CFT duality suggests that the descriptions provided by Kähler function in Euclidian regions and fermionic strings in Minkowskian regions are dual. Could these two negentropies be identical as also quantum classical correspondence suggests.

   An immediate objection is that entanglement negentropy for the outcomes of state function reduction is is a discrete number: logarithm of integer. Kähler function cannot have discrete spectrum. One can consider also the active boundary of CD for which state-complement pairs would be characterized by ordinary entanglement entropy giving a continuous measure of entropy. Kähler function could have an interpretation as entropy as standard thermodynamics suggests.

The above interpretation says nothing about the Kähler action in Minkowskian regions. Both magnetic flux tubes and electric flux quanta are of special interest in Minkowskian regions. Could Kähler action also now have an interpretation as information measure? NE can be assigned to strings accompanying magnetic flux tubes carrying monopole flux. Could the Kähler action for flux tubes be identified as entanglement negentropy at the passive boundary of CD? Again the discontinuous spectrum of entanglement negentropy is a problem unless the parameters of flux tubes are quantized, which is in principle possible by preferred extremal property. Quantization of action is indeed a basic aspects of quantum classical correspondence and Planck constant was introduced originally as quantum of action.

But what about regions carrying Kähler electric fields and Kähler action and information with opposite sign. Is there any reasonable interpretation or should one assume that it is only the total Kähler action that matters and that total Kähler action corresponds to positive negentropy?

2.3 Logic And Fermions

The state basis for the fermionic Fock space has a natural interpretation as a Boolean algebra (fermion number =1/0$\leftrightarrow$ yes/no). In this manner ordinary Boolean algebra is extended to vector space spanned by fermionic states. When cognitive fermion pairs are used instead of fermions, fermion number conservation does not pose any constraints and full linear superposition of the Boolean algebra elements is possible. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic.

The simplest TGD based model for thinking systems leads to the result that thoughts correspond to quantum states in discrete spaces. The reason is that slightly non-deterministic classical time evolution means a finite number of multi-furcations. These additional dynamical degrees of freedom correspond to N-element set labelling the different time evolutions associated with given initial values. This suggests that a suitably defined *binary* Hilbert space having Z_2 rather than complex numbers as a coefficient field could provide a simple quantum model for a thinking system. This raises the following question.

What would a quantum field theory in discrete space and with the field of complex numbers replaced with binary numbers Z_2 (0, 1/Yes, No) look like?

The answer is following.

1. The state basis of the quantum field theory defined in N-element set is nothing but a Boolean algebra consisting of 2^N elements: all possible statements about the N elements interpreted as propositions! Bosons and fermions are one and the same thing and behave like fermions since occupation number can have only the values 0 and 1.

2. The requirement that triangle equality for the inner product is satisfied, does not allow linear superposition and one must choose some orthogonal basis for the space. The absence of quantum superposition means that theory is completely classical. Thus it seems that Boolean QFT is completely classical and the transition from classical mechanics to quantum theory could be regarded as a transition from binary QFT to complex QFT or from a binary logic to complex logic.

3. Quantization means construction of statements about statements: the simplest model for an abstraction process one can imagine! One can of course continue this quantization: second, third, etc., quantization is possible and this corresponds to a construction of statements about statements about..... Hence a direct connection with the ideas about genetic code emerges.

4. Also the state basis in the Fock space of the ordinary fermions has interpretation as a Boolean algebra, all possible statements about some propositions (particle with a definite spin component is at point x).

2.3.1 The State Basis Of Fermionic Fock Space As Boolean Algebra

The state basis of a fermionic Fock space can be interpreted as a basis of a Boolean algebra. In quantum TGD all elementary particles are constructed using fermionic oscillators operators. This suggests that entire quantum field theory is actually a representation of Boolean algebra and N-fermion states have interpretation as statements about basic propositions labelled by the indices labelling fermionic oscillator operators. In particular, WCW spinor structure is constructed in terms of the fermionic oscillator operators for the second quantized spinor fields on space-time and this suggests a deep connection between spinor geometry and logic. Perhaps one could say that quantum logic is C-valued in the sense that all complex superpositions of a statement and its negation are possible.

In Boolean algebra one can select the maximum number of 2^{N-1} statements consistent with given atomic statement (one bit fixed) statements as axioms. An interesting possibility is that only these statements consistent with given atomic statement (one bit fixed) are physically realized so that the number of states is reduced by a factor of one half. Amusingly, in the ordinary fermionic field theory the states created by a finite number of oscillator operators are the counterparts of these preferred statements, their negations would correspond to a vacuum state obtained as an infinite product of all creation operators annihilated by creation operators. The states created by annihilation operators from this states are not allowed in QFT since they would have infinite energy.

One can identify the complex valued linear space of fermions as a generalization of Boolean algebra to complex Hilbert space. Cognitive fermion pairs could provide realization for this space as pairs of fermion and anti-fermion belonging to different space-time sheets and representing logical statement and its negation: the automatic presence of negation is rather natural from the point of view of consciousness theory. The splitting of the wormhole contacts connecting the space-time sheets gives rise to annihilation process generating fermion and anti-fermion pair (fermionic quantum numbers reside on the boundary components of the split wormhole contact). In this manner one avoids problems related to fermion number conservation encountered otherwise in physical realization of the fermionic logic. Alternative possibility is to assume fixed number of fermions and associate truth values with the direction of spin.

2.3.2 Boolean Algebra As Boolean QFT

Boolean algebra $B(N)$ is generated by all possible yes/no statements about N propositions. It consists of sequences of N binary digits of form $(...,1,0,0,..,1)$ having value of 0 or 1. Addition is with respect to Z_2 so that $1+1=0$. Boolean algebra is Z_2 linear space and the elementwise multiplication of the binary digits in the string makes it algebra. $(0,0,0,..)$ and $(1,1,....,)$ are zero and unit elements of the algebra.

Geometrically Boolean algebra $B(N)$ corresponds to all possible subsets of an N-element set. Sum corresponds to a symmetric difference (take the union of sets and throw away the common elements). Multiplication corresponds to the intersection of the sets. Entire set represents unit element and empty set zero. Empty set is not physically realizable, or equivalently, the zero element of the Boolean algebra does not correspond to a physical state in the Z_2 Hilbert space defined by the Boolean algebra.

Quantum field theory in N-element set formed by the basic propositions (analogous to 3-space in QFT) means associating to each element of the N-element set creation and annihilation operators and postulating standard commutation relations with them:

$$[a^{\dagger}(i), a(j)] = 1 \ .$$

One can also consider fermions that is anti-commutation relations but since -1=1 in Boolean algebra, they are equivalent with the bosonic commutation relations so that Boolean bosons and fermions are one and the same thing in the Boolean QFT.

The states of this QFT are constructed in the usual manner. The only difference is the occupation numbers are Z_2 valued and are either one or zero just as in the case of fermions. Thus Boolean particles are fermions always. Since N creation operators are involved one obtains a space generated by 2^N states. The proposition and its negation correspond to the states created by, say I oscillator operators and the dual of this state created by the remaining $N-I$ oscillators operators. Statement corresponds to I particles and its negation to I holes in the dual ground state containing all N oscillator operators.

Thus the state basis is nothing but the Boolean algebra associated with the N element set! Thus the state basis of Z_2 valued quantum field theory in the set of N propositions is nothing but the formation of all possible statements about these statements: a model for abstraction process. One can apply this process to the $2^N - 1$ element set and by continuing this process get a sequence of second quantizations as a sequence of abstractions.

The assumption of unrestricted linear superposition in Z_2 Hilbert space leads to difficulties with Schwartz and triangle inequalities. The physical interpretation of the theory requires that inner product satisfies Schwartz inequality

$$|(x, y)| \leq |x||y| \ .$$

Linear superposition allows states, say y, with zero norm since any superposition of even number of orthonormal states has zero norm in Z_2. The norm of the inner product of one of the basis states appearing in zero norm state, call it x, with the zero norm state y equals to one and is not smaller than the product of the norm of the basis state and state with vanishing norm: one obtains $1 < 0$, which does not make sense if inner product is interpreted as real number (as a Z_2 valued number one could perhaps say $1 = -1 < 0$). One ends up to difficulties also with the triangle inequality: $|x+y| \leq |x|+|y|$ if x and y are zero norm states with single common element of orthonormal basis so that one has $|x + y| = 1$.

The only possible manner to save Schwartz and triangle inequalities is to assume that linear superposition is not allowed for Z_2 Hilbert space. This in turn means that situation is completely classical! If the set generating Boolean algebra consists of entire 3-space, this means that every state is gauge equivalent with an N-particle state of completely localized particles. This in turn implies that Boolean QFT should be more or less equivalent with classical mechanics and one could understand the transition from classical physics to quantum physics as the replacement of Z_2 with complex numbers C as the coefficient field of the state space.

One can change state basis by unitary transformations. Unitary matrices are obtained from orthogonal Z_2 valued unit vectors possessing entries equal to 1 or 0. Any unitary matrix corresponds to a matrix representing the permutation of 2^N elements of the basis of the Boolean algebra. Time development operator in this quantum field theory is always defined for a *finite* time interval only (the length of the "chronon" is fixed naturally in p-adic QFT) and represents a permutation of this basis. In particular, a nonlinear transformation of the oscillator operators in general occurs. All unitary transformations are permutations, which do *not* lead to state basis involving superpositions of the basic states. This is in accordance with the observation that Boolean QFT is completely classical.

2.3.3 Fermions, Zero Energy Ontology, 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 $A \rightarrow B$ 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 [K15]: 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.

2.3.4 Negentropic Entanglement, Fuzzy Logic, Quantum Groups, And Jones Inclusions

Matrix logic [A5] 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 [K96].

2.3.5 Cognitive Codes And Fermions

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 zero energy ontology. 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.

Mersenne primes are especially interesting as far as cognitive codes are considered the Mersenne prime M_{127} assignable to electron is of special interest since the corresponding time scale for CD is.1 seconds whereas the duration of bit corresponds to the time scale of 1 ms assignable to quark CDs.

Combinatorial Hierarchy as a hierarchy of "genetic codes"

The simplest model for abstraction process is based on the process in which one forms first all possible Boolean statements about N basic statements, 2^N altogether. If one drops one of the statements one has $M_N = 2^N - 1$ statements: M_N is Mersenne number. The motivation for the dropping of one statement might be that in set theoretical realization one of the statements corresponds to empty set and is not realizable. Alternatively, in the realization based on many-fermion states, vacuum state could correspond to this kind of state. One can form also statements about statements: the first level of abstraction. This leads to $M_{M_N} = 2^{M_N} - 1$ many-fermion states. Construction is especially intersting if the numbers $M(M_N)$ are primes, so called Mersenne primes.

Indeed, in some cases one obtains hierarchies of Mersenne primes by repeating the construction as long as it works.

The so called Combinatorial Hierarchy, shown already earlier to provide an explanation for the numbers of the Genetic Code, emerges as the most notable hierarchy. The Combinatorial Hierarchy [A15] consists of the Mersenne numbers $2, M(1) = 3, 7\ ,\ 127, 2^{127} - 1, ..$ constructed using the rule $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitly listed ones are known to be primes. Combinatorial Hierarchy emerges from a model of abstraction process as subsequent transitions from level to metalevel by forming Boolean statements about Boolean statements of level n and dropping one statement away and starting from $n = 2$ basic statements. Combinatorial Hierarchy results also by constructing the sets of all subsets with empty set excluded starting from two element set.

The set of statements at level n can be given a structure of Finite Field $G(M(n), 1)$ if $M(n)$ is prime. The multiplicative groups $Z_{M(n)-1}$ form a nested hierarchy and the coset spaces $Z_{k_n} \equiv Z_{M(n+1)-1}/Z_{M(n)-1}$ are cyclic groups. Combinatorial Hierarchy based model of Genetic Code explains the number of DNA: s and amino-acids and the representation of words of the GC as triplets of 4 different codons. Amino-acids correspond to $k_{n=3} = 21$ axioms of a formal system defined by $n = 3$ level of Combinatorial Hierarchy having a unique embedding as the group $Z_{k_n} \subset Z_{M(n)-1} = Z_{126}$ and DNA: s correspond to the set $X_{N(DNA)} \subset Z_{M(n)-1}$ of $N(DNA) = (M(n) + 1)/2 = 64$ statements consistent with given atomic statement (one bit fixed) at level n regarded as special cases of general theorems. GC corresponds to the mapping $x \rightarrow x^{k_{n-1}} = x^6$ in $Z_{M(n)-1}$ mapping DNA type statements to amino-acid type statements. The numbers of DNA: s coding single amino-acid are reproduced in a symmetry breaking mechanism involving the finite groups $Z_{p_{n-1}}$ and Z_{k_n} and symmetry breaking is in a well defined sense minimal. The infinite hierarchy of possible genetic codes suggests the possibility of an infinite hierarchy of increasingly complicated lifeforms or forms of intelligence.

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 $a \rightarrow b$ 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 of 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 [K32, K65, K66, K69].

How nerve pulse patterns and membrane oscillations could be coded to Boolean statements?

The original proposal for the realization of the memetic code was based on the notion of cognitive neutrino pair. Zero energy ontology however disfavors this identification since the time scale assignable to CD of neutrino is of order 10^4 years. Therefore neutrinos would most naturally correspond to a time scale of consciousness much longer than the time scale of.1 seconds predicted to be present. If the proposed view about cell membrane is correct, classical weak fields should be important within the Compton length of any particle and therefore the interactions of neutrinos with Z^0 fields should be important as also the large chiral asymmetry in living matter suggests.

The realization of memetic codewords in terms of sub-CDs assignable to u and d quarks look much more attractive option since they have time scale of 1/1.28 millisecond.

1. The bit would correspond to quark existing in this kind of sub-CD. Memetic codon would correspond to electron's sub-CD containing a row of 127 quark sub-CDs. Standard physics interpretation could be as quantum fluctuation generating virtual pair of quark and negative energy antiquark. For non-standard values of $\hbar$ the durations of codewords and bits would be scaled up.

2. The time-like row of quark sub-CDs resides in em (and possibly also Z^0) field associated with the cell membrane and having the direction of the axon. There is a time-like row of quark sub-CD at some points of axon with one sub-CD per millisecond time interval between sub-CDs. DNA as topological quantum computer hypothesis suggests that each lipid could correspond to quark sub-CD so that many-quark system would be in question. The minimization of the magnetic energy for a given sub-CD fixes the direction of spin and one has spontaneous magnetization in the case that the direction of magnetic field inside quark sub-CD does not change during the pulse.

3. The time that it takes for a nerve pulse to traverse the point is slightly longer than millisecond. If the time which magnetic field has reversed direction is of order millisecond then the magnetic field experienced by quark can preserve its direction during the time interval that quark exists from the point of view of outsider. This is achieved if the temporal center of mass positions of the quark sub-CDs are given by $t_n = nz_0/v$, where z_0 is the distance between lipids containing quark sub-CD and the position of nerve pulse is given by $z = vt$, where v is the conduction velocity of nerve pulse. Unless this condition is satisfied, the direction of magnetic field changes during the time interval associated with sub-CD. In this case a superposition of bits identifiable as a qubit results.

4. This means that nerve pulse sequence defines a (qu-)bit sequence with the direction of spin telling whether there was nerve pulse present in particular sub-CD. The presence/absence of nerve pulse corresponds to true/false statement in accordance with neuro science intuition.

If this view is correct, the values of the positional coordinates and the velocity of the object of the perceptive field should correlate with the CP_2 orientation of the active neuron and/or ME(s) associated with it. First of all, the level of hologrammic activity for ME measured by the strength of the light-like em current depends on its CP_2 orientation. Secondly, different CP_2 orientations correspond to slightly different values of the membrane potential and could be directly mapped to the degree of alertness of neuron. For instance, if a moving object of the perceptive field is in nearby space and moves towards the perceiver, the (P_i, Q_i) values could be such that the resting potential is lowered and nearer to the critical value for firing. Also the light-like em currents associated with MEs would be stronger in this kind of situation.

2.4 Quantum Computationalism

TGD Universe can be formally regarded as infinite quantum computer like structure in the sense that each quantum jump involves the unitary process U analogous to a Schrödinger evolution lasting infinite time and is followed by state function reduction and state preparation process. Therefore TGD suggests what might be called quantum computationalism. Universe would be performing huge quantum computation and the computation like processes performed by us or by our brains would be only a ridiculously small portion of this computation. Of course, this must be taken as a rough metaphor, the quintessence of the conscious quantum computation like processes could be quite different from the essence of the ordinary quantum computation.

The average increment of the psychological time in quantum jump is rather small: the simplest guess suggest that the average quantum of psychological time is or order "CP_2 time", about 10^4 Planck times. This means that the relation of the information processing performed by biosystems to quantum jump would be the same as the relationship of macroscopic physics to physics in CP_2 scale about 10^4 Planck length scales. This would however mean an extremely short de-coherence time in an obvious conflict with the experimental facts. Macrotemporal quantum coherence, which corresponds to the formation of bound states, however effectively fuses a sequence of quantum jumps to a single quantum jump so that the de-coherence occurring otherwise in CP_2 time scale can be circumvented.

The notion of self is absolutely crucial for TGD approach to consciousness and makes possible to understand consciousness in macroscopic time scales. A very natural notion is that of cascades of selves within selves generated spontaneously or by quantum jumps. This implies a connection with the basic conceptual structure of computationalism. The cascades have natural modular structure, which is quintessential for the understanding of the symbol processing performed by brain. A very attractive hypothesis is that selves within selves are conscious counterparts of computational agents or more or less equivalently, of the subroutines of computer program. Selves can perform two kinds of quantum jumps and a natural identification of these modes is as computational and sensory (input) modes. Subjective memory takes automatically care of output in the sense that the subjective history of sub-self is experienced as an abstracted memory by self.

Communication between selves could occur as it does between human beings. Also "mass media" at neuronal level seem to be possible and would make possible the concept of global workspace. Quantum jumps can be regarded hopping in the space of zero modes identifiable as fundamental order parameters and Haken's theory of feature recognition generalizes. Quantum entanglement in turn provides elegant realization of association concept so that the basic ideas of connectionism emerge naturally from quantum computationalism. There are also drastic differences with between TGD and computationalism, basically implied by the different concept of psychological time which implies that cognition has holistic aspect also with respect to time. Thoughts are definitely not deterministic computations and living systems are definitely not robots.

2.4.1 Computationalism And Connectionism

Computational approach to cognition [J71] is the dominating approach in cognititive and neuro sciences and has had undeniable successes. Computationalism is often identified as traditional AI based on the concept of truth preserving manipulation of symbols according to some fixed rules of the formal system. This approach indeed explains nicely computational aspects of mind. Combinatorial explosion is the basic failure of the approach at practical level. Connectionism relies on the concept of association and associative neural net provides a quantitative model for how brain learns. Connectionism is often regarded as a variant of the computationalism and it is believed that neural nets provide models for unconscious parallel information processing whereas conscious information processing is best modelled by hierarchical program like structures. The general philosophical shortcomings of these approaches are obvious: they cannot provide any insights to the problem how meaning, understanding, emotions and volition, which are factors crucially important for the functioning of conscious brain, arise. This has even led some advocates of this approach [J71] to believe that human brain, being computer basically, is simply incapable of understanding the problem of consciousness! This would probably be the case if human beings were robots: fortunately we are not!

Traditional AI approach

In the traditional AI approach brain is modelled as a complicated computer. Computation is realized using rigid algorithms, which are hierarchical structures consisting of subprograms. Using more abstract terminology, the basic concepts are symbols and agents, "demons". Symbols are inputs for "demons", subroutines of program manipulating symbols and creating new outputs as symbols. One could however interpret also agents themselves as symbols. The concept of global work-space [J20] realizes the intuition that short-term memory is available to many users. Also the concepts of belief and desire can be formulated without referring to consciousness. Beliefs are inscriptions about the world and desires are identified as goals. For instance, problem solving means simply making trials with the aim of minimizing the difference between goal and result of trial. The concept of representation is central. It is known that brain realizes several types of representations [J71]. Visual mosaic like representations, phonological representations in short-term memory consisting of few phonemes (say remembering phone number for some time), grammatical language like representations with hierarchical structures and "mentalese", which is the most abstract representation type summarizing in very implicit manner the essentials of, say, mathematical model.

Computationalism explains nicely the general features of language by providing a representation for the hierarchical structure of language. One can also easily think brain as a population of (possibly) conscious demons. Some demons receive sensory input, some demons process it and the ouputs of some demons are realized as motor outputs. It seems that this approach models quite satisfactorily those aspects of cognition, which can be realized as purely mechanical truth preserving symbol manipulation modellable universally by Turing machine. The best proof for the claim that computers have caught something about the basic structure of cognition is that computers are already now able to beat chess champions. The weak point of the computationalism is its extreme rigidity: minor input error or programming error and program fails to work. Combinatorial explosion is second shortcoming. For instance, all possible melodies formed from finite number of musical notes with finite number of durations for each and lasting the typical length of musical piece is immense. In computer chess combinatorial explosion makes the simple-minded trial and error approach completely unpractical and the only possible manner to proceed is to teach the computer by mechanizing the human intuitions about good chess.

Connectionism and neural nets

Connectionism provides a modern version of associationism proposed by British philosophers Locke, Hume, Hartley, Berkeley and Mills. Behaviorism was the first purely mechanistic version of this approach but was quite too simplistic to work. Associationism consists of two laws. The first law states that the ideas which are often experienced together get associated: when one is activated also the other one gets activated. Second law states that similar ideas activate each other. Connectionism tries to realize these two aspects of associationism mathematically and construct practical realizations for associative thinking. Typical application would be feature recognition and machines learing automatically from their inputs some predetermined tasks.

Neural nets provide a mathematical model for the concept of association and associative learning. The simplest model for learning simply associates unique self-organized state of a dissipative neural net to the state of the external world represented as an external force driving the neural net. Dissipation realizes also the second law: if input is sufficiently similar to the standard input generating given standard output, the standard output is indeed generated. Also Haken's model for feature recognition realizes second law as a feature recognition based on non-equilibrium thermodynamics. Features correspond to equilibrium states of a nonlinear dissipative system (free energy minima for order parameters). If input creates initial output belonging to the attractor of the feature, dissipative dynamics takes care that the asymptotic output is feature.

Associative net can be regarded as a many-layered structure, in which the states of some nodes correlate strongly with the states of some other nodes. The state of node is characterized by a component of vector, whose components give the values of the amplitude in the nodes. For a given input the net rapidly achieves equilibrium in which the associations created by the input are determined by those nodes in which the amplitude is large. The equilibrium states of neural nets with coupling to external are identified as representations for stable mental states representing some states of the external world.

The flexibility of the neural nets is the strength of connectionism. Also combinatorial explosion can be avoided. Neural nets might indeed model lower level cognition which is mostly unconscious to us. The absence of the hierarchical structures means the loss of "expressive power" essential for higher cognition and leads to the problems described in [J71].

1. Connectionistic approach is not able to distinguish between individual and class: what is created from the inputs is some kind of average individual: neural network can learn to recognize human face but not a particular human face or to recognize particular human face but not to make abstraction about what human face looks like.

2. Second problem is so called compositionality: the ability of the representation to be build out of parts and represent the meaning of the whole deriving from the meanings of parts. A related problem are the difficulties in the identification of the meaning of linguistic expressions. For instance, the meanings of the expressions consisting of words "the child", "ate" and "the slug" depend on the order in which the words are represented and connectionism is not able to distinguish between "the child ate the slug" and "the slug ate the child". The natural ordering of symbols provided by hierarchical tree solves this problem in AI approach. Simple neural network learns easily to recognize picture containing horse but if the picture contains two horses, network fails completely!

3. The third problem is a combination of these two. An example from [J71] illustrates this. Network can learn to sum 1 and 3 to 4. When it learns to sum 2 and 2 to 4 it can lose the already learned ability. Second example: consider the expression "Every forty five seconds some-one in the United States sustains a head injury". Human brain can easily realize the

meaning of this sentence which suggests that quantification occurs in brain and human brain transforms the sentence either to expression "Every forty-five seconds {there exists an X[who gets injured]} " instead of "There exists an X{who every forty-five seconds[gets injured]} "

4. What multiplies human thoughts is recursion. We can take proposition and give it a role in another proposition and so on. In this manner a combinatorial explosion of propositions is generated. To get propositions-inside-propositions network, one could add a new layer of connections but this solution is clumsy and non-economical. The addition of a new level of abstraction would mean a new network containing additional level. In computationalism the solution of the problem is much more elegant. Each proposition is represented in long term memory once. One can of course combine computationalism and connectivism and use simple neural networks as basic modules of computer program like modular structure.

5. Neural net models, which realize connectionistic philosophy in practice, have serious problems in modelling long term memory. If its is assumed that long term memories are coded into the matrices defining output of the node in terms of its inputs, which are modified during learning process, the unavoidable conclusion is that new memories destroy the old ones. Childhood memories seem however to be the most stable ones.

2.4.2 How Connectionism Emerges From TGD Framework?

Brain as an associative net in TGD

TGD leads to a variant of connectionism which differs from the standard version in some crucial respects. Brain as a quantum self-organizing system moving in spin glass energy landscape generalizes the neural net realization of connectionism. The plasticity of the neural substrate corresponds directly to the spin glass property and the notion of frustration fundamental for spin glass type systems is guaranteed by the inhibitory/excitatory nature of nerve pulses. Neural net becomes dynamical rather than being a fixed structure. One can view brain as system moving in the space of neural nets and perceiving and affecting its own position in this abstract space.

Brain can be regarded as a conscious associative net developing by quantum self-organization to asymptotic self-organization patterns which correspond to recognized features, learned habits, skills $\cdots$: dissipation can be said to serve as fundamental Darwinian selector in this process. By music metaphor each neuron, when it fires, generates a characteristic neuronal experience possibly contributing to our conscious experience: only the intensity of this experience depends on the nerve pulse pattern. The firing of a neuron gives rise to a conscious neuronal association $A \rightarrow B$.

This would suggest that brain is like a conscious music instrument, or rather, entire orchestra, played by the nerve pulse patterns and our experiences corresponds to the sound patterns created by this orchestra. It has turned out that this view is probably quite not correct. Brain and body are much more. The music is at the level of sensory organs as sensory qualia, and neural activity cognizes, that is analyses the sensory music to notes and represents the notes. This view, which is certainly not possible in the standard neuroscience framework and surprisingly close to what a layman knowing nothing about neuroscience would think spontaneously, makes sense in TGD framework if one assumes that entanglement between brain and sensory organs binds sensory qualia with the cognitive associations generated by the sensory input. This view also allows to understand elegantly the differences between sensory experience, dreaming, hallucinations, and imagination. An essential element is the feedback from brain to sensory organs enabling "qualification" during dreaming and hallucinations. This feedback is also active during the ordinary wake-up consciousness.

Spin glass energy landscape is four-dimensional in a well defined sense and the identification of the long term memories as geometric memories solves the basic paradox of the neural net models of memory. One can also understand how brain knows that the mental image represents memory and why repetition and reverberation of nerve pulse patterns in neural circuits leads to learning and why emotional experiences are easily remembered.

Feature recognition

The first law of associationism states that similar ideas tend to induce each other. For instance, a part of familiar face in the visual field induces a memory about the entire face. In computational approach feature recognition is believed to involve unconscious low level parallel processing. [B14] [B14] has proposed an elegant model of feature recognition based on non-equilibrium thermodynamics. The features to be recognized represent the minima of the potential depending on order parameters and the presence of dissipative terms implies that system ends up to potential minimum representing feature.

Haken's theory generalizes to TGD context almost as such. Dissipative time evolution is replaced with quantum self-organization by quantum jumps and in each step entire macroscopic space-time surface is replace by a new one. The zero mode degrees of freedom of the configuration space are identifiable as fundamental order parameters and each quantum jump involves complete localization in continuous zero modes. The localization in discrete zero modes characterizing cognitively degenerate space-time surfaces need not be complete: what is needed is localization to a subset of space-time sheets for which the eigenvalues of the p-adic density matrix are degenerate. This means that the time evolution by quantum jumps corresponds to hopping in the space of zero modes, which leads to that part of zero mode sector, where WCW spinor field has largest value. The maxima of Kähler function are excellent candidates for the attractors of the quantum self-organization process.

A more concrete brain level model of feature detection based on the realization of the self-hierarchy as a hierarchy of Josephson currents frequency-modulating each other perhaps helps to clarify the abstract general ideas about conscious feature detection.

1. The feature to be detected is represented as a reference supra current flowing in a neural circuit and weakly coupled to a parallel neural circuit representing the input. When the supra currents are identical, constructive interference of the Josephson currents flowing between the two circuits occurs and induces large modulation of the rest potentials of neurons of the circuit and leads to a synchronous generation of nerve pulses. Synchronous neural firing can start under rather wide limits depending on the alertness of the neural circuit (how near to the threshold value resting potential is) controlled by the modulating Josephson currents also.

2. Synchronous neural firing wakes-up sub-self which starts to self-organize and develops into an asymptotic pattern representing a mental image about the detected feature. The final state depends only weakly on the initial state of the neural circuit representing self so that genuine feature detection is in question. For instance, some minimal number of neurons firing in the neural circuit leads to given final state pattern so that the constructive interference of the Josephson currents need not be maximal.

3. The self-organization patterns in neural circuits define a population of sub-selves defining cognitive mental images, features. These sub-selves wake-up and fall asleep (even periodically during their lifetime (after images)). Falling asleep occurs, when the sub-system generates a bound state entanglement with some other sub-system, and wake-up by a reduction of the bound state entanglement.

4. Self-organizing neural circuit starts to approach the maximum of "subsystem" Kähler function (recall that approximate representability of Kähler function as a sum of subsystem Kähler functions is probably possible) is accompanied by the wake-up of sub-self. This corresponds to the motion of neural circuit in its spin glass energy landscape induced by various neural transmitters inducing short term or long term changes in the synaptic contacts. Thus self-organization induces also a generalized motor action shifting the position of the neural circuit in the spin glass energy landscape.

5. Feature detection involves kind of *Eureka!* experience. Perhaps the sub-self representing the mental image about recognized object remains for some time irreducible and hence does not possess any sub-selves (and is in "enlightened" state). This could be the situation for some time until sub-selves are generated during self-organization and lead to the analysis of of the recognized feature.

One can ask whether it makes sense to speak about entanglement between different number fields. The original idea was that this might make sense. In the recent vision however fermions responsible for Boolean cognition reside in the intersection of reality and various p-adicities formed by an extension of rationals at the level of parameters characterized string world sheets and partonic

2-surfaces. Hence fermions and string world sheets are number theoretically universal rather than assignable to some particular number field. Hence for fermions the entanglement is also number theoretical universal and expressible in terms of numbers in the extension of rationals.

The emergence of a positive entanglement negentropy is a physical correlate for the experience of love, understanding, Eureka experience and various other experience with positive emotional coloring. Generation of negentropic entanglement can can give rise to experiences like seeing beauty, feeling truth, and feeling love. Both p-adic and real physics, cognitive and symbolic representations are involved automatically in the adelic view about physics in which all structures are Cartesian products of they real and p-adic variants.

Learning of associations

The second law of associationism states that ideas experienced simultaneously tend to form associations. TGD suggests two mechanisms for realizing associative learning.

1. The purely quantal mechanism realizes associations in terms of quantum entanglement. This mechanism would be extremely elegant because super position principle allows huge capacity of forming associations. Quantum entanglement however seems to associate parts to form wholes with the ensuing loss of conscious information about parts rather than giving rise to conscious associations $A \rightarrow B$. One could say that the association in question is spatial rather than temporal. Note also that quantum entanglement lacks the directional character of association. It seems that this mechanism is essential for associating various cognitive features at the level of brain with sensory qualia at the level of sensory organs.

2. In second mechanism the classical neural net type realization is replaced by a process in which sub-self wakes up another sub-self. A process in which presynaptic neuron wakes up postsynaptic neuron and the mental images of these neurons form the association, could indeed serve as building blocks of our associations.

It has turned out that these mechanisms are actually not mutually exclusive, and that both are involved with the association mechanism. The TGD based notion of sub-system, relying on the topological non-triviality of the many-sheeted space-time, makes possible for separate selves (unentangled systems) to share mental images via the entanglement of their sub-selves. Topologically this corresponds to the following situation. Two selves (say sensory mental image and cognitive mental image) are realized as disjoint space-time sheets S_i, $i = 1, 2$ and their sub-selves as smaller space-time sheets S_{ij} glued by wormhole contacts to the space-time sheets S_i. When sub-self space-time sheets S_{1j} and S_{2k} are connected by join along boundaries bonds, the fusion and sharing of these mental images occurs.

The neural network model for the formation of associations relies on the idea that some states of the neural net are in a correspondence with the states of the external world. Also the states of different layers of neural net have natural mutual correspondence. Association basically creates one-one map. In neural net models the interaction with external world occurs via driving force and dissipation leads to asymptotic states, which can be interpreted as association of net-states with the states of the external world. The problem of the neural network models is how the learning process could be realized in living brain. In particular, how two simultaneous ideas represented by the substates of neural net get associated with each other. This seems to require that the presence of two active nodes present in the net tends to strengthen their mutual coupling. There is a lot of empirical supports for this and neural transmitter action is an essential element of this process. In TGD framework this process corresponds to the gradual movement of neurons and brain in their spin glass energy landscape induced by neural transmitter action.

In TGD framework the formation of association $A \rightarrow B$ would mean that the stimulus A alone can generate B. This means that the sub-self representing mental image A tends to wake up the sub-self representing mental image B. At the neuronal level this simply means that the firing presynaptic neuron excites postsynaptic neuron so that it also fires: the long term changes of the synaptic connection promotes this ability. At the level of our mental images the waking up process must involve nerve pulse transmission from neural circuit representing sub-self A to the neural circuit representing sub-self B. Josephson current model suggests that during learning period, when A and B are experienced simultaneously, they are mapped to reference currents in feature recognition network $A+B$. Later when only A serves as input, part A of the circuit $A+B$ begins to fire when it receives A as input. If the synaptic connections between circuits A and B have been strengthened during learning period, the firing spreads out to B and also B wakes up. This in turn leads to the self-organization process generating experience $A+B$.

Many associations are bi-directional: for instance, symbols for real world objects are bi-directional associations. In TGD framework one can model the generation of the bi-directional associations in classical sense along following lines. Denote by A and B the symbols to be associated: A and B correspond to sub-selves of say self X. Neural net philosophy suggests that A and B should co-operate to keep each other in wake-up state (alive!): self-organization by quantum jumps could lead to this kind of co-operation. This is achieved if sensory experiences stimulate automatically co-operative self-populations, whose members tend to keep each other awake. This model is consistent with the fact that associations do not involve conscious thought. For instance, A could generate nerve pulse patterns waking up B and vice versa. Note that at the next level of the self hierarchy this could be regarded as a formation of self-association $X \rightarrow X$ possibly giving rise to a stable short term memory and also as survival of self X guaranteed by co-operation of sub-selves.

2.4.3 Computationalism And TGD

Computationalism in strong sense (brains as deterministic machines) does not emerge from TGD. The basic reason is that the time concept is totally different from that of computationalism. One can say that quantum jumps select between different time evolutions and the overall-important modular structures result from self cascades.

How computationalism and TGD approach differ?

A good example is provided by vision discussed in [J71] . Vision builds representation or description of the world from sensory data. Since inverse optics is not possible, implicit assumptions about the structure of the external world are necessary. Typically illusions rely on the breaking of these implicit assumptions. Illusions are not always undesirable. Two-dimensional pictures are an example of an illusion making possible visual communication! Auto-stereograms [J71] consisting of diffuse soup of points are a particularly striking example of illusion: looking the picture for a sufficient time, one can experience a dramatic re-shapening of the experience: beautiful 3-dimensional picture emerges from the chaos. Auto-stereograms support the hypothesis that vision involves computational activities or quantum counterparts of them. This process can be seen as a school example about how brain adds to a pure sensory input symbolic and cognitive representations.

In TGD universe brain does not probably deduce the representation of the world from picture by a straightforward computation. Certainly the data and implicit or learned assumptions about the world appear as an input in some sense. Some kind of iterated guessing based on implicit assumptions seems to involved: guess is made and compared with the actual picture. Quantum self-organization indeed makes possible the iteration, being in itself an iterative process. Guesses are very probably based on the existing abstract data about possible configurations of the world. The paradigm of 4-dimensional brain allowing to realized long term memories as geometric memories could be crucial in this respect. One can wonder whether the implicit assumptions might also develop from temporal entanglements with larger selves (during sleep) giving rise to information about world in longer length and time scales.

Control of motion is second good example of what might happen. There is no deterministic program proceeding with respect to geometric time and selecting what happens next and creating the quantum history step by step. Rather, the entire pattern of motion is selected by the creation of the main program self by quantum jump. The subsequent quantum jumps occur in the cascade proceeding in top-to-bottom type manner to shorter spatial and temporal scales. Thus the main program corresponds to, say the pattern of large scale motion, and sub-programs correspond to the details of the motion. What is new as compared to computationalism is that the program is created while it runs.

At the level of CNS anatomy sensory perceptions and motor actions loook mirror images of each other. TGD suggests that they could be mirror images at much deeper level. Motor actions would be time reversal of sensory perception in appropriate time scales for MEs (topological light rays, “massless extremals”) and routinely involve breaking of the second law in this p-adic time scales. This assumption implies that motor action results like a painting starting from a rough sketch. Dissipation and its time reversal automatically perform Darwinian selection leading quantum jump by quantum jump to the final motor action. No detailed planning is needed. Motor imagination is motor action starting from some level above the muscles and motor skills can be learned by imagining them.

Real selves as symbols

The ability to think in terms of symbols is certainly one of the key features of intelligence. The hierarchical structure of selves within selves and the possibility of cascades creating selves within selves allows to interpret sub-selves of self as conscious representations for symbols, at least under certain additional conditions. The condition seems to be that symbol sub-self and the primary sub-self representing the real object must be able to wake-up each other bi-directionally. Symbol self and “real self” could also belong to different levels of the hierarchy. For instance, single neuron could serve as a representative of neuron group in the sense that neuron and neuron group can wake-up each other. Perhaps Grandma neuron serves as a symbol for a complicated experience of entire neuron group. Linguistic associations would certainly be sub-selves representing this kind of representative function very effectively. This kind of symbol neurons would correspond to leaders at the level of human society. Indeed, words can generate actions and word selves are excellent candidates for the leaders of the neuronal society!

Selves allow also other interpretations. In very general sense they can be identified as agents or “demons” in the sense of computationalism. Agents can be also regarded as counterparts of submodules of main program. The call of subroutine from main program could be regarded as a wake-up of subprogram self. The main program forms automatically abstraction of the entire subjective history of subprogram self. The input data of submodules realized as sub-selves is most naturally realized as sensory input. For instance, neurons are expected to have chemical senses making communication between neuronal selves possible [K30]. Nerve pulses provide obvious candidate for a communication mode.

The concept of global workspace [J20] is one of the basic concepts used in the modelling of cognition and short term memory. The model visualizes short term memory as a global workspace, kind of common blackboard seen by various agents. The agents in turn can add write data to the global work space. Communication via global workspace is clearly analogous to mass media. Communication via global work space could be realized as chemical communication. Hormonal system could be an example of mass media operating at the level of our conscious experience. A surprisingly large volume of brain is free of neurons and glial cells and there is experimental evidence for chemical communication occurring via this free volume [I3]. In TGD framework global work space could be also realized in terms of coherent photons if selves act as quantum antennas able to receive and send messages: this would be very much like mass media in neuronal and sub-neuronal length scales.

Wholes and parts, classes and individuals

Wholes contra parts and classes contra individuals are basic concepts of computationalism and should allow representation as quantum level concepts. Also in TGD framework these concepts emerge naturally. The sub-selves X_i of self X are individuals and a natural hypothesis is that X experiences X_i as separate sub-selves. The self Y at the next level of hierarchy containing X in turn experiences the set $\{X_i\}$ of sub-selves of X as an average $\langle X_i \rangle$, typical representative of class X. For instance, if sub-selves of X represent different faces, then Y forms abstraction about the concept of face.

“Whole” is a concept different from class. A good example of “whole” is letter F formed from smaller F: s. Whole is something more than a sum of individuals and the problem is to understand how this whole is represented at quantum level. A very natural hypothesis is that the whole formed by sub-selves is formed by quantum entanglement between sub-selves leading to the disappearance of the individual sub-selves. When entanglement is destroyed, sub-selves or some of them are experienced as separate: this mechanism could also be regarded as a quantum mechanism for the formation of associations. Sensory experiences would wake up sensory selves involving sensory organ and parts of brain giving rise to different representations of sensory data and the analysis of sensory experience would involve the decomposition of these selves to sub-selves.

Our body consciousness provides testing ground these ideas. Contrary to the basic dogma of neuroscience, in TGD framework the fundamental representation of the body is formed by the body itself as is clear also on basis of the concept of self. Of course, representations at the level of brain are also involved and make possible the analysis of the body experience. We do not however experience our bodies as a huge number of separate cells. The explanation is that our sub-selves correspond to structures that are much larger than cell. Various parts of our body could obviously correspond to the sub-selves of our self. The fact that we recognize all parts of our body as such suggests that our self is at least as large as our body or perhaps even larger. Interestingly, in some brain disorders patient does not admit that some part of body, say left side of the body, belongs to them. This would suggest that the self of these persons is reduced to the self of the other side of the body rather than that of entire body.

Predictions and memories

The paradigm of 4-dimensional brain (and of 4-dimensional body and even of 4-dimensional Universe!) differentiates between TGD based computationalism and classical computationalism. One of the most important predictions is the possibility of two kinds of memories: geometric "memory" generating simulations of past and future and subjective memory making it possible to have genuine memories about previous moments of consciousness. The comparison of the predictions with what actually happened seems to be basic activity of conscious mind. The fundamental realizations of both subjective and geometric memory elegantly circumvent the memory storage problems encountered in the computationalistic approach and multiplied by the combinatorial explosion.

These basic memory types allow several realizations. The identification of immediate short term memories as subjective memories is very natural. Geometric memories seem to be the only reasonable candidate for long term memories. Procedural memories relying on association of say nerve pulse patterns with experiences are possible.

Self at a given level of hierarchy forms automatically abstractions about the wake-up periods of the lower level selves. This makes possible to form abstractions about the time development of sub-selves and to gain wisdom given by experience. Long term memories involve both the formation of abstractions as some kind of time averages and detailed information. This is difficult to realize in the neural network approach.

Boolean logic and logical deductions

One can easily invent models of logical reasoning but probably the most realistic model is based on representing the premises of the logical deduction using Boolean statements realized in terms of fermions. These cognitive representations defined in the intersection of realities and p-adicities symbolic representations, and generate a neural activity representing the logical deduction, which is basically realized using learned associations. This model involves minimum amount of p-adic physics, is essentially isomorphic with the model of imagination, and is consistent with neuroscience facts.

An interesting possibility is that many particle states of cognitive neutrino pairs providing representation of logical thoughts could replicate. This might be possible. If the macroscopic phase determined by cognitive neutrino pairs is completely fixed by the structure of mind-like space-time sheets then the replication of the material space-time sheet and mind-like space-time sheet would lead to the replication of thought. DNA replication seems to occur in too short length length scale to be associated with this process. Cell replication could however quite well involve replication of thoughts. Cell replication does not seem to occur at the level of brain. Presumably nerve pulses generating standardized patterns of cognitive neutrino pairs have replaced direct decay of cell as a more effective manner to replicate thoughts and eventually even communicate them.

Beliefs and desires

Computational approach does not have much to say about emotions. Beliefs and desires are however concepts allowing symbolic (one might say computational) representation: this of course does not explain what gives for belief or desire its emotional content.

Beliefs could be very generally regarded as basic axioms of formal system from which various deductions by truth preserving symbol manipulations are obtained. The mathematical model behind numerical calculation is a nontrivial example of this kind of belief system. Desires can be realized in computational science in terms of goals assigned with the initial state. For instance, the desire of the problem solver is to solve the problem that is get from initial state to the desired final state by applying fixed rules. Initial state could correspond to the assumptions of a theorem and final state to the theorem itself. If it is possible to solve the problem at the level of symbolic representation, the solution of problem can be mapped to the real world. Beliefs and desires could easily be represented symbolically in terms of neural activity using associations. A Boolean representation of beliefs could be in terms of logical statements using cognitive neutrinos or real neutrinos.

It is not so easy to understand what gives rise to the conscious experience of belief or desire. The geometric time development can be regarded as a prediction of future (and past) whereas "reality" corresponds to the subjective time development. The belief about what happens in the future is a special belief and could be seen as "memories" with respect to the geometric time: seeing to the future. Intention would be the p-adic counterpart of this kind of belief, seeing to the p-adic future. A wide class of emotions could result from the comparison of the predicted and real. That predicted and real coincide, could correspond to nearly identical sub-selves able to form a bound state accompanied by a a period of macrotemporal quantum coherence and a positive emotion like understanding.

The fundamental desire of the sub-self is to stay conscious, to survive. Cognitive, symbolic, and Boolean representations would give for the desire of the mental images of the conscious world model to survive an interpretation as a higher level desire. Also beliefs might be determined to a large extend by the desire of the sub-selves to survive: giving up a belief means death of the corresponding mental images and unpleasant mental images are a threat for mental images defining the self model. We tend to have beliefs which do not threat our ego.

Simple model for problem solving

Problem solving is certainly quite high level cognitive skill. A good test for the proposed scenario is how simple conscious problem solving could proceed. The basic desire of problem solver is to achieve the goal given the initial state. Problem solver makes trials and when goal and achieved state are sufficiently near to each other problem can be said to be solved. The model for this activity could be roughly like follows:

1. Goal is represented as a physical state of some subsystem and the basic problem is how problem solver can compare the result of trial with the goal. It seems that all conscious comparisons must reduce at fundamental level to the comparisons of geometric and subjective time developments of some sub-self. Thus it seems that problem solver self must directly experiences whether the goal was achieved by experiencing how much the hoped for geometric time development and subjective time development generated by the trial resembled each other.

2. This approach as such is not practical. Standard computationalism would the comparison of the result of a trial to the goal necessitates circuit which carries out comparisons. This kind of circuit is easy to realize. For instance, Josephson junctions could physically realize the difference between the result of trial and goal as the phase difference between weakly coupled superconductors. To know whether the trial was successful, problem solver must compare the desire represented by a binary digit one in geometric memory with the result of comparison represented by a binary digit having one one or zero in subjective memory. For instance, limbic brain could be the seat of these binary digits and comparison could occur there.

3. Problem-solver sub-self generates solution trials. Most naturally this involves quantum jump leading to decomposition of problem solver self to two subsystems. This decomposition represents the trial. Good problem solver must be able to generate very many different trials: this means that entanglement entropy is almost constant function of sub-self generated in quantum jump.

4. Problem solver self performs the comparison. When output is "No" problem-solver self generates a new trial. System must have a *Eeureka!* experience, when the problem is solved. This is achieved if "problem solver" self is "enlightened" when it receives output "yes" from the comparison circuit. This means that problem-solver selves begins to make quantum jumps reducing matter-mind entanglement and does not generate trials anymore.

5. The trials could be representable as p-adic space-time sheets defining the initial states of the symbolic representation defining the world model and realized as patterns of neural activity based on association mechanism. Their transformation to real ones would initiate the simulation. Also this process is very similar to that behing logical reasoning and imagination.

There is no need to add that in reality problem solving is much more complicated procedure! The above model could however provide insight about the conscious experiences related to the problem solving.

Quantum computationalism in TGD Universe

Macrotemporal quantum coherence makes also quantum computation like processes possible since a sequence of quantum jumps effectively binds to a single quantum jump with a duration, which corresponds to the lifetime of the bound state. Quantum computation like process starts, when the quantum bound state is generated and halts when it decays. Spin glass degeneracy increases the duration of the quantum computation to time scales which are sensical for human consciousness. In case of cognitive quantum computation like processes the quantum coherence is stabilized by NMP.

1. Spin glass degeneracy provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the join along boundaries bonds/flux tubes and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis emerges.

2. Bio-systems would be especially attractive candidates for performers of both non-cognitive and cognitive quantum computation like processes. The binding of molecules by lock and key mechanism is a basic process in living matter and the binding of information molecules to receptors is a special case of this process. All these processes would involve new physics not taken into account in the standard physics based biochemistry.

3. The possibility of cognitive quantum computation like information processing forces generalize the standard quantum computer paradigm also because ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. Qubits must be replaced by qupits since for algebraic $R-R_p$ entanglement two-state systems are naturally replaced with p-state systems and for $R_{p_1}-R_{p_2}$ entanglement with $p_1\times p_2$ state systems. For primes of order say $p\simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which means 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 idea about neuron as a classical bit might be a little bit wrong!

4. It might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macrotemporal 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.

The progress taken place in quantum TGD during the period 2005-2010 allows to add to this picture several new elements.

1. The hierarchy of Planck constants and identification of ordinary particles at magnetic flux tubes with arbitrarily large value of Planck constant as dark matter leads to the vision about DNA and nuclear and cell membrane acting as topological quantum computer with the

braiding of flux tubes defining the space-time correlate for the quantum computation [K2]. The intronic portions of genome are natural candidates for the parts of genome specialized to quantum computation like activities and for these purposes the exact nucleotide content of the DNA sequence is not crucial so that DNA looking like "junk" is not junk from the point of view of quantum computation.

2. Zero energy ontology brings in naturally the 4-D ensemble of quantum computations assignable to sub-CDs of given CD. The classical correlates for quantum computations are 4-D classical field patterns assignable to space-time surfaces inside CDs. Causal diamonds bring in the time scales of 1 ms and.1 s associated with quarks and leptons, which are also the time scales of nerve pulse activity and of memetic code. This supports the view that dark quarks at the ends of magnetic flux tubes connecting DNA nucleotides and the lipids of the cell membrane are indeed the key element of computation.

3. In the intersection of real and p-adic worlds negentropic entanglement is possible. This stabilizes qubits but makes them fuzzy. This requires reformulation of topological quantum computation in terms of the U-matrix characterizing U-process for zero energy states and restricted to the states with negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book).

2.4.4 How Brain Builds The Model Of The External World?

What we experience is not completely determined by the sensory data: a lot of computation like processes at the level of cortex is involved. In TGD generation of symbolic representations would perhaps be more appropriate term. The phenomenon of illusions, most importantly, our ability to see planar pictures as 3-dimensional, shows that this computation involves a model of external world based on definite assumptions [J71]. Stereo vision [J71] is a good example of a sensory experience involving a lot of cognitive processing at the level of cortex. Depth cannot be experienced directly and the deduction of the actual positions for the points of the visual field must involve large amount of cognitive processing carried out in cortex. At the level of conscious experience the fusion of right and left visual fields to single visual field seems to be responsible for the emergence of the 3-D visual experience.

That complicated information processing is involved is demonstrated by autostereograms, in which a chaotic set of points experienced as a planar picture organizes to a beautiful 3-dimensional picture after intensive concentration (all subject persons are not able to see the 3-dimensional picture). It is known that stereo vision develops in age of few months at the same time when some cortical neurons specialize to receive input from only single eye instead of superposing the inputs from both eyes. Brain is also able to estimate the state of motion of objects of visual field from sensory data and this must involve a lot of computation. The fact that some people cannot experience motion in the visual field provides a support for the claim that this experience is a result of a complicated neuronal processing. At first, the computational aspects of the conscious experience would seem to be in conflict with the idea that sensory organs are the primary sensory experiencers. The situation is however not so simple as the closer examination of the computational aspects of the visual experience demonstrates. The basic point is that brain quantum entangles to the sensory representation various symbolic and cognitive representations giving meaning to what is sensed.

TGD based view about construction of sensory representations

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 and cognitive 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 and symbolic representations outside brain. Magnetic flux tube structures would serve as the sensory canvas to which sensory images are projected from brain and possibly from 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. Thus the experiencer would the complex containing so called material body and hierarchy of field bodies.

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 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 [K10] indeed support this view. Of course, this view about human consciousness is not new, it is shared by all spiritual practices. What is new is the concrete physical model realizing this view physically.

It would seem that the generation of the visual experience involves some kind of iterative computational process laeding to an optimal conscious sensory representation of the external world. This process must involve a model of the external world, which is improved iteratively. Each computational step must provide an estimate for the various positional coordinates of the object and features associated with it and a subsequent comparison of the real sensory data with the virtual sensory data yielded by the model world. The virtual world sensory input yielded by this model is compared with the real world sensory input in comparison circuit and when virtual and real inputs are sufficiently near each other synchronous neural firing leading to a wake-up of sensory sub-self and conscious recognition of the object of the perceptive field occurs. This could also involve intermediate cognitive, symbolic, and sensory representations not conscious to us who see only the final product of this process. In case of vision the model suggests that both eyes yield actually stereovision separately in ordinary circumstances. This might be the case: one must hold second eye closed for sufficiently long time before the picture gradually flattens.

This quasi-computational process is cognitive process involving imagined sensory, motor and Boolean representations ("this is true" experiences) realized. If the primary qualia are at the level of sensory organs it is easy to understand why imagination lacks the sensory qualia. Only during dreams and hallucinations would the back-projection to the sensory organs occur and "qualiafy" the symbolic representations generated by imagination.

The original proposal was that imagination is a purely p-adic process involving transformation of p-adic space-time sheets to real ones. In the adelic vision this does not make sense. Both real and p-adic (cognitive) aspects are always present. If motor action is a geometric time reversal of sensory perception in relevant p-adic time scales, it is initiated at some level above muscles and proceed to higher levels so that there is no danger that real motor actions are generated. Dissipation and its time reversal implying a Darwinian selection of mental images are probably the basic tools of imagination and problem solving: second law becomes an ally rather than an enemy. Problem solving and motor actions quite generally start from a rough sketch and there is no need for rigid and bureucratic program structures as in case of AI. Program develops as it runs.

There are several information sources at use when cortex deduces the positional coordinates for the objects of the perceptive field. In case of vision the decomposition of the right and left visual fields to objects is an essential element of the approach. For instance, simple estimate for the distance of object results from the comparison of the positions of the images of object in the retina. If illumination is constant, the comparison of the intensities of the reflected light coming from various planar pieces of the surface representing object gives estimate for the normal direction of the planar piece. Also the fact, that some points of the object are not seen simultaneously by right and left eye can be used as a constraint. In case of autostereograms there is no decomposition into objects and the problem is to identify, which points of the right eye and left eye correspond to same point of the external world: the color of the points is obvious clue. Also long term memories about objects seen earlier are obviously involved.

In the simple situation that the visual world consists of simple objects, no comparison of the model world with the real world is needed provided that cortex is able to perform some simple arithmetics (which is not at all obvious!). In the general situation experience is yielded by the iterative computation like process (actually a rather long sequence of quantum computations if single quantum computation lasts about 10^4 Planck times).

A possible model for the computational aspects of sensory experience

The mind-like space-time sheets in the regions of cortex and various brain nuclei could see each other in the illumination provided by the Bose-Einstein condensed photons propagating along axonal (possibly also microtubular) wave guides. This would make possible comparison circuits in which inputs from two different areas of brain to area of brain are compared. The comparison circuit based on Josephson currents is ideal for this purpose. In case that inputs are identical, synchronous neural activity results. The comparison of the images could be crucial in realizing the iterative evaluation of the computational aspects of sensory experience. This iterative comparison process need not be conscious to us.

From our point of view brain seems to generate only symbolic representations. Cortex might however also generate virtual world sensory experiences at lower levels of the self hierarchy and not conscious to us. These could be compared with the genuine sensory input in (say) thalamus and convergent iteration would lead to a resonant firing and conscious experience of recognition. This would explain the observed adaptive resonance phenomenon in which thalamo-cortical feedback loop directs conscious attention to those aspects of sensory percept which agree with the expectation. Direction of attention would mean generation of a sensory sub-self representing the recognized part of perceptive field. Novelty detection could occur at higher information processing level and could be based on inhibitory projections from feature detectors to the novelty detecting neural circuit.

Just to concretize the idea, one could imagine the following rough scenario for how the comparison involving neuronal sensory qualia (not ours) could proceed.

1. Neurons in some parts of brain, most naturally in the thalamus, have neural window to the primary sensory organ radiating coherent light propagating along microtubular waveguides to thalamus. Besides vision and perhaps even hearing, neurons would also have chemical senses and receptor-transmitter complexes would define different qualia. Different sensory modalities feed different regions of thalamus with difference wavelengths characterizing the sensory modality so that the neuronal window based on coherent light might be used by all sensory modalities to achieve this comparison. This is consistent with the fact that microtubuli are present in all axons. There is an intensive feedback from cortex to thalamus and this feedback could quite generally be related to the cognitive representations generated in cortex and communicated to thalamus for comparison. The results of the comparison are sent back to the cortex coded in nerve pulse patterns and change the properties of the model world to give a better fit.

2. The imagery model world consisting of neuronal mind-like space-time sheets in cortex represents the results of a cortical computation. Mind-like space-time sheets radiate coherent light with the intensity determined by the model of the external world specifying the intensity of the reflected light from a particular object. The simplest possibility is that the representation consists of mind-like space-time sheets whose size and shape are deduced from the size and shape of the objects and from the estimated values of the height function. Only the active cortical neurons send coherent light along microtubules to thalamus. The result of the comparison is coded to nerve pulse pattern and sent back to cortex to make possible next trial.

Connection with the observations of Barbara Shipman

There is also an interesting connection with the model the model of Barbra Shipman for the dance of honeybee [A7, A8, A9].

The model relies on the puzzling observation that the manifold $F_3 = SU(3)/U(1) \times U(1)$ parametrizing different choices of color quantum numbers seems to be involved with the dance [K30]. In TGD framework color rotations do not leave classical Z^0 and em fields invariant although induced Kähler field is color invariant. For instance, in a color rotation a pure Z^0 ME is in general transformed to a ME carrying a light-like vacuum em current generating a hologram possibly acting as a biological control command. This suggests an explanation for the observations of Shipman and also that the canonical coordinates (P_i, Q_i) for the 6-dimensional symplectic space F_3 play crucial role in the construction of sensory representation. In fact, in Shipman's model the Hamiltonians associated with color isospin and hypercharge take the role of planar coordinates for the dance floor at which the dance of honeybee takes place. More generally, it might be possible to represent the position of the object of a perceptive field using some coordinates of F_3. The optimal situation would be that both the velocity and position would be coded to a point of F_3 so that CP_2 orientation of space-time sheet would represent position for an object of a perceptive field.

2.5 Number Theoretical Feats and TGD Inspired Theory of Consciousness

Number theoretical feats of some mathematicians like Ramanujan remain a mystery for those believing that brain is a classical computer. Also the ability of idiot savants - lacking even the idea about what prime is - to factorize integers to primes challenges the idea that an algorithm is involved. In this article I discuss ideas about how various arithmetical feats such as partitioning integer to a sum of integers and to a product of prime factors might take place. The ideas are inspired by the number theoretic vision about TGD suggesting that basic arithmetics might be realized as naturally occurring processes at quantum level and the outcomes might be "sensorily perceived". One can also ask whether zero energy ontology (ZEO) could allow to perform quantum computations in polynomial instead of exponential time.

The indian mathematician Srinivasa Ramanujan is perhaps the most well-known example about a mathematician with miraculous gifts. He told immediately answers to difficult mathematical questions - ordinary mortals had to hard computational work to check that the answer was right. Many of the extremely intricate mathematical formulas of Ramanujan have been proved much later by using advanced number theory. Ramanujan told that he got the answers from his personal Goddess. A possible TGD based explanation of this feat relies on the idea that in zero energy ontology (ZEO) quantum computation like activity could consist of steps consisting quantum computation and its time reversal with long-lasting part of each step performed in reverse time direction at opposite boundary of causal diamond so that the net time used would be short at second boundary.

The adelic picture about state function reduction in ZEO suggests that it might be possible to have direct sensory experience about prime factorization of integers [L19]. What about partitions of integers to sums of primes? For years ago I proposed that symplectic QFT is an essential part of TGD. The basic observation was that one can assign to polygons of partonic 2-surface - say geodesic triangles - Kähler magnetic fluxes defining symplectic invariance identifiable as zero modes. This assignment makes sense also for string world sheets and gives rise to what is usually called Abelian Wilson line. I could not specify at that time how to select these polygons. A very natural manner to fix the vertices of polygon (or polygons) is to assume that they correspond ends of fermion lines which appear as boundaries of string world sheets. The polygons would be fixed rather uniquely by requiring that fermions reside at their vertices.

The number 1 is the only prime for addition so that the analog of prime factorization for sum is not of much use. Polygons with $n = 3, 4, 5$ vertices are special in that one cannot decompose them to non-degenerate polygons. Non-degenerate polygons also represent integers $n > 2$. This inspires the idea about numbers $\{3, 4, 5\}$ as "additive primes" for integers $n > 2$ representable as non-degenerate polygons. These polygons could be associated many-fermion states with negentropic entanglement (NE) - this notion relate to cognition and conscious information and is something totally new from standard physics point of view. This inspires also a conjecture about a deep connection with arithmetic consciousness: polygons would define conscious representations for integers $n > 2$. The splicings of polygons to smaller ones could be dynamical quantum processes behind arithmetic conscious processes involving addition.

2.5.1 How Ramanujan did it?

Lubos Motl wrote recently a blog posting (`http://tinyurl.com/zduu72p`) about $P \neq NP$ computer in the theory of computation based on Turing's work. This unproven conjecture relies on a classical model of computation developed by formulating mathematically what the women doing the hard computational work in offices at the time of Turing did. Turing's model is extremely beautiful mathematical abstraction of something very every-daily but does not involve fundamental physics in any manner so that it must be taken with caution. The basic notions include those of algorithm and recursive function, and the mathematics used in the model is mathematics of integers. Nothing is assumed about what conscious computation is and it is somewhat ironic that this model has been taken by strong AI people as a model of consciousness!

1. A canonical model for classical computation is in terms of Turing machine, which has bit sequence as inputs and transforms them to outputs and each step changes its internal state. A more concrete model is in terms of a network of gates representing basic operations for the incoming bits: from this basic functions one constructs all recursive functions. The computer and program actualize the algorithm represented as a computer program and eventually halts - at least one can hope that it does so. Assuming that the elementary operations require some minimum time, one can estimate the number of steps required and get an estimate for the dependence of the computation time as function of the size of computation.

2. If the time required by a computation, whose size is characterized by the number N of relevant bits, can be carried in time proportional to some power of N and is thus polynomial, one says that computation is in class P. Non-polynomial computation in class NP would correspond to a computation time increasing with N faster than any power of N, say exponentially. Donald Knuth, whose name is familiar for everyone using Latex to produce mathematical text, believes on $P = NP$ in the framework of classical computation. Lubos in turn thinks that the Turing model is probably too primitive and that quantum physics based model is needed and this might allow $P = NP$.

What about quantum computation as we understand it in the recent quantum physics: can it achieve $P = NP$?

1. Quantum computation is often compared to a superposition of classical computations and this might encourage to think that this could make it much more effective but this does not seem to be the case. Note however that the amount of information represents by N qubits is however exponentially larger than that represented by N classical bits since entanglement is possible. The prevailing wisdom seems to be that in some situations quantum computation can be faster than the classical one but that if $P = NP$ holds true for classical computation, it holds true also for quantum computations. Presumably because the model of quantum computation begins from the classical model and only (quantum computer scientists must experience this statement as an insult - apologies!) replaces bits with qubits.

2. In quantum computer one replaces bits with entangled qubits and gates with quantum gates and computation corresponds to a unitary time evolution with respect to a discretized time parameter constructed in terms of fundamental simple building bricks. So called tensor networks realize the idea of local unitary in a nice manner and has been proposed to defined error correcting quantum codes. State function reduction halts the computation. The outcome is non-deterministic but one can perform large number of computations and deduce from the distribution of outcomes the results of computation.

What about conscious computations? Or more generally, conscious information processing. Could it proceed faster than computation in these sense of Turing? To answer this question one must first try to understand what conscious information processing might be. TGD inspired theory of consciousnesss provides one a possible answer to the question involving not only quantum physics but also new quantum physics.

1. In TGD framework Zero energy ontology (ZEO) replaces ordinary positive energy ontology and forces to generalize the theory of quantum measurement. This brings in several new

elements. In particular, state function reductions can occur at both boundaries of causal diamond (CD), which is intersection of future and past direct light-cones and defines a geometric correlate for self. Selves for a fractal hierarchy - CDs within CDs and maybe also overlapping. Negentropy Maximization Principle (NMP) is the basic variational principle of consciousness and tells that the state function reductions generate maximum amount of conscious information. The notion of negentropic entanglement (NE) involving p-adic physics as physics of cognition and hierarchy of Planck constants assigned with dark matter are also central elements.

2. NMP allows a sequence of state function reductions to occur at given boundary of diamond-like CD - call it passive boundary. The state function reduction sequence leaving everything unchanged at the passive boundary of CD defines self as a generalized Zeno effect. Each step shifts the opposite - active - boundary of CD "upwards" and increases its distance from the passive boundary. Also the states at it change and one has the counterpart of unitary time evolution. The shifting of the active boundary gives rise to the experienced time flow and sensory input generating cognitive mental images - the "Maya" aspect of conscious experienced. Passive boundary corresponds to permanent unchanging "Self".

3. Eventually NMP forces the first reduction to the opposite boundary to occur. Self dies and reincarnates as a time reversed self. The opposite boundary of CD would be now shifting "downwards" and increasing CD size further. At the next reduction to opposite boundary re-incarnation of self in the geometric future of the original self would occur. This would be re-incarnation in the sense of Eastern philosophies. It would make sense to wonder whose incarnation in geometric past I might represent!

Could this allow to perform fast quantal computations by decomposing the computation to a sequence in which one proceeds in both directions of time? Could the incredible feats of some "human computers" rely on this quantum mechanism (see `http://tinyurl.com/hk5baty`). The indian mathematician Srinivasa Ramanujan (see `http://tinyurl.com/l42q7a2`) is the most well-known example of a mathematician with miraculous gifts. He told immediately answers to difficult mathematical questions - ordinary mortals had to hard computational work to check that the answer was right. Many of the extremely intricate mathematical formulas of Ramanujan have been proved much later by using advanced number theory. Ramanujan told that he got the answers from his personal Goddess.

Might it be possible in ZEO to perform quantally computations requiring classically non-polynomial time much faster - even in polynomial time? If this were the case, one might at least try to understand how Ramanujan did it although higher levels selves might be involved also (did his Goddess do the job?).

1. Quantal computation would correspond to a state function reduction sequence at fixed boundary of CD defining a mathematical mental image as sub-self. In the first reduction to the opposite boundary of CD sub-self representing mathematical mental image would die and quantum computation would halt. A new computation at opposite boundary proceeding to opposite direction of geometric time would begin and define a time-reversed mathematical mental image. This sequence of reincarnations of sub-self as its time reversal could give rise to a sequence of quantum computation like processes taking less time than usually since one half of computations would take place at the opposite boundary to opposite time direction (the size of CD increases as the boundary shifts).

2. If the average computation time is same at both boundaries, the computation time would be only halved. Not very impressive. However, if the mental images at second boundary - call it A - are short-lived and the selves at opposite boundary B are very long-lived and represent very long computations, the process could be very fast from the point of view of A! Could one overcome the $P \neq NP$ constraint by performing computations during time-reversed re-incarnations?! Short living mental images at this boundary and very long-lived mental images at the opposite boundary - could this be the secret of Ramanujan?

3. Was the Goddess of Ramanujan - self at higher level of self-hierarchy - nothing but a time reversal for some mathematical mental image of Ramanujan (Brahman=Atman!), representing

very long quantal computations! We have night-day cycle of personal consciousness and it could correspond to a sequence of re-incarnations at some level of our personal self-hierarchy. Ramanujan tells that he met his Goddess in dreams. Was his Goddess the time reversal of that part of Ramanujan, which was unconscious when Ramanujan slept? Intriguingly, Ramanujan was rather short-lived himself - he died at the age of 32! In fact, many geniuses have been rather short-lived.

4. Why the alter ego of Ramanujan was Goddess? Jung intuited that our psyche has two aspects: anima and animus. Do they quite universally correspond to self and its time reversal? Do our mental images have gender?! Could our self-hierarchy be a hierarchical collection of anima and animi so that gender would be something much deeper than biological sex! And what about Yin-Yang duality of Chinese philosophy and the ka as the shadow of persona in the mythology of ancient Egypt?

2.5.2 Symplectic QFT, $\{3,4,5\}$ as Additive Primes, and Arithmetic Consciousness

For years ago I proposed that symplectic QFT is an essential part of TGD [K11, K85]. The basic observation was that one can assign to polygons of partonic 2-surface - say geodesic triangles - Kähler magnetic fluxes defining symplectic invariance identifiable as zero modes. This assignment makes sense also for string world sheets and gives rise to what is usually called Abelian Wilson line. I could not specify at that time how to select these polygons in the case of partonic 2-surfaces.

The recent proposal of Maldacena and Arkani-Hamed [B16] (see http://tinyurl.com/ych26gcm) that CMB might contain signature of inflationary cosmology as triangles and polygons for which the magnitude of n-point correlation function is enhanced led to a progress in this respect. In the proposal of Maldacena and Arkani-Hamed the polygons are defined by momentum conservation. Now the polygons would be fixed rather uniquely by requiring that fermions reside at their vertices and momentum conservation is not involved.

This inspires the idea about numbers $\{3,4,5\}$ as "additive primes" for integers $n > 2$ representable as non-degenerate polygons. Geometrically one could speak of prime polygons not decomposable to lower non-degenerate polygons. These polygons are different from those of Maldacena and Arkani-Hamed and would be associated many-fermion states with negentropic entanglement (NE) - this notion relates to cognition and conscious information and is something totally new from standard physics point of view. This inspires also a conjecture about a deep connection with arithmetic consciousness: polygons would define representations for integers $n > 2$. The splicings of polygons to smaller ones could be dynamical quantum processes behind arithmetic conscious processes involving addition. I have already earlier considered a possible counterpart for conscious prime factorization in the adelic framework [L19].

Basic ideas of TGD inspired theory of conscious very briefly

Negentropy Maximization Principle (NMP) is the variational principle of consciousness in TGD framework. It says that negentropy gain in state function reduction (quantum jump re-creating Universe) is maximal. State function reduction is basically quantum measurement in standard QM and sensory qualia (for instance) could be perhaps understood as quantum numbers of state resulting in state function reduction. NMP poses conditions on whether this reduction can occur. In standard ontology it would occur always when the state is entangled: reduction would destroy the entanglement and minimize entanglement entropy. When cognition is brought in, the situation changes.

The first challenge is to define what negentropic entanglement (NE) and negentropy could mean.

1. In real physics without cognition one does not have any definition of negentropy: on must define negentropy as reduction of entropy resulting as conscious entity gains information. This kind of definition is circular in consciousness theory.

2. In p-adic physics one can define number theoretic entanglement entropy with same basic properties as ordinary Shannon entropy. For some p-adic number fields this entropy can be

negative and this motivates an interpretation as conscious information related to entanglement - rather to the ignorance of external observer about entangled state. The prerequisite is that the entanglement probabilities belong to an an extension of rationals inducing a finite-dimensional extension of rationals. Algebraic extensions are such extensions as also those generate by a root of e (e^p is p-adic number in Q_p).

A crucial step is to fuse together sensory and cognitive worlds as different aspects of existence.

1. One must replace real universe with adelic one so that one has real space-time surfaces and their p-adic variants for various primes p satisfying identical field equations. These are related by strong form of holography (SH) in which 2-D surfaces (string world sheets and partonic 2-surfaces) serve as "space-time genes" and obey equations which make sense both p-adically in real sense so that one can identify them as points of "world of classical worlds" (WCW).

2. One can say that these 2-surfaces belong to intersection of realities and p-adicities - intersection of sensory and cognitive. This demands that the parameters appearing in the equations for 2-surface belong algebraic extension of rational numbers: the interpretation is that this hierarchy of extensions corresponds to evolutionary hierarchy. This also explains imagination in terms of the p-adic space-time surfaces which are not so unique as the real one because of inherent non-determinism of p-adic differental equations. What can be imagined cannot be necessarily realized. You can continued p-adic 2-surface to 4-D surface but not to real one.

There is also second key assumption involved.

1. Hilbert space of quantum states is *same* for real and p-adic sectors of adelic world: for instance, tensor product would lead to total nonsense since there would be both real and p-adic fermions. This means same quantum state and same entanglement but seen from sensory and various cognitive perspectives. This is the basic idea of adelicity: the p-adic norms of rational number characterize the norm of rational number. Now various p-adic conscious experiences characterize the quantum state.

2. Real perspective sees entanglement always as entropic. For some finite number number of primes p p-adic entanglement is however negentropic. For instance, for entanglement probabilities $p_i = 1/N$, the primes appearing as factors of N are such information carrying primes. The presence of these primes can make the entanglement stable. The total entropy equal to the sum of negative real negentropy + various p-adic negentropies can be positive and cannot be reduced in the reduction so that reduction does not occur at all! Entanglement is stabilized by cognition and the randomness of state function reduction tamed: matter has power over matter!

3. There is analogy with the reductionism-holism dichotomy. Real number based view is reductionistic: information is obtained when the entangled state is split into un-entangled part. p-Adic number based view is holistic: information is inthe negentropic entanglement and can be seen as abstraction or rule. The superposition of state pairs represents a rule with state pairs (a_i, b_i) representing the instance of the rule A↔B. Maximal entanglement defined by entanglement probabilities $p_i = 1/N$ makes clear the profound distinction between these views. In real sector the negentropy is negative and smallest possible. In p-adic sector the negentropy is maximum for p-adic primes appearing as factors of N and total negentropy as their sum is large. NE allows to select unique state basis if the probabilities p_i are different.

   For $p_i = 1/N$ one can choose any unitary related state basis since unit matrix is invariant under unitary transformations. From the real point of view the ignorance is maximal and entanglement entropy is indeed maximal. For instance, in case of Schrödinger cat one could choose the cat's state basis to be any superposition of dead and alive cat and a state orthogonal to it. From p-adic view information is maximal. The reports of meditators, in particular Zen buddhists, support this interpretation. In "enlightened state" all discriminations disappear: it does not make sense to speak about dead or alive cat or anything between these two options. The state contains information about entire state - not about its parts. It is not information expressible using language relying on making of distinctions but silent wisdom.

How do polygons emerge in TGD framework?

The duality defined by strong form of holography (SH) has 2 sides. Space-time side (bulk) and boundary side (string world sheets and partonic 2-surfaces). 2-D half of SH would suggest a description based on string world sheets and partonic 2-surfaces. This description should be especially simple for the quantum states realized as spinor fields in WCW ("world of classical worlds"). The spinors (as opposed to spinor fields) are now fermionic Fock states assignable to space-time surface defining a point of WCW. TGD extends ordinary 2-D conformal invariance to super-symplectic symmetry applying at the boundary of light-cone: note that given boundary of causal diamond (CD) is contained by light-cone boundary.

1. The correlation functions at embedding space level for fundamental objects, which are fermions at partonic 2-surfaces could be calculated by applying super-symplectic invariance having conformal structure. I have made rather concrete proposals in this respect. For instance, I have suggested that the conformal weights for the generators of supersymplectic algebra are given by poles of fermionic zeta $\zeta_F(s) = \zeta(s)/\zeta(2s)$ and thus include zeros of zeta scaled down by factor 1/2 [L9]. A related proposal is conformal confinement guaranteeing the reality of net conformal weights.

2. The conformally invariant correlation functions are those of super-symplectic CFT at light-cone boundary or its extension to CD. There would be the analog of conformal invariance associated with the light-like radial coordinate r_M and symplectic invariance associated with CP_2 and sphere S^2 localized with respect to r_M analogous to the complex coordinate in ordinary conformal invariance and naturally continued to hypercomplex coordinate at string world sheets carrying the fermionic modes and together with partonic 2-surfaces defining the boundary part of SH.

Symplectic invariants emerge in the following manner. Positive and negative energy parts of zero energy states would also depend on zero modes defined by super-symplectic invariants and this brings in polygons. Polygons emerge also from four-momentum conservation. These of course are also now present and involve the product of Lorentz group and color group assignable to CD near its either boundary. It seems that the extension of Poincare translations to Kac-Moody type symmetry allows to have full Poincare invariance (in its interior CD looks locally like $M^4 \times CP_2$).

1. One can define the symplectic invariants as magnetic fluxes associated with S^2 and CP_2 Kähler forms. For string world sheets one would obtain non-integrable phase factors. The vertices of polygons defined by string world sheets would correspond to the intersections of the string world sheets with partonic 2-surfaces at the boundaries of CD and at partonic 2-surfaces defining generalized vertices at which 3 light-like 3-surfaces meet along their ends.

2. Any polygon at partonic 2-surface would also allow to define such invariants. A physically natural assumption is that the vertices of these polygons are realized physically by adding fermions or antifermions at them. Kähler fluxes can be expressed in terms of non-integrable phase factors associated with the edges. This assumption would give the desired connection with quantum physics and fix highly uniquely but not completely the invariants appearing in physical states.

The correlated polygons would be thus naturally associated with fundamental fermions and a better analogy would be negentropically entangled n-fermion state rather than corresponding to maximum of the modulus of n-point correlation function. Hierarchy of Planck constants makes these states possible even in cosmological scales. The point would be that negentropic entanglement assignable to the p-adic sectors of WCW would be in key role.

Symplectic invariants and Abelian non-integrable phase factors

Consider now the polygons assignable to many-fermion states at partonic 2-surfaces.

1. The polygon associated with a given set of vertices defined by the position of fermions is far from unique and different polygons correspond to different physical situations. Certainly one must require that the geodesic polygon is not self-intersecting and defines a polygon or set of polygons.

2. Geometrically the polygon is not unique unless it is convex. For instance, one can take regular n-gon and add one vertex to its interior. The polygon can be also constructed in several ways. From this one obtains a non-convex $n+1$-gon in $n+1$ ways.

3. Given polygon is analogous with Hamiltonian cycle connecting all points of given graph. Now one does not have graph structure with edges and vertices unless one defines it by nearest neighbor property. Platonic solids provide an example of this kind of situation. Hamiltonian cycles [A1, A2] are key element in the TGD inspired model for music harmony leading also to a model of genetic code [K65] [L5].

4. One should somehow fix the edges of the polygon. For string world sheets the edges would be boundaries of string world sheet. For partonic 2-surfaces the simplest option is that the edges are geodesic lines and thus have shortest possible length. This would bring in metric so that the idea about TGD as almost topological QFT would be realized.

One can distinguish between two cases: single polygon or several polygons.

1. One has maximal entanglement between fundamental fermions, when the vertices define single polygon. One can however have several polygons for a given set of vertices and in this case the coherence is reduced. Minimal correlations correspond to maximal number of 3-gons and minimal number of 4-gons and 5-gons.

2. For large $h_{eff} = n \times h$ the partonic 2-surfaces can have macroscopic and even astrophysical size and one can consider assigning many-fermion states with them. For instance, anyonic states could be interpreted in this manner. In this case it would be natural to consider various decompositions of the state to polygons representing entangled fermions.

The definition of symplectic invariant depends on whether one has single polygon or several polygons.

1. In the case that there are several polygons not containing polygons inside them (if this the case,then the complement of polygon must satisfy the condition) one can uniquely identify the interior of each polygon and assign a flux with it. Non-integrable phase factor is well-defined now. If there is only single polygon then also the complement of polygon could define the flux. Polygon and its complement define fluxes Φ and $\Phi_{tot} - \Phi$.

2. If partonic 2-surface carries monopole Kähler charge Φ_{tot} is essentially $n\pi$, where n is magnetic monopole flux through the partonic 2-surface. This is half integer - not integer: this is key feature of TGD and forces the coupling of Kähler gauge potential to the spinors leading to the quantum number spectrum of standard model. The exponent can be equal to -1 for half-odd integer.

   This problem disappears if both throats of the wormhole contact connecting the space-time sheets with Minkowski signature give their contribution so that two minus-signs give one plus sign. Elementary particles necessarily consist of wormhole contacts through which monopole flux flows and runs along second space-time sheet to another contact and returns along second space-time sheet so that closed monopole flux tube is obtained. The function of the flux must be single valued. This demands that it must reduce to the cosine of the integer multiple of the flux and identifiable as as the real part of the integer power of magnetic flux through the polygon.

The number theoretically deepest point is geometrically completely trivial.

1. Only $n > 2$-gons are non-degenerate and 3-, 4- and 5-gons are prime polygons in the sense that they cannot be sliced to lower polygons. Already 6-gon decomposes to 2 triangles.

2. One can wonder whether the appearance of 3 prime polygons might relate to family replication phenomenon for which TGD suggests an explanation in terms of genus of the partonic 2-surface [K14]. This does not seem to be the case. There is however other three special integers: namely 0,1, and 2.

The connection with family replication phenomenon could be following. When the number of handles at the parton surface exceeds 2, the system forms entangled/bound states describable in terms of polygons with handles at vertices. This would be kind of phase transition. Fundamental fermion families with handle number 0,1,2 would be analogous to integers 0,1,2 and the anyonic many-handle states with NE would be analogous to partitions of integers $n > 2$ represented by the prime polygons. They would correspond to the emergence of p-adic cognition. One could not assign NE and cognition with elementary particles but only to more complex objects such as anyonic states associated with large partonic 2-surfaces (perhaps large because they have large Planck constant $h_{eff} = n \times h$) [K59].

Integers $(3,4,5)$ as "additive primes" for integers $n \geq 3$: a connection with arithmetic consciousness

The above observations encourage a more detailed study of the decomposition of polygons to smaller polygons as a geometric representation for the partition of integers to a sum of smaller integers. The idea about integers $(3,4,5)$ as "additive primes" represented by prime polygons is especially attractive. This leads to a conjecture about NE associated with polygons as quantum correlates of arithmetic consciousness.

1. Motivations

The key idea is to look whether the notion of divisibility and primeness could have practical value in additive arithmetics. 1 is the only prime for addition in general case. $n = 1 + 1 + ...$ is analogous to p^n and all integers are "additive powers" of 1.

What happens if one considers integers $n \geq 3$? The basic motivation is that $n \geq 3$ is represented as a non-degenerate n-gon for $n \geq 3$. Therefore geometric representation of these primes is used in the following. One cannot split triangles from 4-gon and 5-gon. But already for 6-gon one can and obtains 2 triangles. Thus $\{3,4,5\}$ would be the additive primes for $n \geq 3$ represented as prime polygons.

The n-gons with $n \in \{3,4,5\}$ appear as faces of the Platonic solids! The inclusions of von Neumann algebras known as hyperfinite factors of type II_1 central in TGDs correspond to quantum phases $exp(\pi/n)$ $n = 3,4,5....$ Platonic solids correspond to particular finite subgroups of 3-D rotation group, which are in one-one correspondence with simply laced Lie-groups (ADE). There is also a direct connection with the classification of $\mathcal{N} = 2$ super-conformal theories, which seem to be relevant for TGD.

I cannot resist the temptation to mention also a personal reminiscence about a long lasting altered state of consciousness about 3 decades ago. I called it Great Experience and it boosted among other things serious work in order to understand consciousness in terms of quantum physics. One of the mathematical visions was that number 3 is in some sense fundamental for physics and mathematics. I also precognized infinite primes and much later indeed discovered them. I have repeatedly returned to the precognition about number 3 but found no really convincing reason for its unique role although it pops up again and again in physics and mathematics: 3 particle families, 3 colors for quarks, 3 spatial dimensions, 3 quaternionic imaginaryunits, triality for octonions, to say nothing about the role of trinity in mystics and religions. The following provides the first argument for the special role of number 3 that I can take seriously.

2. Partition of integer to additive primes

The problem is to find a partition of an integer to additive primes $3,4,5$. The problem can be solved using a representation in terms of $n > 2$-gons as a geometrical visualization. Some general aspects of the representation.

1. The detailed shape of n-gons in the geometric representation of partitions does not matter: they just represent geometrically a partition of integer to a sum. The partition can be regarded as a dynamical process. n-gons splits to smaller n-gons producing a representation for a partition $n = \sum_i n_i$. What this means is easiest to grasp by imagining how polygon can be decomposed to smaller ones. Interestingly, the decompositions of polytopes to smaller ones - triangulations - appear also in Grassmannian twistor approach to $\mathcal{N} = 4$ super Yang Mills theory.

2. For a given partition the decomposition to n-gons is not unique. For instance, integer 12 can be represented by 3 4-gons or 4 3-gons. Integers $n \in \{3,4,5\}$ are special and partitions to these n-gons are in some sense maximal leading to a maximal decoherence as quantum physicist might say.

   The partitions are not unique and there is large number of partitions involving 3-gons,4-gons, 5-gons. The reason is that one can split from n-gons any n_1-gon with $n_1 < n$ except for $n = 3,4,5$.

3. The daydream of non-mathematician not knowing that everything has been very probably done for aeons ago is that one could chose n_1 to be indivisible by 4 and 5, n_2 indivisible by 3 and 5 and n_3 indivisible by 3 and 4 so that one might even hope for having a unique partition. For instance, double modding by 4 and 5 would reduce to double modding of $n_1 \times 3$ giving a non-vanishing result, and one might hope that n_1, n_2 and n_3 could be determined from the double modded values of n_i uniquely. Note that for $n_i \in \{1,2\}$ the number $n = 24 = 2 \times 3 + 2 \times 4 + 2 \times 5$ playing key role in string model related mathematics is the largest integer having this kind of representation. One should numerically check whether any general orbit characterized by the above formulas contains a point satisfying the additional number theoretic conditions.

   Therefore the task is to find partitions satisfying these indivisibility conditions. It is however reasonable to consider first general partitions.

4. By linearity the task of finding general partitions (forgetting divisibility conditions) is analogous to that of finding of solutions of non-homogenous linear equations. Suppose that one has found a partition

$$n = n_1 \times 3 + n_2 \times 4 + n_3 \times 5 \leftrightarrow (n_1, n_2, n_3) \ . \tag{2.5.1}$$

   This serves as the analog for the special solution of non-homogenous equation. One obtains a general solutions of equation as the sum $(n_1 + k_1, n_2 + k_1, n_3 + k_3)$ of the special solution and general solution of homogenous equation

$$k_1 \times 3 + k_2 \times 4 + k_3 \times 5 = 0 \ . \tag{2.5.2}$$

   This is equation of plane in N^3 - 3-D integer lattice.

   Using $4 = 3 + 1$ and $5 = 3 + 2$ this gives equations

$$k_2 + 2 \times k_3 = 3 \times m \ \ , \ \ k_1 - k_3 + 4 \times m = 0 \ \ , \ \ m = 0, 1, 2, ... \tag{2.5.3}$$

5. There is periodicity of $3 \times 4 \times 5 = 60$. If (k_1, k_2, k_3, m) is allowed deformation, one obtains a new one with same divisibility properties as the original one as $(k_1 + 60, k_2 - 120, k_3 + 60, m)$. If one does not require divisibility properties for all solutions, one obtains much larger set of solutions. For instance $(k_1, k_2, k_3) = m \times (1, -2, 1)$ defines a line in the plane containing the solutions. Also other elementary moves than (1,-2,1) are possible.

One can identify very simple partitions deserving to be called standard partitions and involve mostly triangles and minimal number of 4- and 5-gons. The physical interpretation is that the coherence is minimal for them since mostly the quantum coherent negentropically entangled units are minimal triangles.

1. One starts from n vertices and constructs n-gon. For number theoretic purposes the shape does not matter and the polygon can be chosen to be convex. One slices from it 3-gons one by one so that eventually one is left with $k \equiv n \mod 3 == 0, 1$ or 2 vertices. For $k = 0$ no further operations are needed. For $k = 1$ *resp.* $k = 2$ one combines one of the triangles and edge associated with 1 *resp.* 2 vertices to 4-gon *resp.* 5-gon and is done. The outcome is one of the partitions

$$n = n_1 \times 3 \ , \quad n = n_1 \times 3 + 4, n = n_1 \times 3 + 5 \tag{2.5.4}$$

   These partitions are very simple, and one can easily calculate similar partitions for products and powers. It is easy to write a computer program for the products and powers of integers in terms of these partitions.

2. There is however a uniqueness problem. If n_1 is divisible by 4 or 5 - $n_1 = 4 \times m_1$ or $n_1 = 5 \times m_1$ - one can interpret $n_1 \times 3$ as a collection of m_1 4-gons or 5-gons. Thus the geometric representation of the partition is not unique. Similar uniqueness condition must apply to n_2 and n_3 and is trivially true in above partitions.

   To overcome this problem one can pose a further requirement. If one wants n_1 to be indivisible by 4 and 5 one can transform 2 or or 4 triangles and existing 4-gon or 5-gon or 3 or 6 triangles to 4-gons and 5-gons.

   (a) Suppose $n = n_1 \times 3 + 4$. If n_1 divisible by 4 *resp.* 5 or both, $n_1 - 2$ is not and 4-gon and 2 3-gons can be transformed to 2 5-gons: $(n_1, 1, 0) \rightarrow (n_1 - 2, 0, 2)$. If $n_1 - 2$ is divisible by 5, $n_1 - 3$ is not divisible by either 4 or 5 and 3 triangles can be transformed to 4-gon and 5-gon: $(n_1, 1, 0) \rightarrow (n_1 - 3, 2, 1)$.

   (b) Suppose $n = n_1 \times 3 + 5$. If n_1 divisible by 4 *resp.* 5 or both, $n_1 - 1$ is not and triangle and 5-gon can be transformed to 2 4-gons: $(n_1, 0, 1) \rightarrow (n_1 - 1, 2, 0)$. If $n_1 - 1$ is divisible by 4 or 5, $n_1 - 3$ is not and 3 triangles and 5-gon can be transformed to 2 5-gons and 4-gon: $(n_1, 0, 1) \rightarrow (n_1 - 3, 1, 2)$.

   (c) For $n = n_1 \times 3$ divisible by 4 or 5 or both one can remove only $m \times 3$ triangles, $m \in \{1, 2\}$ since only in these case the resulting $m \times 3$ (9 or 18) vertices can partitioned to a union of 4-gon and 5-gon or of 2 4-gons and 2 5-gons: $(n_1, 0, 0) \rightarrow (n_1 - 3, 1, 1)$ or $(n_1, 0, 0) \rightarrow (n_1 - 6, 2, 2)$.

   These transformations seem to be the minimal transformations allowing to achieve indivisibility by starting from the partition with maximum number of triangles and minimal coherence.

Some further remarks about the partitions satisfying the divisibility conditions are in order.

1. The multiplication of n with partition (n_1, n_2, n_3) satisfying indivisibility conditions by an integer m not divisible by $k \in \{3, 4, 5\}$ gives integer with partition $m \times (n_1, n_2, n_3)$. Note also that if n is not divisible by $k \in \{3, 4, 5\}$ the powers of n, n^k has partition $n^{k-1} \times (n_1, n_2, n_3)$ and this could help to solve Diophantine equations.

2. Concerning the uniqueness of the partition satisfying the indivisibility conditions, the answer is negative. $8 = 3 + 5 = 4 + 4$ is the simplest counter example. Also the m-multiples of 8 such that m is indivisible by 2,3,4,5 serve as counter examples. 60-periodicity implies that for sufficiently large values of n the indivisibility conditions do not fix the partition uniquely. (n_1, n_2, n_3) can be replaced with $(n_1 + 60 + n_2 - 120, n_3 + 60)$ without affecting divisibility properties.

3. Intriguing observations related to 60-periodicity

60-periodicity seems to have deep connections with both music consciousness and genetic code if the TGD inspired model of genetic code is taken seriously code [K65] [L5].

1. The TGD inspired model for musical harmony and genetic involves icosahedron with 20 triangular faces and tetrahedron with 4 triangular faces. The 12 vertices of icosahedron correspond to the 12 notes. The model leads to the number 60. One can say that there are 60 +4 DNA codons and each 20 codon group is 60=20+20+20 corresponds to a subset of aminoacids and 20 DNAs assignable to the triangles of icosahedron and representing also 3-chords of the associated harmony. The remaining 4 DNAs are associated with tetrahedron.

   Geometrically the identification of harmonies is reduced to the construction of Hamiltonian cycles - closed isometrically non-equivalent non-self-intersecting paths at icosahedron going through all 12 vertices. The symmetries of the Hamiltonian cycles defined by subgroups of the icosahedral isometry group provide a classification of harmonies and suggest that also genetic code carries additional information assignable to what I call bio-harmony perhaps related to the expression of emotions - even at the level of biomolecules - in terms of "music" defined as sequences 3-chords realized in terms of triplets of dark photons (or notes) in 1-1 correspondence with DNA codons in given harmony.

2. Also the structure of time units and angle units involves number 60. Hour consists of 60 minutes, which consists of 60 seconds. Could this accident somehow reflect fundamental aspects of cognition? Could we be performing sub-conscious additive arithmetics using partitions of n-gons? Could it be possible to "see" the partitions if they correspond to NE?

4. Could additive primes be useful in Diophantine mathematics?

The natural question is whether it could be number theoretically practical to use "additive primes" $\{3, 4, 5\}$ in the construction of natural numbers $n \geq 3$ rather than number 1 and successor axiom. This might even provide a practical tool for solving Diophantine equations (it might well be that mathematicians have long ago discovered the additive primes).

The most famous Diophantine equation is $x^n + y^n = z^n$ and Fermat's theorem - proved by Wiles - states that for $n > 2$ it has no solutions. Non-mathematician can naïvely ask whether the proposed partition to additive primes could provide an elementary proof for Fermat's theorem and continue to test the patience of a real mathematician by wondering whether the parition for a sum of powers $n > 2$ could be always different from that for single power $n > 2$ perhaps because of some other constraints on the integers involved?

5. Could one identify quantum physical correlates for arithmetic consciousness?

Even animals and idiot savants can do arithmetics. How this is possible? Could one imagine physical correlates for arithmetic consciousness for which product and addition are the fundamental aspects? Is elementary arithmetic cognition universal and analogous to direct sensory experience. Could it reduce at quantum level to a kind of quantum measurement process quite generally giving rise to mental images as outcomes of quantum measurement by repeated state function reduction lasting as long as the corresponding sub-self (mental image) lives?

Consider a partition of integer to a product of primes first. I have proposed a general model for how partition of integer to primes could be experienced directly [L19]. For negentropically entangled state with maximal possible negentropy having entanglement probabilities $p_i = 1/N$, the negentropic primes are factors of N and they could be directly "seen" as negentropic p-adic factors in the adelic decomposition (reals and extensions of various p-adic number fields defined by extension of rationals defined the factors of adele and space-time surfaces as preferred extremals of Kähler action decompose to real and p-adic sectors).

What about additive arithmetics?

1. The physical motivation for n-gons is provided symplectic QFT [K11, K85], which is one aspect of TGD forced by super symplectic conformal invariance having structure of conformal symmetry. Symplectic QFT would be analogous to conformal QFT. The key challenge is to identify symplectic invariants on which the positive and negative energy parts of zero energy states can depend. The magnetic flux through a given area of 2-surface is key invariant of this kind. String world sheet and partonic 2-surfaces are possible identifications for the surface containing the polygon.

Both the Kähler form associated with the light-cone boundary, which is metrically sphere with constant radius r_M (defining light-like radial coordinate) and the induced Kähler form of CP_2 define these kind of fluxes.

2. One can assign fluxes with string world sheets. In this case one has analog of magnetic flux but over a surface with metric signature (1,-1). Fluxes can be also assigned as magnetic fluxes with partonic 2-surfaces at which fundamental fermions can be said to reside. n fermions defining the vertices at partonic 2-surface define naturally an n-gon or several of them. The interpretation would be as Abelian Wilson loop or equvalently non-integrable phase factor.

3. The polygons are not completely unique but this reflect the possibility of several physical states. n-gon could correspond to NE. The imaginary exponent of Kähler magnetic flux Φ through n-gon is symplectic invariant defining a non-integrable phase factor and defines a multiplicative factor of wave function. When the state decomposes to several polygons, one can uniquely identify the interior of the polygon and thus also the non-integrable phase factor.

   There is however non-uniqueness, when one has only single n-gon since also the complement of n-gon at partonic 2-surface containing now now polygons defines n-gon and the corresponding flux is $\Phi_{tot} - \Phi$. The flux Φ_{tot} is quantized and equal to the integer valued magnetic charge times 2π. The total flux disappears in the imaginary exponent and the non-integrable phase factor for the complementary polygon reduces to complex conjugate of that for polygon. Uniqueness allows only the cosine for an integer multiple of the flux.

   The non-integrable phase factor assignable to fermionic polygon would give rise to a correlation between fermions in zero modes invariant under symplectic group. The correlations defined by the n-gons at partonic 2-surfaces would be analogous to that in momentum space implied by the momentum conservation forcing the momenta to form a closed polygon but having totally different origin.

Could it be that the wave functions representing collections of n-gons representing partition of integer to a sum could be experienced directly by people capable of perplexing mathematical feats. The partition to a sum would correspond to a geometric partition of polygon representing partition of positive integer $n \geq 3$ to a sum of integers. Quantum physically it would correspond to NE as a representation of integer.

This might explain number theoretic miracles related to addition of integers in terms of direct "seeing". The arithmetic feats could be dynamical quantum processes in which polygons would decompose to smaller polygons, which would be directly "seen". This would require at least two representations: the original polygon and the decomposed polygon resulting in the state function reduction to the opposite boundary of CD. An ensemble of arithmetic sub-selves would seem to be needed. NMP does not seem to favour this kind of partition since negentropy is reduced but if its time reversal occurs in geometric time direction opposite to that of self it might look like partition for the self having sub-self as mental image.

2.6 Holographic Brain And Quantum TGD

Brain as a hologram paradigm states that one cannot locate the information in brain in any specific region. There is indeed considerable empirical support for this hypothesis [J63, J53, J51].

2.6.1 Evidence For Holographic Brain

The first empirical motivations for holographic brain came from the experiments of Lashley [J53] with rats. Psychologist Karl Lashley started 1920 lifelong study of the effect of brain vaults in memory. Lashley studied the behaviour of rats in mazes and found that the reduction of the brain tissue did not destroy the visual memory of rats totally, only the intensity of the memory was weakened. This led to the introduction of the terms mass action and equi-potentiality. Mass action says that the intensity of the memory depends on the amount of the brain tissue present and equi-potentiality says that each neuron carries the memory traces. The experiments of Lashley lead to the idea that the memory storage mechanism in brain is non-local and hologram like.

In 1948 physicists Dennis Gabor discovered the idea of optical hologram and within twenty years the same principles had been applied to brain. What hologram stores is the information about both amplitude and phase of incoming light wave, quantum mechanically identifiable as the order parameter characterizing coherent light. What makes holographic information storage so attractive is its extreme robustness and flexibility: a small piece of hologram carries same information as entire hologram, albeit in blurred form. Philip Westlake [J64] was one of the first mathematicians to argue that hologram priciple matches with what brain does with the information. Karl Pribram [J51] and colleagues have done a lot of experimental work with monkeys using the holographic theory to see in detail how the theory makes it possible for brains to remember. The book "Shuffle brain" [J63] popularizes in an enjoyable manner the idea of holographic brain and the work Pietch with salamanders. The experimental work of Pietch provides rather convincing experimental support for the idea of holographic data storage [J63] . The experiments of Pietch with salamanders involved the cutting the brain of the salamander to pieces, shuffling the pieces randomly and putting them back together: no detectable changes in the behaviour of salamander occurred as a result of this operation! It is hard to imagine a computer which would function after this kind of treatment.

Holographic data storage is extremely flexible and stable. Since brains have developed in jungle rather than in safe computer laboratory, these properties make the idea of holographic brain much more attractive than the paradigm of computer brain. Also transformations between sensory modalities are easily realized. For instance, acoustic holograms can be transformed to optic holograms. One can however also invent objections against holographic data and memory storage.

1. The creation of hologram is based on the interference of a reference beam of light with the beam of light reflected from the object. The reading of the hologram is done by using reference beam to regenerate the original picture. It is however not clear whether this kind of mechanism is possible to realize at the level of brain. Furthermore, in reality it is the real beam which stimulates memory recall rather than the hypothetical reference beam! It seems that comparison of reference pattern representing the expected experience with input is what happens in brain rather than illumination of holograms.

2. In order to have holographic memory, it should be possible to code very many holograms simultaneously to single hologram. Multiple holograms are indeed possible [J63]. One must however admit that the idea about storing large number of temporal events to same multiple hologram does not look very attractive. The identification of the long term memory as geometric memory solves these problems in TGD framework so that hologram idea could survive as a a restricted principle determining how the experience is generated.

3. The structure of the human brain suggests that data representation is not completely hologram like. For instance, the various phonemes are recognized by well defined regions located in linguistic areas of the brain like potatoes in the field. The differences between right and left brain are a challenge for the hologram idea in its simplest form. One must however notice that it is brain functions that are localized whereas data storage could quite well be hologram like. Of course, it could quite well be that brain decomposes into regions in which data represented as a hologram is different: for instance, different sensory modalities seem to use different regions of brain. In particular, the existence of various sensory homunculi in brain is consistent with the holographic data representation.

2.6.2 Three Explanations For The Hologram Like Properties Of Brain

The fact is that brain seems to be extremely flexible and this does not fit nicely with the idea that brain is some kind of extremely complicated electronic circuit. Hologram like data storage in which each neuron is like a part of hologram provides only one explanation for the empirical data. The common feature of TGD based explanations is that conscious experience is not so strongly dependent on the neurophysiogical state of the neural substrate as the vision about brain as a computer would suggest.

1. Quantum self-organization implies that systems self-organize to dynamical patterns which do not depend very much on the initial state. For sufficiently simple brains, whose presence

is not absolutely crucial for the "household" activities of the organism, this could be all that is needed. For instance, the ability of a lizard to generate a new head supports this view. Salamanders are simple creatures and the mere quantum self-organization without recourse to hologram memory could explain the results of the experiments of Pietch.

2. TGD based model of conscious brain relies on self hierarchy realized in terms of various Josephson currents forming a master-slave hierarchy. Josephson currents do not depend very strongly on the material substrate of brain. Josephson currents and associated supra currents allow also basic wave like phenomena like interference crucial for hologram model. Comparison circuits formed by weakly coupled super conductors and constructive interference of Josephson currents provide a quantum model of brain which resembles hologram model but also differs from it in certain crucial aspects. In particular, reference ray is replaced by reference current representing expected experience. Also comparison circuits in which parallel supra currents of same intensity flow in coupled superconductors, are possible. In this case large Josephson net current is generated by constructive interference of Josephson currents when the phases of supra currents differ by a constant phase.

3. It might be that brain is indeed hologram like in some sense although reference rays are probably not involved. In TGD framework it seems to be possible to abstract from the hologram idea its essentials, namely the fact that a piece of hologram is like a small window. This makes it possible to circumvent the most obvious objections against the idea.

   i) The essential feature of the hologram is that a small piece of a hologram acts like a window. The visual experience is not changed much even when one perceives through a small window. Hence one could give up the assumption that brain prepares holograms. Rather, one could consider the possibility that neurons see part of the same sensory scene through neuronal windows. Seing would be made possible by some field like quantity whose values would be determined by its sources in the same non-local manner as electromagnetic field is determined by its sources. Sources could be either objects of the external world or of model world generated by sensory experience, consisting perhaps of mind-like space-time sheets. Massless fields are especially attractive alternative since the form of the wave is preserved during propagation. Hence coherent photons generated by so called massless extremals [K55] assumed to be associated with the linear structures like microtubules contained inside every axon, are especially promising as a tool of neuronal vision.

   ii) TGD framework provides extremely general mechanisms of subjective and geometric memory corresponding to actual memories and expectations for what will happen and possibly happened. In principle it is possible to avoid memory storage completely. The experiments of Lashley could be understood by assuming only that the sensory data are experienced through neuronal windows. Thus there is no need to store memories in multiple holograms and even holograms are un-necessary. All boils down to the idea of neural window and TGD based quantum model of memory.

   iii) The existence of sensory homunculi is not in conflict with the holographic data representation. What happens is that single neuron sees part of the perceptive landscape through a window. Each neuron could be specialized to particular task, such as recognizing whether particular feature is present in the sensory landscape. This would involve simple comparison circuit making possible feature recognition perhaps involving neuronal wake-up. Feature recognition could rely basically on the generalization of Haken's theory [K72].

2.6.3 From Holographic Brain To Neuronal Window?

The notion of neural window

All 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?). If the primary or secondary stimuli generate Kähler electric fields proportional to the gradient of the intensity one can understand the generation of the objects of the perceptive field. If the gradient is strong, as it is on the boundary of the 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 secondary sensory organ would automatically create representation for the objects of the perceptive field as mind-like space-time sheets, which in turn could give rise to selves representing objects of the perceptive field as mental images.

The idea that parts of brain automatically form a model for the objects of the external world as mind-like space-time sheets suggests an interesting connection with the holographic model of brain [J63] and with micro-tubules as quantum antenna hypothesis [K55].

1. If mind-like space-time sheets are massless extremals, they act as quantum antennae and generate coherent photons. Axons contain microtubules and this leads to ask whether these axons could serve as wave guides for the coherent light generated by the mind-like space-time sheets representing the objects of the external world. Also the vacuum currents associated with these microtubular massless extremals could code the intensity of the coherent light emitted by the mind-like space-time sheets. If either of these guesses is correct, axons provide neurons with a direct sensory window to the representation of the external world formed by the mind-like space-time sheets residing at sensory organs. Coherent photons would also give rise to neuronal lingua franca realized as a direct neuronal/microtubular vision.

2. Sensory window would be in question in a rather literal sense. The fact that a piece of hologram provides the representation given by the entire hologram, albeit in a somewhat blurred form, is essentially equivalent with the possibility to see through a small window. Therefore the idea about neuronal window is in accord with the holographic model of brain [J63, J51], which is based on the idea that all neurons receive more or less the same sensory input, analogous to the visual experience generated by a piece of hologram. Clearly, coherent photons would serve as kind of mass media at the level of brain.

3. What is interesting is that the decomposition of the neuronal vision to a large number of different views represented by small groups of light sensitive neurons could even help to build monocular stereoscopic vision since much more information would be used about the visual field.

4. Music metaphor provides a considerable restriction to the neuronal window idea. The Bose-Einstein condensed photons should correspond to single frequency equal to some cyclotron frequency. Thus it would seem that the sensory input of single neutron is yes/no type. The neuronal window however makes however still sense for neuronal groups: in this case the input would be determined by light and dark pixels. Various nuclei or brain could thus have neuronal windows to cortex and other nuclei of brain.

Neural window and imagery

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 [J71]. Rather remarkably, also imaginative thought resembles very much visual imagery as is clear from the fact that language is full of visual metaphors [J71]. It is also known that imagery uses same regions of cortex as real sensory experience and the problem is to understand why there is genuine 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 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. Could the correct interpretation be that thalamus, cortex and sensory organs temporarily formed a larger self during this experience?

If one accepts that sensory qualia are at the level of sensory organs and neural activity only builds symbolic and cognitive representations, it is easy to understand the difference between imagination and sensory perception. Sensory imagination is sensory perception without sensory qualia. Quantum entanglement between sensory organs and cortex and TGD based view about long term memory resolves the obvious objections against this view.

This does not exlude the possibility that neurons have chemical senses and even see and hear. Neurons would not only contribute to our experience. Neurons able to perceive sensorily would be probably much more effective information processors than neurons which are blind and deaf. Therefore the notion of neuronal window could be useful metaphor in the modelling the neuronal basis of the mental imagery. For instance, the understanding of processes like rotation of an imagined object of visual field provides an exciting challenge. The rotation of mind-like space-time sheet should induce the rotation of the region containing nerve pulse activity. Neuronal window idea suggest that the imagined rotation of the object involves virtual sensory experience generated in the somatosensory- auditory-visual association region of the neocortex (note that only humans have these association regions). This region would be able to form representations of the basic objects of the perceptive field and manipulate them. The imagined rotation of the object could occur here and would be observed by the primary sensory regions.

Sensory perceptions involve a lot of computation like processing at the level of cortex (consider stereo vision as an example), which can be naturally identified as imagination yielding successive models for the external world as consisting of familiar objects. Both the imagined world represented by the mind-like space-time sheets inside cortex and the mind-like space-time sheets in the sensory organ could be seen by the secondary sensory organs in thalamus and compared to see whether the imagined world yields the same sensory input as the real world. The result of the comparison would be fed back to cortex as a nerve pulse pattern serving as a feedback modifying the model.

Neuronal window and blind sight

The phenomenon of blind sight [J73] suggests that there is kind of a Zombi within us [J14], which can see but that this vision does not give rise to a conscious vision. Typically persons who have blind sight can grasp the object of the visual field once they have been told that it contains the object. The Zombi within us seems to be much more rapid and reliable than the conscious "I" in its responses but it seems to be much less flexible. It also seems that Zombi within us cannot be cheated by illusions unlike conscious "I", which suggests that much less theorizing and pattern recognition is involved. Rapid responses of Zombies within us are certainly consistent with the fact that cortical processing is not involved. Non-flexibility would be the price paid for the reliability and absence of higher level cognitive processing.

One can imagine many models for Zombi within us and probably there are many of them (and they are actually not Zombies at all!).

1. Thalamus projects sensory data to amygdala which is often called brain inside brain, or emotional brain. Amygdala would thus have neuronal window to thalamus and could give rise to unconscious-to-us mental activity responsible also for the blind sight. Also the sensory perception at the level of retinae might be enough if one assumes that primary sensory qualia are at the level of sensory organs.

2. Formation of the symbolic representations for the objects of the perceptive field could occur also in the thalamic nuclei.

3. The decomposition of the perceptive field to objects could occur for the first time already at the level of retina and the coherent light from the mind-like space-time sheets provides a representation of the visual field seen by neurons of thalamus, whose regions serve as secondary secondary organs identifiable Zombies within us (Zombies only from our view point!).

2.6.4 Possible Evidence For The Neuronal Window Idea

To find whether the neuronal window based on coherent light hypothesis could make sense, it would be important to eliminate the effects of the higher level information processing. This requires the study of simple organisms having primitive sense of vision. There is indeed experimental support for identifying the coherent states of photons as associated with vision. It is known that some mono-cellulars possess elementary vision based on the microtubules [I6]. The emergence of the multi-cellulars during the Cambrian explosion was preceded by the appearance of the microtubules. If the emergence of the microtubules meant the emergence of the visual consciousness in the length scale of the cell, then the formation of the multi-cellulars as cell societies can be understood as a natural consequence.

The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. The coherent light in question could be identifiable as bio-photons of Popp [I13]. The architecture of retina is "wrong" from the engineering point of view. The ganglial axons feeding sensory input to brain are in front of the retina. This is in accordance with the TGD based model of vision in which the photons of incoming light Bose-Einstein condense on the ganglial axons and amplify the signal to the thalamus.

A further piece of evidence comes from the work of Callahan about the sense of smell of insects [I14]. 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 (alone) but to a maser like emission of infrared light generated by various molecules such as pheromones, scent molecules and many other biomolecules. Insects see rather than smell the sources of the infrared light. The sensillae of the insects serve as receiving antennas and amplify the incoming infrared radiation. 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. In any case, the results of Callahan suggest that coherent light could be important also in our neuronal sensory experiencing.

The infrared light emissions from pheromones mediate sexual messages in case of insects. Quite remarkably, pheromones are known to mediate sexual and social signals also in case of many mammals. For instance, certain chemical messages from a 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 [J1], 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 an entire perfume industry based on this evidence. The chemicals giving rise to sexual attraction are probably pheromones. The fact that pheromones mediate sexual signals in 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 behaviour of higher mammals including humans.

There is a further peculiar coincidence: the cascade of transduction events occurring in the absorption of photon in retina is repeated in a remarkably similar way in olfactory receptor cells, which respond to odours whereas the receptor cells that respond to sound use a very different system [J1]. Could this mean that also the experience of odour primarily involves the detection of (also) infrared light so that humans would not basically differ from insects or that olfactory system has evolved from the receptor neurons originally sensing infrared light? This would conform with the idea that the Kähler field generated in ear corresponds to classical Z^0 field, which does not generate coherent photons but couples with neutrinos. One must however notice that the resemblances between visual and linguistic imagery suggest that some part of ear generates cognitive representation based on coherent light and experienced by the secondary sensory organs in the thalamus.

2.6.5 Massless Extremals As Quantum Holograms

It took long time to really understand what MEs really and along with this understanding came the vision about precisely how MEs could act as holograms and what biological functions these holograms could correspond to. It indeed seems that massless extremals (MEs) are perhaps the most fundamental solutions of the field equations as far as TGD inspired theory of consciousness is considered. What is important is that MEs play both the roles of quantum gravitational holograms [B6] and dynamical holograms [B12].

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 the WCW geometry relies crucially on the assumption that the complications due to the non-determinism of Kähler action do not radically modify the picture resulting assuming complete determinism.

It has indeed turned out that the basic construction in which everything 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. The basic construction survives as a template of 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 prescribed arbitrarily. This brings in also time effectively absent in a strictly deterministic theory. 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-symplectic and superconformal invariances of the light-like boundaries generalize in an elegant manner on basis of the basic properties of MEs.

There are good reasons to expect that the light-like selves defined by the boundaries of MEs are fundamental in TGD inspired theory of consciousness. The super-symplectic quantum states associated with the light-like boundaries are genuine quantum gravitational states defined by WCW spinor fields, whose dependence on configuration space fiber degrees of freedom does not reduce to mere vacuum functional, and therefore do not possess any quantum field theoretic counterparts. They are state functionals in the world of worlds, so to say, and therefore should represent highest level in the hierarchy of quantum control in living systems.

MEs carry light-like vacuum currents. In passive state these currents are Z^0 currents whereas in active state, obtained by a color $SU(3)$ rotation, the current is electromagnetic and generates coherent state of photons. One can say that the light-like current provides a dynamical variant of the diffraction grating defined by the ordinary static hologram. This leads to a model of living matter in which the coherent states of ordinary photons and colored WCW photons act as control commands. Their phase conjugates (time reversals) in turn correspond to the time reversed commands. What is especially beautiful is that simple reference wave can activate arbitrarily complex hologram acting as a control command. This provides new visions about healing by time reversed reference waves forcing the biological program responsible for an illness like cancer to run backwards in time. One can also construct a general theory of sensory representations based on MEs [K68]. To sum up, it seems that the hologram principle is they key element of brain and biological functioning but in a sense somewhat different from what it was believed to be by the pioneers.

2.6.6 The Notion Of Conscious Hologram

The notion of conscious hologram is the last step in the development of ideas related to bioholograms. The basic challenge is to generalize the notion of the ordinary hologram to that of a *conscious* hologram, about which bio-holograms would be examples. The notion of quantum gravitational hologram is defined at the level of geometric, purely physical existence whereas conscious holograms exist at the level of subjective existence defined by the sequence of quantum jumps and giving rise to the self hierarchy. Of course, these two notions of hologram must be closely related.

The notion of conscious hologram combines the saint and sinner aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition on the other hand.

In nutshell, the notion of conscious hologram follows from the topological field quantization. Classical fields and matter form a Feynman diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules, ...), and virtual bosons are replaced by topological light rays ("mass-less extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to “real photons” are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by “virtual photon” MEs also analogous to laser beams. Hence also “self-holograms” with no laser beam from external world are possible (brain without sensory input).

The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as mass-less particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length. The particle like high frequency MEs induce “bridges” between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. Under certain conditions the leakage followed by dropping back to the larger space-time sheet can also give rise to a many-sheeted laser. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competition.

The 3-D vision associated with ordinary holograms generalizes to stereo consciousness resulting in the fusion of mental images associated with the points of conscious hologram [K8].

2.7 Four-Dimensional Fractal Brain As An Associative Net

The identification of brain as 4-dimensional fractal associative net seems to provide a promising paradigm for the understanding of brain functioning. The associative net structure and mere real physics considerations are certainly not all that is needed. p-Adic physics as physics of cognition means that fundamental cognitive representations correspond to p-adic space-time regions, and, needless to say, in this respect huge amount of work remains to be done in order to build connections between theory and observations. In the following only the real physics aspects of brain as an associative net are considered.

2.7.1 Brain As An Associative Net

The notion of associative net suggests a general paradigm making it possible to understand brain functioning. The subjective time development of an associative net consists of experiences representing associations $A \rightarrow B$. In case of brain associative net is a network of neurons. “A$\rightarrow$ B” association is made possible because the emission of synaptic vesicles implies that postsynaptic and presynaptic neuronal space-time sheets form a connected space-time sheet. A is represented by the various presynaptic inputs and B corresponds to the output of the postsynaptic neuron. A and B can correspond to various sensory qualia or Boolean statements represented in terms of memes which in turn decompose into sequences of codons consisting of 126 binary digits and represented in terms of cognitive neutrino-antineutrino sequences. Memetic codons could also have interpretation as binary representations of integers providing quantitative measures for qualities. In Boolean case associations are experienced as logical implications “If A then B” is true. A and B can represented arbitrarily complicated statements composed of elementary statements. Neuron receives the conclusions of postsynaptic neuron as premises and feeds its own conclusion as premises to its own postsynaptic neuron.

Self-organization by quantum jumps selects gradually the allowed “A $\rightarrow$ B” correspondences as asymptotic self- organization patterns. Quantum self-organization and quantum statistical determinism suggest a natural Darwinian selection of the memes caused by the dissipation inside self and completely analogous to protein folding. The correspondences $A \rightarrow B$ would be determined by chemical macro variables characterizing the state of the neuron and chemical transmitters would play a crucial part in the learning of the responses. Synchronization is necessary for the function of the network. Emotional control can modify the associations “A$\rightarrow$ B” in long time scale (conditioning and de-sensitization): for instance, some conditions belonging to premises A of Boolean association drop away or B can change.

2.7.2 4-Dimensional Fractal Brain

One needs two additional principles in order to have vision about brain a la TGD.

1. Brain is 4-dimensional in well-defined and very restricted sense. This follows from the classical non-determinism of Kähler action. Self-organization by quantum jumps replaces the classical space-time surface repeatedly with a new one and the final result represents classically the activity as it would be detected by a completely mechanical instrument. One can say that the classical time development describing say sensory experience, long term memory, motor activity or logical thought is gradually refined by starting from a rough sketch and making successively finer corrections iteratively. The process is like making a painting stating from a rough sketch. The four-dimensionality of the brain and difference between subjective and geometric time is absolutely essential element.

2. Fractality is second element. The successive refinement process proceeds from long to short time and spatial length scales. Thus large and slow neural circuits correspond to rough sketches and small and rapid circuits to small details. Small circuits are simultaneously active (in sense of subjective time) in the entire space-time region defining the duration of the activity. Thus again the 4-dimensionality of brain is crucial.

The notion of associative net suggests a very general view about how brain functions and gives rise to conscious experiences. Brain itself is a huge associative circuit but decomposes into more or less autonomous subcircuits.

2.7.3 Sensory Experiences, Logical Thinking, Associations And Simulations

The notion of associative net allows readily to understand what happens in sensory experiencing, logical thinking, formation of associations and imagination

1. Sensory representations are formed by an iterative process involving comparison which takes also care about the computation of unknown data such as distances of the objects of the perceptive field. For instance, various cortico-thalamic loops could be related this process. The updating of the zero modes of the sensory inputs from sensory organs is performed in the thalamic neurons receiving real sensory input from the sensory organ and expected sensory input from cortex. An automatic comparison process possibly realized at quantum level in terms of two weakly coupled super conductors is in question [K57, K56]. This process involves also the concentration of attention to specific features of the sensory experience.

2. Neuronal input represents in general case several sensory modalities and conscious output single sensory modality or "Boolean quale" represented by memetic codon. Thus associative circuits can represent the formation of associations in associative regions of brain. Note however that pre- and postsynaptic neurons in principle represent always an association at the neural level and neuronal associations are basic building blocks of "our" associations involving entire groups of neurons and entire neural circuits. Also the formation of associations is very probably an iterative process.

3. The circuits of the associative net provide an ideal realization for predictive simulations of type $A \rightarrow B \rightarrow ....$ in terms of various kinds of sensory qualia. This makes possible imagination. The difference with respect to the standard neural net is that conscious neuron represents some sensory modality or Boolean modality: this makes the simulation "real" and assigns meaning to nerve pulse patterns: note that the generation of meaning is basic problem of the neural net models of consciousness. This kind of simulation circuits are expected to be related with frontal lobes and to be crucial for the planning of the future activities. Motor circuit involving basal ganglia, thalamus and prefrontal cortex is also a possible example of this kind of circuit. Again iteration bringing in more and more details to the motor plan is involved.

4. Logical deductions do not differ from simulation in an essential manner: the only difference is the replacement of the temporal causation by logical causations. In case of logical deductions premises and conclusions are coded to memetic codons represented by cognitive neutrino pairs. Much of our logical thinking might be actually habitual and almost deterministic deduction sequences associated with circular loops and unconscious to us. Logical consistency is thus not guaranteed and, unless the brain of a ideal mathematician is not in question, and results only from the logical consistency of the external world.

2.7.4 Formation Of Long Term Memories

Associative circuit give rise to learning of long term memories. Short term memories correspond to reverberating nerve pulse patterns in closed circuits giving rise to a repetition of the same component of experience again and again. In Boolean case periodic association sequences represented by closed loops $A \rightarrow B \rightarrow ...A$ correspond to tautologies. Reverberating memories are remembered with high probability if long term memories are realized as geometric memories. The reason is that there is high probability for a randomly generated cognitive space-time sheet in geometric past to reside on the region occupied by a reverberating loop. Repetition is the manner to learn. It is rather plausible that Nature has discovered effective learning in this manner and there are indeed circuits associated with long term learning.

A quite recent finding in neuroscience is that during the learning of spatial tasks hippocampus and some other parts of brain generate long spike sequences. Typical interval between spikes varies between 1-2 milliseconds. This would mean that a sequence of 126 spikes would correspond to.1-.25 seconds which is of the same order of magnitude as the duration of our self identified as the duration of immediate sensory memory. Also long term memories are constructed as kind of artworks or charicatures.

2.7.5 Planning And Realization Of Motor Programs

Associative circuits are associated with planning and realization of the motor programs.

1. Motor activity is the reverse of sensory experiencing in a well-defined sense. The imagined motion of the object in the working memory representing perceptive field is transformed to the motion of the real world counterpart of the object so that motor organs are like puppets bound to axonal strings and moved by the little man in the brain. The perceptive field, where imagined motion occurs is located in the frontal cortex with primary motor cortex excluded. Several copies of the perceptive field providing different representation of the perceptive field are probably involved as "working memories". These working memories are formed by topographical maps between different parts of brain.

2. Planning of the motor action is almost motor action: the only difference is that the last stage when nerve pulse patterns characterizing the motion are fed to motor organs is not performed. Plan is essentially four-dimensional pattern of nerve pulse activity.

3. The ability to realize plan seems to require that it is memorized: this would require that the performance of the motor activity is repeatedly imagined and finally allowed to occur. Thus the nerve pulse activity representing plan becomes a periodical nerve pulse pattern and the actual motion starts when the coupling to primary organs is turned on. As a matter fact, 4-dimensional brain allows to give up the assumption about reverberation. Also the activation of a motor plan in the geometric past could be possible! This would be consistent with the results of the experiments of Libet about active aspects of consciousness: what was observed that neural activity started before the conscious decision to raise index finger. The relevant time scale would be of the order of second. Of course, an interesting question is whether adult person could initiate in the geometric childhood a motor action affecting dramatically the geometric present, say leading to traffic accident! This possibility would seem to lead to paradoxal looking consequences.

4. Learning of a motor skill presumably means that motor plans very rapidly self-organize to their final shapes. Learned skills correspond to motor plans which are winners in the Darwinian selection associated with self-organization.

5. The realization of the motor plan requires initial value sensitivity and muscles indeed provide an excellent example of an initial value sensitive system in which single nerve pulse generates macroscopic motion.

Motor action is planned and performed as a four-dimensional pattern. Construction of the motor plan means that *four-dimensional* virtual perceptive landscape is gradually deformed into the desired shape. Motor activity can be seen as a fractal top-down process analogous to the construction of a space-time fractal: fractal classical determinism of Kähler action is absolutely crucial for this and $1/f$ noise [K56] is one of the consequences of the fractality. The non-determinism of the p-adic differential equations is very probably a direct correlate of the classical non-determinism of the Kähler action.

Macroscopic motor activity starts from a rough 4-dimensional sketch of motion which is gradually refined to the final artwork and possibly memorized to represent a reverberating structure. The sketch and its various refinements are represented at the virtual perceptive landscape of the premotor cortex. More concretely:

1. First a large quantum jump realizing in rough sense the motor action occurs (for instance, hand grasps the object): this corresponds to certain classical time development starting in geometric past on new space-time surface. This stage corresponds to the activation of slow and large neural circuits with time scale characterizing the entire motion. This is like construction of the first sketch of a 4-dimensional fractal representing motor plan.

2. After this a cascade of smaller scale quantum jumps adding details to the motor plan occur: this is like adding further details to a four-dimensional fractal. The neural circuits involved are smaller and faster. Addition of details takes places in the entire time interval T of the geometric time associated with the full motion. This involves multitime moments of consciousness so that also neural circuits are active in the geometric interval defined by T.

2.7.6 Language

Memetic codons represented as temporal sequences of 126 binary digits should be the basic building blocks of the linguistic consciousness. The value of single binary digit is represented at the neural level by the presence/absence of nerve pulse and at the level of cognitive consciousness by the direction of the spin of the cognitive antineutrino. Boolean interpretation is not necessary: the interpretation of the sequences of 126 bit as integers providing quantitative measures for, say the intensities of the sensory experiences, is also possible. The proposed quantum models for the quantum correlate of hearing and for Boolean mind [K52, K30, K32] suggest that sound frequencies are mapped to Z^0 magnetic cyclotron frequencies of ions whereas thinking corresponds to Z^0 magnetic cyclotron frequency which is above the range of the audible sound frequencies. This supports the idea that memetic codons are as such experienced as some kind of internal speech and also that only certain brain regions allow Boolean mind: the generation of cognitive neutrino pairs indeed requires strong axonal Z^0 magnetic fields which could be present only in the postsynaptic axons of the associative regions of cortex.

The differences between right and left brain suggest that the output axons in the associative regions of left brain represent information using cognitive neutrino pairs whereas the corresponding axons in the right brain hemisphere could represent information in terms of Z^0 cyclotron frequency varying above the audible frequency range (left brain talks and right brain sings!). If audible frequencies are involved, Josephson frequencies must be sufficiently far from cyclotron frequencies so that right brain imagines of hearing the thoughts rather than actually hears them. Unless higher harmonics of the cyclotron frequency are used (which is quite possible!), this requires parallel mode of representation since music metaphor suggests that the Z^0 cyclotron frequency of the axon is not variable.

Language circuits would be involved with the translation of the Boolean statements to linguistic expressions coded eventually to motor activities yielding speech. This process is only special case of a motor activity and thought as an internal speech is like a motor plan. Language represents one possible realization of the memetic code analogous to the translation of DNA sequences to proteins. It is instructive to look what contraints the memetic code poses on the general structure of language. The first empirical fact is that the meaning of the linguistic experience is insensitive to the local variations in the speed of speech. In particular, the repetition of a phoneme is usually interpreted as providing no additional purely linguistic information. On the other hand, the linguistic meaning of speech is determined by its purely local structure.

These facts are consistent with the hypothesis that phonemes are the basic codons of speech having fixed duration and that a repeated phoneme has the same linguistic meaning as single phoneme. This supports the identification of the phonemes as representations of the memetic codons: phoneme would thus represent single linguistic sub-self. By the previous estimate the duration of the memetic codon should have duration in the range $.1 - .25$ seconds. A more precise estimate comes from the detailed model for the physical realization of the memetic code and from the model of nerve pulse [K32, K66]: the resulting estimate for the duration of the memetic codon is about .14 seconds. The facts that a frequency $f \sim 10$ Hz represents the fundamental frequency associated with speech organs and that 20 Hz frequency represents the lower limit for the audible frequencies are consistent with the identification of the phonemes as linguistic images of the memetic codons.

Note that cognitive neutrino pairs of duration of order one millisecond are not experienced as separate components of conscious experience if time averaging is involved with temporal binding. This is consistent with the fact that language does not contain any smaller consciously experienced constituents than phonemes. Not that speech represents (very-!) many-to one expression of the memetic code (faithful coding would require language with 2^{126} different phonemes: this gives good idea about the present evolutional level of human culture!). Genetic code is not unique and some cell organelles, such as mitochondria, possess their own genetic code. Various languages could correspond to different translations of the memetic code to nerve pulse patterns in turn coded to motor activities representing expressions of language. The Mersenne prime $2^{127} - 1$ could be clearly re-christened to be the number of Babel!

2.8 Connection With The Neuroscience View About Brain

In the following an attempt to formulate a connection with the brain as it is seen in neuroscience is made. Learning is basic aspect of intelligence and the discussion concentrates on this aspect of intelligence.

2.8.1 A Simple Model For Cognition

Self hierarchy 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 intersection of real and p-adic worlds understood as partonic 2-surfaces 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 cognitive representations. Negentropic entanglement 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. One consequence of the quantum criticality could be the existence of a lot of sub-systems which are near the critical line at which phase transition changing the local topology (real or p-adic) occurs. TGD universe would be in a state of maximal alertness ready to generate cascades of selves representing cognitive acts. Our cognitive acts would be only part of the cognitive acts 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 [K72].

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 are possible.

Quantum jump as cognitive process

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 negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) 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 negentropic entanglement 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. Negentropic entanglement 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.

2.8.2 Cognition, Learning, And Negentropic Entanglement At The Level Of Brain

Negentropic entanglement 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 negentropic entanglement could be realized at the level of brain? Is it time-like, space-like, or both? Can one assign the generation of negentropic entanglement 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 [J4, J12] 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 respose 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 [J11] and involves several mechanisms. Synaptic plasticity means that the sensitivity of the postsynaptic neuron to the signals from presynaptic neuron can change.

1. Sensivity 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 [J11].

   (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 [J7]) and - depression (LTD [J6]) 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 [J2] to which glutamate binds this mechanism is well-established. Also phosphorylation and dephosphorylation of AMPA receptors and change in the probability of glutamate release is a decisive factor.

3. The notion of Hebbian learning [J5] 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. Subselves 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. Negentropic entanglement 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, negentropic entanglement 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 maximing 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 unvoidable 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 unentagled state via the liberation of metabolic energy associated with the negentropic entanglement.

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 [K72]. 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 $A \rightarrow B$. 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 [K2]. 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 approxiation 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 negentropic entanglement 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 $ATP \rightarrow ADP + P_i$ process defining the key stop of metabolism [K27, K28].

Also space-like negentropic entanglement 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.

2.8.3 Negentropic Entanglement 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* [J50] 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 [K2].

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 postsynpatic 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 [J22]. 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 ofe cell mebrane 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 negentropic entanglement. Good is not possible without Evil! There are no winners without loosers!

   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 activitites of cell be regarded as motor actions of the genome acting as the brain of cell receiving sensory imput 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 activitites 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 negentropic unentanglement 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 nerge 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 [I18] the time scales of protein folding vary from.1 s to 10^3s. According to Wikipedia [I2] 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 negentropic entanglement 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 entanglemement would be naturally time-like and in this case only negentropic entanglement 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.

2.9 Two ways to learn and what goes wrong with vulgar skeptics?

I had with two fellows - I call them A and B - an "entertaining" although not totally pleasant discussion, which taught a lot, I hope also for A and B -, and actually gave a good example of two kinds of learning. Learning by conditioning and learning by discovery. It also led to a possible understanding about what goes wrong in what I would call ultra-skeptic cognitive syndrome.

Remark: This discussion by the way gave me good laughs. A summarized his academic background by "studied strings" an B was a Bachelor in computer science but pretending to be M-theorist. They tried to demonstrate that I am a crackpot. They carried out an "investigation" following the principles of the investigations made for witch candidates at middle ages. The victim had two options: she drowns or not in which case she is burned at stake. I guess that my feelings during the examination were very similar to those of witch candidates.

The highly emotional discussion was initiated by a totally non-sense hype about transferring consciousness of C Elegance to computer program (see `http://tinyurl.com/y8wnyxxr`). I told that the news was hype and this raised the rage of A and B. The following considerations have very little to do with this article. Note however that I have done some work AI in general and even with with the basic ideas of deep learning. For instance, we had two years ago a collaboration about AI, IIT approach to consciousness, and about a possible connection with remote mental interactions together with Lian Sidorov and Ben Goertzel, who is behind Sophia robot. There two chapters related to this [L19, K76] (see `http://tinyurl.com/zwqbj8y` and `http://tinyurl.com/zq8k3jl`). I think that the latter chapter is published in a book by Goertzel. There is also a critical article inspired by Sophia robot about which Ben Goertzel wrote an enthusiastic article and sent to Lian Sidorov and me [L23] (`http://tinyurl.com/y75246rk`).

2.9.1 The two ways to learn

Learning by conditioning

The first kind of learning is learning by conditioning, which deep learning algorithms try to mechanize (for TGD view see [L23, L19]). Second kind of learning is learning by discovery impossible for computers because they obey deterministic algorithm and are unable to do anything creative.

Emotions play a strong role in the learning by conditioning in the case of living systems and in the simplest form it is learning of X-good and X-bad type associations helping C elegance to survive in the cruel world. In the case of humans this kind of associations can be extremely dangerous as for instance the recent course of events in USA has shown.

Very large part of our learning is just forming of associations: this is what Pavlov's dogs did. In school we learn to associate to "2×3=" symbol "6". In our youth we learned also algorithms for sum, division, multiplication and division, and even for finding the roots second order polynomial. Often this is called learning of mathematics. Later some mathematically gifted ones however discovered that this is just simple conditioning of an algorithm, and has very little to do with genuine mathematical thinking. The discovery of the algorithm itself would be mathematical thinking. The skill to code for algorithm - usually given - is also an algorithm and it can be also coded in AI.

If we are good enough in getting conditioned we get a studentship in University and learn science. This involves also learning of simple conditionings of type X-good and X-bad. In this learning social feedback from others reinforces learning: who would not like to earn the respect of the others!

For X-bad conditionings X can be homeopathy, water memory, cold fusion, telepathy, remote viewing, non-reductionistic/ non-physicalistic world view, quantum theories of consciousness, TOEs other than M-theory, etc... For X-good conditionings X can be physicalism, reductionism, strong AI, superstrings, Witten, etc...

The student learns also to utter simple sentences demonstrating that he has learned the desired conditionings. This is important for the career. Proud parents, who hear their baby say he first word encourage the child. In the same manner environment reinforces the learning of "correct" opinions by a positive feedback. The discussion with A and B gave a quite a collection of these simple sentences. "I guessed that he is a crank" from A is a good example intended to express the long life experience and wide wisdom of the youngster.

These conditionings make it also easy "recognize" whether someone is a crank/crackpot/etc... and even to carry out personal "investigations" whether some-one is a crank or not. This is what A and B in their young and foolish arrogance indeed decided to carry out.

I have considered the TGD view about learning and the role of emotions in learning [L32, L36]. The recent surprising experimental findings about the role of RNA in learning by conditioning inspire the view that emotions are involved even at the molecular level [L30]. Together with the TGD based model of bioharmony [L5, L34] inspired by the fact that music both expresses and induces emotions, this leads to a concrete model. For the general philosophic background see [L33].

Learning by Eureka experience

There is also second kind of learning. Learning by discovery. Computers are not able to do this. I mentioned in the discussion what happens when you look certain kind of image consisting of mere random looking spots in plane. After enough staring suddenly a beautiful 3-D patterns emerges. This is a miracle like phenomenon, Eureka experience. Quantum consciousness based explanation is the emergence of quantum coherence in the scale of the neuronal cognitive representation in visual cortex at least. New 3-D mental image emerges from purely 2-D one. One goes outside the system, so to say.

The increase of dimension might provide an important hint about what happens more generally: and this would indeed occur for the dimension of extension of rationals in Eureka quantum jump in TGD based model of what could occur. Physically this would correspond to the increase of the effective Planck constant $h_{eff} = n \times h_0$, $h = 6 \times h_0$ (this is the best guess [L14, L31]) assignable to the mental image created by the image. n is indeed the dimension of extension of rationals and would increase and also scale of quantum coherence would increase from that for single spot to that for the entire picture. The increase of n requires metabolic energy and learning in this manner is actually essentially what it is to be alive. Most of this Eureka learning would be analogous to re-discovery in molecular length scales.

This kind of learning by Eureka is probably very common for children since they live a very intense period of personal evolution: they are often said to be genii. Later the increasing dominance on the learning by conditioning often supresses this mode of learning, and we become gradually collections of existing programs. The irony is that the worst outcome is a mainstream scientist, who has become a hard-nosed skeptic. What is worrying that our society strongly reinforces this degeneration to mere automatons in the name of effectiveness.

Solving genuine problems rather than applying existing algorithms is the manner to gain these learning experiences but they come only now and then. Some of them are really big: during my professional career there have been - I would guess about 10 really big experiences of this kind involving discovery of a new principle or totally new physical idea.

2.9.2 What goes wrong with vulgar skeptics?

For me the discussion with my inquisitors A and B was very useful since it led me to ponder why it is so hopeless to explain something extremely simple idea for skeptics. You give explain the problem patiently, you list the assumptions, you explain the solution. But all in vain: skeptic refuses to even read and shouts that every single assumption contains a fatal mistake. When you ask him to make a list about these fatal mistakes, he throws a personal insult. The discussion with these fellows A and B forced me to seriously ask what goes wrong with them, how to understand their intellectual rigidity, even intellectual paralysis implying inability to consider any alternative views. Perhaps one could speak about ultraskeptic cognitive syndrome, which involves also emotions very intensely.

There is a beautiful connection with a learning based on Eureka experience. Physically this corresponds in TGD to a phase transition increasing the scale of quantum coherence and algebraic complexity: more technically effective Planck constant h_{eff} increases at some levels. More intelligent mental images become possible and Eureka experience happens as in the situation when chaotic 2-D set of points becomes beautiful 3-D object.

Biological evolution at the level of species is based on this: we humans are more intelligent than banana flies. This evolution occurs at all levels - also at the level of individuals but it is not politically correct to say this aloud. Some of us are in their intellectual evolution at higher level than others, either congenitally or by our own efforts or both. This creates of cause bitter feelings. Intellectual superiority irritates and induces hatred. Maybe this partially explains why so many intellectuals spend most of their life in jail.

Take seeing as an example. If person has become blind at adult age, he understands that he is blind and also what it **feels** to see. Also congenitally blind person believes that he is blind: this because most people in his environment tell that it is possible to see and that he is blind. However, he does **not feel** what it is to see. Suppose now that most of us were blind and then comes some-one and tells that he sees. How many would believe him? They can **not feel** what it to see. Very probably they conclude that this fellow is a miserable fool.

Suppose now that certain person - call him MP - has used 4 decades to develop a TOE generalizing superstring model made 5 years before the first superstring evolution and expanding also to a theory of consciousness as a generalization of quantum measurement theory. MP tries his best to explain his TOE to A and B but finds it hopeless. They even arrange "investigation" following the best traditions of witch hunt to demonstrate his crackpotness. And indeed, they conclude that they were correct: all that this person writes is totally incoherent non-sense just as this 2-D set of random points.

These you guys are arrogant and full of the vanity of a young man. But this alone does not explain their behavior. To say that they are just evil, is not a convincing explanation. My proposal is that hey are simply intellectually blind and suffer what one might call ultra-skeptic syndrome. Expressing it more technically in TGD context: their personal hierarchy of Planck constants does not contain the required higher values. An Eureka experience would be required to jump to the level containing higher values of n, at which understanding is possible. What MP says is for them like this chaotic 2-D set of points: they are not able to see the beautiful 3-D pattern.

MP could of course cheat and tell that he believes in superstrings and even give a false hint suggesting that he is a good friend of Witten. This would certainly help but would only lead to a fake understanding. The fellows would take MP seriously only because MP agrees with Witten and claims to be a friend of Witten but still they would not have a slightest idea what TGD is. They cannot **feel** what it is to understand TGD.

The only hope is personal intellectual evolution increasing the needed Planck constants in the personal h_{eff} hierarchy of these guys. But this is possible only if these fellows admit that they are intellectually blind in some respects but if they are young arrogant skeptics they furiously deny this and therefore also the possibility of personal intellectual evolution. There could also suffer a genuine intellectual paralysis meaning inability to make this kind of quantum phase transition. There indeed is a personality disorder in which the patient has extremely rigid personality and is unable to consider any alternative views.

Acknowledgements: I want to express my gratitude for these two young fellows A and B in Bio-A.I. group, who are so modest that want to remain anonymous. Gratitude for both inspiration and serving as guinea pigs. This was very nice. On the other hand, I served as a - should I say voluntary(?) - target in their crackpot investigation.

2.10 Could TGD Provide Justification For The Ideas Of Rupert Sheldrake?

Rupert Sheldrake [I15] has developed a theory of learning and memory based on the concepts of morphic fields and morphic resonance. In the following I describe briefly the theory of Sheldrake and consider a TGD variant of of the theory.

2.10.1 Sheldrake's Theory

The following summarizes very briefly the basic ideas of Sheldrake's theory.

1. The basic hypothesis is that learning occurs also at the level of species. If some individuals of the species have learned some habit, it becomes easier for the remaining individuals of the species to learn the same habit. The individuals who learned the habit first need not even live anymore or can live in a distant part of the world. Collective learning is claimed to occur in a morphic resonance analogous to a phase transition leading from a small seed of individuals with new habit to a population having the same habit. Morphic field provides a representation for a habit and resemble the concept of meme in this respect. Sheldrake states the basic assumptions of his theory in the following manner:

The idea is that there is a kind of memory in nature. Each kind of thing has a collective memory. So, take a squirrel living in New York now. That squirrel is being influenced by all past squirrels. And how that influence moves across time, the collective squirrel-memory both for form and for instincts, is given by the process I call morphic resonance. It's a theory of collective memory throughout nature. What the memory is expressed through are the morphic fields, the fields within and around each organism. The memory processes are due to morphic resonance.

2. Sheldrake defines morphic fields in the following manner:

   Basically, morphic fields are fields of habit, and they've been set up through habits of thought, through habits of activity, and through habits of speech. Most of our culture is habitual, I mean most of our personal life, and most of our cultural life is habitual. "We don't invent the English language. We inherit the whole English language with all its habits, its turns of phrase, its usage of words, its structure, its grammar. "

   "Alike likes alike" rule states that learning induces learning only in the members of same species. This suggests that the morphic fields correlate strongly with genome.

4. *Sheldrake represents the learning of language as a good example of morphic resonance.*

   Occasionally people invent new words, but basically, once we've assimilated it, it happens automatically. I don't have to think when I'm speaking, reaching for the next word. It just happens, and the same is true about physical skills, like riding a bicycle, or swimming, or skiing if you can ski, these kinds of things. So I think the more often these things happen the easier they become for people to learn. Things like learning language have happened over-well, we don't know how long human language has been around, at least 50, 000 years, so there's a tremendously well-established morphic field for language-speaking. Each particular language has its own field which is usually established over centuries at least.

5. *Sheldrake notices also that morphic resonance and morphic fields are not all what is needed to understand evolution.*

   The whole idea of morphic resonance is evolutionary, but morphic resonance only gives the repetitions. It doesn't give the creativity. So evolution must involve an interplay of creativity and repetition. Creativity gives new forms, new patterns, new ideas, new art forms. And we don't know where creativity comes from. Is it inspired from above? Welling up from below? Picked up from the air? What? Creativity is a mystery wherever you encounter it, in the human realm, or in the realm of biological evolution, or of cosmic evolution. We know creativity happens. And then what happens is a kind of Darwinian natural selection. Not every good idea survives. Not every new form of art is repeated. Not every new potential instinct is successful. Only the successful ones get repeated. By natural selection and then through repetition they become probable, more habitual.

2.10.2 TGD Based Interpretation Of Morphic Fields And Collective Memory

I have proposed for more than decade ago a TGD based formulation justifying the basic ideas of Sheldrake to some degree. The recent formulation involves several new elements. Zero energy ontology implying that WCW ("world of classical worlds") spinor fields allow an interpretation as memes or morphic fields, the model for living matter in which the notion of magnetic body plays a key role, and the model of DNA as topological quantum computer allowing to identify the morphic quanta relevant for living matter.

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 lower tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of upper tip to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [K80]. 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.

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 [A7]. 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.

WCW spinor fields as morphic fields?

The interpretation of the WCW spinor fields as memes or morphic fields is encouraged by two observations.

1. Zero energy states have an interpretation as Boolean rules $A \rightarrow B$ as well as self-organization patterns. Fermion number 1 and 0 for a given fermion mode represents values of one particular Boolean statement in positive *resp.* negative part of the state. The instances of A are assigned to the positive energy (initial) state and those of B to the negative energy (final) state and the quantum superposition of the paired instances defines the rule. Since time-like entanglement coefficients define M-matrix, the interpretation as a law of physics coded to the structure of the physical state itself is possible. Fermionic degrees of freedom correspond to the spin indices of WCW spinor fields. Besides this there are "orbital" degrees of freedom in the moduli space for CDs and in the space of deformations of light-like 3-surfaces. It is natural to assign these degrees of freedom to sensory perception.

2. The p-adic description of cognition involves a generalization of the notions of number and of embedding space. The hierarchy of Planck constants means a further generalization of

the notion of embedding space by replacing it with a book like structure. It seems that the discrete intersection of real and p-adic partonic 2-surfaces consisting of points in algebraic extension of rationals is crucial from the point of view of consciousness theory. This is true also for the intersection of real and p-adic variants of WCW identified as 3-surfaces whose mathematical representation makes sense in both real and p-adic number fieldsin preferred coordinate fixed by symmetries.

The first intersection is expected to be relevant at quantum field theory limit, which involves the replacement of the partonic 2-surfaces with a discrete subset of points carrying quantum numbers. The second intersection is relevant in the full quantum theory. The notion of number theoretic Shannon entropy having negative values makes sense in both intersections since entanglement probabilities must make sense in both number fields so that they are rational or belong to an algebraic extension of rationals. In these intersections of realities and various p-adicities the evolution of memes is expected to take place.

One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

If one defines morphic field so that also ideas and imagined things, simply memes, are included within the scope of definition, one is led to ask whether the p-adic description of imagination as space-time WCW spinor fields in the space of 2-surfaces allowing continuation by strong form of holography to some p-adic sectors but not necessarily to real sector could represent morphic fields in this generalized sense.

One can however criticize the proposed definition as quite too general: every zero energy state would define morphic field!

2.10.3 Magnetic Body As Morphic Field

The second option is more concrete and assumes that morphic fields correspond to space-time surfaces which in ZEO are analogous to behavioral patterns and functions. Since magnetic body carrying dark matter is intentional agent in TGD Universe, morphic fields of Sheldrake [I15, I16] could be therefore replaced with field body: magnetic body and the "topological light rays" serving as correlates of dark photon beams are involved and are parallel to flux tubes and topologically condensed at them.

Magnetic body - and even more so topological light rays - are essentially 4-D objects, a temporal pattern of topologically quantized fields associated with a pair of 3-D magnetic bodies at the opposite boundaries of CD. Magnetic body having an ion-like structure would serve as a template for the biological system and its evolution. The lowest layers of the onion would correspond to flux tubes connecting biomolecules. DNA and nuclear and cell membranes would have magnetic bodies having connections to larger magnetic bodies, such as magnetic Mother Gaia.

The findings of Levin [I12] and others about what happens to cut planaria can be understood if the replication of of magnetic body precedes the replication of the biological body [L6]. The replication of magnetic body would be analogous with the decay of particle in the vertex of Feynman diagram (particles are replaced with 3-surfaces in TGD).

The experiments indicate that also memories interpreted as learned behaviors are replicated in the sense that the new worms resulting from the pieces of the cut worm have the memories of uncut worm and the replication of magnetic body in the sense of ZEO would explain this (the pair of 3-surfaces at opposite ends of CD would replicate). The replication of behaviours could be seen as replication of memes. This would help to understanding how skills can be discovered by several individuals simultaneously and how learning of skill becomes easier when it is already possessed by several individuals.

The following is an attempt to define morphic resonance using language of TGD.

1. Morphic resonance would relate to the presence of collective levels of consciousness. They could have direct counterparts as a hierarchy of genomes in which genomes of cells could form coherent units in the sense that their magnetic bodies fuse to larger ones. Also the genomes of different organisms could fuse to single super-genome in this manner. In this case, then

morphic resonance could manifest itself as a collective gene expression. One manifestation would a discovery of same thing in separate places simultaneously due to the fact that the problem solving would also take place at collective level.

2. Negentropic entanglement resources generated in the quantum evolution would give rise to “Akashic records”, which would serve as universal library from which any-one could loan a book. Independent discovery of same idea at different places and times would not be actually independent since the needed information could derive from “Akashic records”.

3. In ZEO 3-D self-organization becomes 4-D self-organization for spatio-temporal patterns since also the geometric past changes in quantum jump. At space-time level this means that space-time surfaces representing temporal patterns of various fields would becomes the basic patterns. Quantum states would correspond to superpositions of these temporal patterns. This would mean that morphic resonance would be essentially 4-D: behaviors/skills could be learned from “Akashic records”.

4. Morphic resonance would also correspond to resonance in concrete sense. Only the flux tubes of two magnetic bodies having the same value of magnetic field and thus same cyclotron frequency scale and same thickness could fuse by reconnection. Also the values of h_{eff} should be same. This might also explain $h_{eff} = h_{gr}$ as a condition guaranteeing the resonant interaction between biological organisms with conscious entities in scale of Earth and Sun.

Morphic fields relevant to living matter

All zero energy states have interpretation as memes or quanta of morphic fields in TGD framework. One can however ask what zero energy states are relevant for biological systems.

1. The memes relevant to living matter must have a very concrete connection to biology. DNA as topological quantum computer hypothesis states the magnetic flux tubes connecting nucleotides to lipids of nuclear and cell membranes define braid strands needed to realize topological quantum computations. Nerve pulse patterns induce fluid flows of cytoplasma and of lipids in turn inducing time-like braidings defining running topological quantum computation programs and their memory representations as space-like braidings in the final state. These programs living (in very literal sense) in the brains of geometric future and past define a 4-D population of memes. The intronic part of the genome is specialized to topological quantum computations and the time scale in this case can be and must be faster than for the chemical gene expression. The repetitive character of many intronic DNA sequences regarded as evidence for their junk character does not mean any restriction for topological quantum computation.

2. The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion-like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism. The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

3. Morphic resonance and alike likes alike rule can be understood from the condition that the intronic parts of genomes must be similar enough to allow the realization of the topological quantum computation. Also neuronal pathways involved must resemble each other in order that spatial nerve pulse patterns can be re-produced faithfully enough. Also the evolutionary levels must be more or less the same in order that the topological quantum computation has same meaning for the receiver and sender. Therefore the collective memory might be restricted to the level of species. This might be however too strong an assumption. For instance, shamanism could represent an example of interspecies memory. The TGD based view about memory allows also the possibility to use the memories of the already deceased members of species which can in principle continue to exist in the geometric past.

4. The general vision about evolution as recreation of the quantum Universe implies that creativity is in very literal sense a basic aspect of TGD Universe. The U process represents the creative aspect of consciousness generating quantum super-position of Universes from which generalized state function reduction process selects the outcome. Both volitional actions and sensory perception involves the selection but quantum statistical determinism implies that sensory percepts are usually predictable.

Collective memory, geometric memory and self hierarchy

The notion of species memory is rather radical departure from the teachings of standard neuroscience so that TGD based view about memory deserves a separate discussion.

TGD predicts infinite hierarchy of selves and if this hierarchy has levels between living systems and entire universe, the idea about collective memory makes sense and generalizes to an entire hierarchy of them.

Geometric memory provides a promising candidate for the mechanism of a long term memory. Geometric memory is made possible by the fact that self can have multitime experiences such that the space-time sheets associated with various values of the geometric time give contributions to the experiences and past contributions are experienced as memories. In zero energy ontology these space-time sheets are associated with sub-CDs of CD associated with self. Both time-like entanglement between sub-CDs of recent and past implying sharing and fusion of mental images an classical communications between these CDs are possible and give rise to episodal memories (direct re-experiences) and symbolic memories.

Since both geometric past and future change in each quantum jump these memories are not stable: long term memories are certainly unreliable. The memory formation mechanism of brain however tends to stabilize these memories. There is in principle no upper bound for the span of the geometric memories and one can consider the possibility of racial memory and even species memory. Under suitable conditions organism could be able to have the space-time sheets of the geometric past as its sub-selves and experiences these memories. Thus geometric memory is consistent with Sheldrake's claims and to some degree supports them.

Language learning and morphic resonance

The easiness of children to learn language could have explanation in terms of morphic resonance. The strong quantum entanglement between the child and parents, especially mother, could make the morphic resonance possible in the proposed sense. One can even imagine that mother's magnetic body directly induces nerve pulse sequences representing linguistic memes in the brain of child.

One can of course wonder why it is so difficult for the older people to learn language. Do we force us to learn the language at reflective level although it could occur at proto-level also. Older people learn rules but find difficult to apply them whereas child learns to apply the rules without learning the rules themselves. Are older people so far from quantum criticality that the large fluctuations leading to the generation of the new level of self-organization are not possible anymore? The reason could also relate to the degeneration of the magnetic flux tubes circuits due to ageing so that new topological quantum computation programs are not establishes so easily anymore.

Self hierarchy, bio-feedback and sociofeedback

Magnetic bodies act as intentional agents in the proposed model. They form also a hierarchy analogous to master-slave hierarchy. The proposed mechanism of collective learning involves the magnetic body of Earth in an essential manner. Also magnetic bodies of larger structures could be involved: there is indeed evidence that remote cognition involves galactic magnetic fields [K67] , [J48].

The phenomenon of bio-feedback provides direct evidence for this phenomenon in a length scale familiar to us. By monitoring the behavior of say single neuron, it is possible to learn to affect the behavior of neuron volitionally. No knowledge about how this happens is needed: the volition is enough. The explanation would be that the information provided by the monitoring goes to the magnetic body of the person which reacts by sending control signals to the brain. The already existing magnetic flux tube connections guarantee that the volitional act affects the neuron. The possibility of biofeedback suggests the possibility of socio-feedback and feedback even at the level of species and entire biosphere.

An interesting test for the idea that people very close to each other could directly affect the brain function of each other would be biofeedback in which subject person tries to affect the behavior of a neuron of a close friend or relative. Mother and child might be an optimal choice in this respect.

Chapter 3

p-Adic Physics as Physics of Cognition and Imagination

3.1 Introduction

TGD as a generalized number theory vision stimulates the hypothesis about p-adic physics provides the physical correlates of cognition and imagination. 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 is present even at this level. In this chapter these implications are studied from the point of view of cognitive consciousness.

The view about cognition relies also heavily on the developents that have occurred during the last ten years in the understanding of TGD. The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is certainly the most important aspect in this respect and 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 and the notion of causal diamond (CD) with zero energy states having interpretation as memes in very general sense is also of central importance. The hierarchy of Planck constants assigned with a hierarchy of quantum criticalities 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.

3.1.1 Clarifying Some Basic Concepts

Before continuing it is could to clarify basic conceps.

The earlier view was that p-adic space-time surfaces are correlates for both cognition and intentionaity. The recent view is that p-adic space-time sheets correspond only to cognition and that their intersections with real space-time sheets in the intersection of real and p-adic worlds (intersection briefly) define cognitive representations. These representations are defined in terms of the data coming from the rational and algebraic points common to real and partonic 2-surfaces with the algebraic extension in question characterized by the mathematical representation of the partonic 2-surfaces making sense for both real and p-adic 2-surfaces simultaneously. The immediate powerful implication is that the algebraic extensions of rationals define a cognitive hierarchy. One can also understand preferred p-adic primes as so called ramified primes of the extension and NMP suggests strongly an extension of p-adic length scale hypothesis.

The original view was that cognitive representations as p-adic space-time surfaces are built and define images of real space-time surface [K98]: the problems with symmetries forced to challenge this view. The recent view is adelic. Space-time surfaces are adeles with a book-like structure with pages representing preferred extremals of Kähler action in various number fields, and real and p-adic space-time sheets serve as correlates of sensory experience and cognition are present in all length scales and for all systems, even elementary particles. The success of p-adic mass calculations conforms with this assumption.

TGD must be number theoretically universal in order to have a first principle description of conscious intelligence and cognition and the algebraic continuation from the intersection to various number fields from the back of Big Book allows to realize this idea.

The earlier view about discretization was that space-time surfaces are replaced with discrete point sets defined by points of surface for which embedding space coordinates are in an extension of rationals. This led to problems with symmetries and general coordinate invariance. Discretization is more abstract than originally believed and occurs at the level of "world of classical worlds" (WCW). Co-dimension two rule holds true. n-dimensional object is discretized as a collection of $n-2$-dimensional objects. In the case of space-time surfaces the lower-dimensional objects are string world sheets and partonic 2-surfaces: co-dimension 2 rule is equivalent with the strong form of holography. The discretization is physically: physics itself defines its representation with finite resolution. Discretization occurs for the parameters (conformal moduli) characterizing these 2-surfaces and the parameters - naturally conformal moduli - are in some algebraic extension of rationals so that the space-time surfaces themselves are not discretized. This allows to get of rid of difficulties as one tries to map real and p-adic space-time surfaces to each other locally.

The classical non-determinism of Kähler action quite generally implies that space-time surfaces define what might be called symbolic representations realizing quantum classical correspondence. This applies irrespective of the number field used and in p-adic context p-adic non-determinism is an additional ingredient. For instance, nerve pulse patterns define symbolic real physics representations of the sensory input but do not give rise to sensory qualia which reside at the level of the primary sensory organs (contrary to the expectations raised by various findings of neuro-science). Sensory experience is always a multiverse experience since sensory qualia have quantum number increments as quantum correlates, and is thus not reducible to the level of space-time.

I have use also the notions of meme and morphic field. One could defend the identification of the geometric correlates of memes and morphic fields as p-adic space-time sheets. On the other, all negentropic quantum states in zero energy ontology have the character of a rule A→B, where quantum superposition represents various instances $a \rightarrow b$ of the rule and one could say that every negentropic zero energy state can be seen as a meme. I leave the choice between these interpretations for the reader.

3.1.2 Basic Vision

It is useful to summarize the recent TGD inspired view about quantum biology and conscious intelligence since it serves as background for the chapter.

Magnetic body as intentional agent and experiencer

The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism [K23].

The magnetic body of Earth - magnetic Mother Gaia - could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

Magnetic flux tubes and flux sheets are basic building bricks of the magnetic body and DNA as topological quantum computer hypothesis assumes that DNA nucleotides are connected to cell membrane by flux tubes defining braids playing a key role in topological quantum computation [K2]. Therefore magnetic body is essential for realizing the software of biological intelligence. The essential assumption is that magnetic body carries dark matter consisting of ordinary with a non-standard value of Planck constant. The phase transition changing the value of Planck constant change the size scale of the flux tube and this process together with reconnection of the flux tubes would define mechanisms of bio-catalysis.

Zero energy ontology, causal diamonds, and identification of memes

In zero energy ontology (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 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.

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 [K96]. The space-time correlate for the finite resolution is discretization in terms of string world sheets and partonic 2-surfaces forced also by the well-definedness of em charge for Kähler-Dirac action [K97].

At the embedding space-level CD serves as a correlate of self whereas space-time sheets having their ends at the light-like boundaries of CD - more precisely, partonic 2-surfaces and the distributions of the 4-D tangent spaces of space-time sheet associated with them - 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 to 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) [K93, K4].

The original interpretation of the space-time correlates of mental images was as “mind-like” space-time sheets identified as space-time sheets with a finite temporal size. In zero energy ontology all space-time sheets have a finite size and serve as correlates for zero energy states, which could be interpreted as representations of laws of physics as superpositions of pairs of initial and final states given by M-matrix. In state function reduction process these states are reduced to states for which only negentropic time-like entanglement is possible and one might say that the negentropy measures the conscious information associated with the final state of the reduction process. One can interpret negentropic quantum states as memes or morphogenetic fields [K72]. [I15] These negentropic quantum states are possible only in the intersection of real and p-adic worlds so that living systems are the systems carrying information and intelligence.

Boolean mind and fermions

The connection of fermionic Fock space basis with Boolean algebra was one of the first ideas related to the quantum modelling of intelligent systems. The state basis for the fermionic Fock space has a natural interpretation as Boolean algebra (fermion number =1/0$\leftrightarrow$ yes/no). In this way ordinary Boolean algebra is extended to a vector space spanned by fermionic states. Fermion number conservation poses an obvious problem for this scenario in positive energy ontology. Zero energy ontology resolves this problem quite generally and zero energy states resulting as an outcome of state function reduction process represent Boolean statements of type A$\rightarrow$ B in terms of time-like negentropic entanglement in fermionic degreees of freedom.

The original proposal was to use cognitive fermion pairs instead of fermions with fermion and anti-fermion located at the opposite throats of wormhole contact. In the recent formulation of quantum TGD bosons and their super counterparts correspond to wormhole contacts. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic and whether our logical mind could have something to do with Boolean algebra. For instance, could primary "this is true" experiences correspond to Boolean qualia having increments of fermionic quantum numbers as physical correlates. Boolean truth values could also correspond to spin directions of fermions. In this case fermion number conservation does not pose any constraints and the macroscopic realization replaing single spin as a representative of bit with a magnetized ensemble of fermions, makes the realization robust.

Negentropic entanglement (NE) means that qubits are always fuzzy and the fuzziness depends on the situation. The positive aspect is that the quantum superposition gives rise to an abstraction, rule about pairing of say initial and final states represented as positive and negative energy parts of zero energy state with the pairs of superposition representing the instances of the rule. p-Adic-real entanglement with positive definite number theoretical entanglement entropy in the intersection could give rise the experience of understanding and makes possible cognitive quantum computation like processes. Interestingly, negentropic entanglement corresponds to an entanglement matrix characterized by a unitary matrix encountered in quantum computation.

p-Adic physics as physics of cognition and imagination

The vision about p-adic physics as physics of cognition has gradually established itself as one of the key idea of TGD inspired theory of consciousness. There are several motivations for this idea.

The strongest motivation is the vision about living matter as something residing in the intersection of real and p-adic worlds. One of the earliest motivations was p-adic non-determinism identified tentatively as a space-time correlate for the non-determinism of imagination. 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 the 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 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 some unique 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. p-Adic reality is much like the dream reality consisting of rational fragments glued together in illogical way or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious looking interpretation for the solutions of the p-adic field equations would be as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general could have p-adic space-time sheets as their geometric correlates. A deep principle could 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.

The original idea was that p-adic space-time regions can suffer topological phase transitions to real topology and vice versa in quantum jumps replacing space-time surface with a new one is given up as mathematically awkward: quantum jumps between different number fields do not make sense. The new adelic view states that both real and p-adic space-time sheets are obtained by continuation of string world sheets and partonic 2-surfaces to various number fields by strong form of holography.

The idea about p-adic pseudo constants as correlates of imagination is however too nice to be thrown away without trying to find an alternative interpretation consistent with strong form of holography. Could the following argument allow to save p-adic view about imagination in a mathematically respectable way?

1. Construction of preferred extremals from data at 2-surfaces is like boundary value problem. Integration constants are replaced with pseudo-constants depending on finite number pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces.

2. Preferred extremal 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. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets and partonic 2-surfaces not allowed in real context and realizing imagination.

3. Could imagination be realized as a larger size of the p-adic sectors of WCW? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could the modes of WCW spinor fields for which 2-surfaces are extandable to space-time surfaces only in some p-adic sectors make sense? The real space-time surface for them be somehow degenerate, for instance, consisting of string world sheets only. Could imagination be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real preferred extremals? 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.

Although p-adic space-time sheets as such are not conscious, p-adic physics would provide a beautiful mathematical realization for the intuitions of Descartes. The formidable challenge is to develop experimental tests for p-adic physics. The basic problem is that we can perceive p-adic reality only as “thoughts” unlike the “real” reality, which represents itself to us as sensory experiences. Thus it would seem that we should be able generalize the physics of sensory experiences to physics of cognitive experiences.

Life as something in the intersection of real and p-adic worlds and negentropic entanglement

In the p-adic context one must modify Shannon’s definition of entropy by replacing the ordinary logarithm based on p-adic norm. This definition gives rise to a real valued entropy in both real and p-adic contexts if entanglement coefficients are rational/algebraic numbers. For irrational/non-algebraic entanglement standard Shannon formula and its p-adic variant must be used and gives rise to non-negative entropy. Unlike Shannon entropy, the p-adic entropies (one for each p) can be also negative so that the entanglement entropy defines a genuine information measure whose sign tells whether the system contains information or dis-information. For the p-adic entropies Negentropy Maximization Principle (NMP) [K45] tends to preserve the quantum coherence if p divides the common denominator of the entanglement probabilities. The states with rational/algebraic entanglement can be regarded as new kind of states analogous to bound, which are not at all fragile like the states with non-algebraic entanglement are. In particular, these states need not be bound due to the binding energy.

For instance, the problematic notion of high energy phosphate bond might be understood in terms of negentropic entanglement making possible correlations without binding energy so that the ATP$\rightarrow$ADP process defining fundamental step of metabolism could be interpreted in terms of negentropy transfer. Negentropic entanglement is highly stable in state function reduction process so that the randomness of quantum jump does not apply to it. Weak form of NMP [K45, K95] supports this view and allows also to derive a generalization of p-adic length scale hypothesis.

Although the entropy of second law is ensemble entropy and one cannot expect second law to be in conflict with NMP, breakdown of the second law of thermodynamics might be implied by NMP in the scale defined by the size of CD involved: consider only transformation of thermal ensemble to single dark particle for which original particles are negentropically entangled. Certainly it requires a generalization to take into account the possibility that the arrow of geometric time changes in volitional acts meaning death of self at some level of self hierarchy.

I have proposed that sub-selves lose consciousness as ordinary entropic bound state entanglement is generated but experience expansion of consciousness when negentropic entanglement is generated. Positive emotions like love, experience of understanding would naturally accompany the generation of negentropic entanglement.

These observations suggest a purely number-theoretic characterization of life: life is in the intersection of real and p-adic worlds: life corresponds to islands of rational/algebraic numbers in the seas of real and p-adic continua. This vision have rapidly become the most important source of insight in attempts to develop TGD based vision about conscious intelligence and cognition.

As explained, strong form of holography following from strong form of GCI allows to identify the intersection of reality and p-adicities as string world sheets and partonic 2-surfaces for which defining parameters (relevant WCW coordinates characterizing them physically) are in some algebraic extension of rationals defining also algebraic extension of p-adic numbers. Parameters correspond to conformal moduli, which are GCI invariants.

These surfaces define space-time surfaces by holography, and general space-time surfaces in various number fields are obtained by algebraic continuation of parameters to reals and various p-adic number fields. Also adelic scattering amplitudes are obtained in the similar way from those in the intersection. Induced spinor fields are localized to these 2-surfaces - this guarantees the well-definedness of em charge - and fermions can be interpreted as correlates for Boolean cognition. The hierarchy of algebraic extensions of rationals becomes the characterizer of the fundamental cognitive hierarchy. So called ramified primes define preferred p-adic primes and NMP allows to deduced generalization of p-adic length scale hypothesis. Hence rather concrete view about number theoretical aspects of cognition emerges.

3.1.3 Topics Of The Chapter

The topics of the chapter is as follows.

1. The relationship between p-adic physics of cognition is discussed on general level. Possible evidence for p-adic cognition is considered.

2. In the mathematical sections the relationship between cognition and number theory is discussed. Also the relationship 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.

3. Frontal lobes are known to be the seat of the higher level cognition and also responsible for intentional action and are discussed from p-adic point of view.

4. 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 and the condition that the time scales involved correspond to time scales assignable to the CDs of the known elementary particles does not favor the generalization. On the other hand, the dark matter sector could allow entire fractal hierarchy of elementary particle physics whose existence is reflected as fundamental bio-rhythms and cognitive codes.

5. 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.

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` [L4].

3.2 P-Adic Physics And Cognition

The basic vision based on adelic TGD is that p-adic space-time sheets serve as correlates for cognition. The original idea that the transformation if intention to action is realized as a quantum jump replacing p-adic space-time region with a real one is given up for both mathematical difficulties and the fact that there is no need for this in Zero Energy Ontology (ZEO), where development of intentions and volitional action can be understood differently.

3.2.1 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 ZEO.

Second non-determinism is classical non-determinism of Kähler action and is closely related to quantum criticality. It is also relevant for symbolic representations and perhaps serves as a correlate for macroscopic volition. The third non-determinism is inherent to all p-adic field equations and might relate 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 are candidates for 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 zero energy ontology (ZEO) all space-time sheets satisfy the criterion for mind-likeness and therefore serve as correlates for selves.

Classical and p-adic non-determinisms inspired the the notion of association sequence defined as a sequence of space like 3-surfaces with time like separations determining uniquely the preferred extremal going through these 3-surfaces. In the case of CP_2 vacuum type extremals discrete association sequences become in principle continuous sequences of 3-surfaces but topological condensation is expected to reduce this non-determinism to its discrete version. It has however turned out that the notion of association sequence is redundant. The hierarchy of causal diamonds (CDs) defining kind of spot-lights of consciousness and serving as correlates of selves is the natural notion. Mind-like space-time sheets correspond to space-time surfaces inside CDs.

3.2.2 Classical Non-Determinism And Symbolic Representations

In the special case that classical non-determinism gives rise to macroscopic multi-furcations of the time development of 3-surface, it is tempting to identify the branches of the multi-furcations as alternative choices involved with volitional acts. Contrary to the long held beliefs, it however seems that classical non-determinism is most naturally associated with symbolic representations understood in a very general sense (one could even understand classical space-time surfaces as symbolic representations of quantum dynamics). The assignment of sensory experiences with real mind like space-time sheets explains why the contents of sensory experiences are localized with respect to geometric time.

The book "Gödel, Escher, Bach" by Douglas Hofstadter about self-reference has been perhaps the most fascinating of my intellectual arm chair adventures and it stimulated the dream about the identification of the physical counterpart of self-reference. The physics as a generalized number theory vision stimulated concrete ideas about how this self-reference might be realized in terms of quantum universe repeatedly re-creating itself. The quantum jump building sensory and cognitive representations about the Universe means the replacement of the Universe with a new one containing these representations. Hence the paradoxical infinite regress resulting from the assumption that it is possible to be conscious about what one is conscious of is avoided with a simple modification of this assumption by replacing "is" with "was". By quantum classical correspondence this vision requires also the failure of classical determinism in the conventional sense of the word.

In accordance with the crossing symmetry of standard quantum field theories, one can interpret the elements of M-matrix (generalization of S-matrix in TGD framework) as time-like entanglement coefficients between positive and negative energy parts of the zero energy state with incoming and outgoing particles having positive and negative energies respectively. Thus the classical non-determinism and zero energy ontology make possible for the TGD Universe according to represent the laws of physics in the structure of the zero energy physical states. That all possible vacua provide representation for physics is very much akin to the ideas of Eastern philosophies, and is bound to have deep implications from the point of view of TGD inspired theory of consciousness.

3.2.3 Basic Vision About Qualia

Before proceeding it is useful to summarize the basic view about sensory qualia [K30].

1. Geometric qualia correspond to the increments of WCW zero modes in quantum jump and are cognitive qualia. Shape, size, length duration, ... etc. are good examples of geometric qualia. Real geometric qualia could be also called symbolic qualia. The universe of symbolic representations is completely classical if a complete localization in the zero modes occurs in each quantum jump. It is not completely clear whether this must be the case also in the real WCW degrees of freedom. In p-adic WCW degrees (WCW, "the world of classical worlds") of freedom it must take place so that cognition would be completely classical. The moduli space for CDs is an excellent candidate for the fundamental geometric qualia [K74, K68].

2. Sensory qualia correspond to the increments of quantum numbers related to the quantum fluctuating degrees of freedom, non-zero modes. They are genuine multi-verse qualia since the final states of quantum jumps are superpositions of space-time surfaces with varying values of non-zero modes. One cannot understand color red in terms of space-time geometry.

3. The trinity sensory-symbolic-cognitive is central for understanding consciousness in TGD framework. Also the division to fermionic (WCW spinor) and WCW degrees of freedom at the level of qualia is important. Fermionic qualia correspond to Boolean qualia and are number theoretical universal. WCW qualia correspond to geometric and sensory qualia. If cognition and sensory experience is restricted to the intersection also these qualia would be number theoretically universal. The original idea was that sensory qualia could be assigned with real physics. One can also speak about geometric qualia having both real and p-adic counterparts. These would be abstact qualia like position, velocity, etc...

3.2.4 The New View About Intentional Actions

The original rather naïve view that volitional acts involve a quantum jump transforming p-adic space-time sheet to a real one has turned out to be mathematically unfeasible. The new adelic view about the fusion of real and p-adic physics makes this idea also un-necessary. Cognition is present always and everywhere and ZEO based view about quantum jump allows to understand volitional act as initiated by the first state function reduction at the opposite boundary of CD in which self dies and re-incarnates. Intention develops during the sequence of repeated state function reductions and is how NMP forcing this reduction to eventually occur is experienced consciously. It has both cognitive and sensory components (plan and desire). One can say that sensory perceptions and motor actions are time reversals of each other and correspond to opposite boundaries of CD.

Volitional act as a quantum jump transforming p-adic space-time sheet to a real one?

If one accepts the idea that real and p-adic space-time regions are correlates for matter and cognition, one encounters the question how matter and mind interact. As already noticed, the first guess for this interaction was the quantum jump replacing real space-time regions with p-adic ones and vice versa. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or intention to an action. The reverse phase transition would relate to the transformation of the sensory experience to cognition.

It turned out that this idea raises mathematical challenges, which are probably too heavy. Instead, one can assume that the Universe is adelic. Real and p-adic existences form a Cartesian product so that an adele is obtained. Cognitive aspects of existence correspond to various p-adic variants of the space-time surface.

p-Adic space-time sheets would indeed define a theory about real space-time sheets. The interaction between real and p-adic number fields would mean that p-adic space-time surfaces define cognitive representations of real space-time surfaces (preferred extremals). 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.

Strong form of holography implied by strong form of General Coordinate Invariance (GCI) leads to the suggestion that partonic 2-surfaces and string world sheets at which the induced spinor fields are localized in order to have a well-defined em charge (this is only one of the many reasons) and having having discrete set as intersection points with partonic 2-surfaces define what might called "space-time genes". Space-time surfaces would be obtained as preferred extremals satisfying certain boundary conditions at string world sheets and carrying vanishing super-symplectic Noether charges in a sub-algebra for which conformal weights are n-multiples of those for the entire algebra. Space-time surfaces are defined only modulo transformations of this algebra acting as conformal gauge transformations so that one can talk about conformal gauge equivalences classes of space-time surfaces.

The map assigning to real space-time surface a cognitive representation would be replaced by a correspondence assigning to the string world sheets preferred extremals of Kähler action in various number fields: string world sheets would be "space-time genes". String world sheets would be in the intersection of realities and p-adicities in the sense that the parameters characterizing them would be algebraic numbers associated with the algebraic extension of p-adic numbers in question. It is not clear whether the preferred extremal is possible for all p-adic primes but this would fit nicely with the vision that elementary particles are characterized by p-adic primes. It could be also that the classical non-determinism of Kähler action responsible for the conformal gauge symmetry corresponds to p-adic non-determinism for some particular prime so that the cognitive map is especially good for this prime.

Volitional actions as first state function reductions to the opposite boundary of CD

Adelic vision forces to modify the original view about intentional action. Ontology (ZEO) volitional action begins with the first state function reduction to the opposite boundary of causal diamond (CD) involving "death" of corresponding self and re-incarnation at opposite boundary [**?**, K4]. Intention develops during the sequence of state function reductions at same boundary of CD as a mental state of self. Basically NMP gradually forces self to make the first state function reduction to the opposite boundary and this is experienced as gradually maturing decition to realize the act of volition. In this profess self dies and re-incarnates at opposite boundary. We experience these deaths as disappearances of mental images.

A more concrete picture about the acts of volition would rely on generation of negative energy MEs representing signals propagating backwards in geometric time when the first state function reduction at the opposite boundary of CD changes the arrow of geometric time.

1. Although ZEO in principle allows a creation of zero energy states with arbitrarily large energies of positive energy part of the state as analogs of quantum fluctuations, the condition that the entanglement is negentropic poses energetic constraints. The interpretation of metabolic energy transfer as transfer of negentropic entanglement (NE) allows to understand the somewhat foggy concept of energetic phosphate bond central for ATP-ADP process [K27, K28]. What is transferred in this process would be negentropy rather than mere energy.

2. Em fields, in particular ELF em fields, are crucial for TGD inspired model of brain and a natural question. I have proposed the generation MEs as a mechanism of coherent locomotion made possible by the maximally coherent momentum carried by ME and resulting as a recoil momentum of material system absorbing second ME. In fact, the mechanism is optimal since the momentum of ME is completely coherent. Thus a possible interpretation is as a transformation of intention to real motion. Of course, it is difficult to say whether this mechanism occurs in cellular or micro-tubular length scales or perhaps even in macroscopic lengths scales. And there are certainly also other mechanisms.

A more refined picture about the realization of volitional action emerges, when one asks how a precisely targeted intention could be realized at the atomic or molecular level.

1. The change must involve energetic changes in the scale of the entire system so that the quantum numbers characterizing the positive energy part of the state change. This includes energy and momentum. It seems safe to assume that zero energy states are created in rather small length scales and that macroscopic systems cannot transform between real and p-adic states. Hence the bottle neck step of the process would be the generation of zero energy states from vacuum as sub-CD with a rather short characteristic time scale and their subsequent interaction with the existing state inducing the desired action.

2. This favors the generation of zero energy states representing elementary particles and electrons and quarks are excellent candidates in this respect for reasons that should be already clear. The sub-CD created from vacuum could be p-adic and transform to a real one and interact with the background to induce the transition. Protons and electrons are key actors in bio-catalysis and TGD forces to consider the possibility that at least electron and quarks exist only in the sense of zero energy ontology.

3. The creation of sub-CD can be interpreted direction of attention of CD to a particular spatiotemporal region inside it. If this region is near vacuum extremal it is critical and the subsequent interaction of sub-CD with 4-D environment can induce a large change of the entire system.

Another view about motor action is as negative energy signal sent to the geometric past and inducing a neural activity leading to the motor action as a consequence. This view conforms with the findings of Libet and others [J18]. It should be possible to fuse these two views together.

1. The intention can be realized in a precisely targeted manner only for the transitions which do not occur spontaneously, and thus involve the emission of negative energy MEs. For a transition involving emission of positive energy, the direction of ME is random so that targeted intentional action is not possible.

2. The emission of negative energy ME translates to a quantum jump in which the energy of the positive energy part of zero energy state increases in the interaction with sub-CD or some other CD. The generation of negative energy MEs would utilize the quantum credit card mechanism of metabolism implying extreme flexibility.

3. Quantum credit card mechanism requires the existence of a system analogous to a population reversed laser. The TGD based model for metabolism assumes that electrons or protons kicked to a small space-time sheet provide this system and that their dropping to a larger space-time liberates zero point kinetic energy as metabolic energy. Hence sensory, cognitive and memory representations would be realized in terms of positive energy MEs spontaneously whereas intentionality and motor actions would be much like time reversed sensory representations and realized in terms of negative energy MEs.

Motor actions as time reversed perceptions

ZEO view about self allows to see motor actions as time reversed perceptions. This allows a simple view about imagined motor activities. Imagined motor actions would be sensory percepts with stimulus generated at some level above muscles - rather than at brain! - and proceed to the cortex as time reversed activities as far as the MEs controlling these activities are considered. If looked in standard time direction they would start from brain and end at some level before ending to the muscles. In a symmetric manner, imagination would correspond to virtual percepts with sensory input generated at level of neural pathways above sensory organs involving perhaps virtual sensory input from higher level.

Negative energies make possible precisely targeted intention. There is no need to stop the imagined motor action so that it is not a safety risk. It is possible to learn motor actions by initiating them from a level above the muscles. Time reversal means negative energies for MEs and buy now-let others pay mechanism implies extreme flexibility. Time reversed dissipation can be interpreted as a healing mechanism since entropy decreases in the standard direction of the geometric time. ZEO view about self organization allows to see motor action as a carving of a four-dimensional statue by a gradual refinement and error corrections using dissipation as a Darwinian selector. No detailed planning is needed: only a rough sketch is enough in the time scale of the motor action and Nature takes care of the rest.

p-Adic fractality suggests that cognitive representations realized in the intersection of realities and p-adicities and reducing by strong form of holography to string world sheets and partonic 2-surfaces plus fermions at them are present at all length scales. In particular, MEs in the intersection are excellent candidates for defining cognitive representations. Nothing forbids a repertoire of simple MEs serving as symbols, typically frequencies or field patterns, and generating neural activities in turn amplified to macroscopic actions.

3.2.5 P-Adic Physics As Correlate For Cognition

The original vision was that p-adic non-determinism could serve as a correlate for imagination. The recent view is much more cautious. Certainly imagination does not reduce to p-adic non-determinism since it has also real physics correlates. Real and p-adic space-time surfaces are also extensions of same basic objects (string world sheets and partonic 2-surfaces) to 4-D surfaces and therefore highly correlated rather than almost independent. One might however consider that the classical non-determinism and p-adic non-determinism serve as correlates for quantum non-determinism which makes possible both volition and imagination.

Could p-adic non-determinism serve as a correlate for imagination?

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piece-wise constant functions in the p-adic context.

1. p-Adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the 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 unique solution of field equations results. Since the fundamental formulation of quantum TGD [K96] indeed relies on the notion of finite measurement resolution, a highly attractive interpretation of this cutoff is in terms of measurement resolution of some kind.

2. Solution can be fixed in a discrete subset of rational (algebraic) points of the embedding space. In the case of space-time surfaces this set is expected to have inherent cutoff since the condition of rationality (or algebraicity in the extension of p-adic numbers used) posed separately for all embedding space coordinates is very strong. Note that preferred embedding space coordinates are required and this kind of coordinate systems indeed existence thanks to the isometries of the embedding space.

Clearly, 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. 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.

A possible interpretation for the solutions of the p-adic field equations would be as geometric correlates of cognition 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.

If one accepts the idea that real and p-adic space-time regions are correlates for matter and cognitive mind, one encounters the question how matter and mind interact. The original candidate for this interaction was as a phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations would take place in quantum jumps. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or to an action. The reverse phase transition might relate to the transformation of the sensory experience to cognition. Sensory experiences could be also transformed to cognition by initial values realized as common rational points of a real space-time sheet representing sensory input and a p-adic space-time sheet representing the cognitive output. In this case the cognitive mental image is unique only in case that p-adic pseudo constants are ordinary constants.

It turned out that this interpretation leads to grave mathematical difficulties: one should construct U-matrix and M-matrix for transitions between different number fields, and this makes sense only if all the parameters involved are rational or algebraic. A more realistic view is that the interaction between real and p-adic number fields is that p-adic space-time surfaces define cognitive representations of real space-time surfaces (preferred extremals). 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 notion of p-adic manifold [K98] tries to catch this idea mathematically.

Strong form of holography implied by strong form of General Coordinate Invariance leads to the suggestion that partonic 2-surfaces and string world sheets at which the induced spinor fields are localized in order to have a well-defined em charge (this is only one of the reasons) and having having discrete set as intersection points with partonic 2-surfaces define what might called "space-time genes". Space-time surfaces would be obtained as preferred extremals satisfying certain boundary conditions at string world sheets. Space-time surfaces are defined only modulo transformations of super-symplectic algebra defining its sub-algebra and acting as conformal gauge transformations so that one can talk about conformal gauge equivalences classes of space-time surfaces.

The map assigning to real space-time surface cognitive representation would be replaced by a correspondence assigning to the string world sheets preferred extremals of Kähler action in various number fields: string world sheets would be indeed like genes. Mathematically this formulation is much more elegant that based on p-adic manifold since discretization seems to be un-necessary at space-time level and applies only to the parameters characterizing string world sheet.

String world sheets and partonic 2-surfaces would be in the intersection of realities and p-adicities in the sense that the parameters characterizing them would be algebraic numbers associated with the algebraic extension of p-adic numbers in question. It is not clear whether the preferred extremal is possible for all p-adic primes but this would fit nicely with the vision that elementary particles are characterized by p-adic primes. It could be also that the classical non-determinism of Kähler action responsible for the conformal gauge symmetry corresponds to p-adic non-determinism for some particular prime so that the cognitive map is especially good for this prime.

The idea about p-adic pseudo constants as correlates of imagination is however too nice to be thrown away without trying to find an alternative interpretation consistent with the strong form of holography. Could the following argument allow to save p-adic view about imagination in a mathematically respectable manner?

1. The construction of preferred extremals from data at 2-surfaces is like boundary value problem. Integration constants are replaced with pseudo-constants depending on finite number pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces.

2. Preferred extremal 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. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets and partonic 2-surfaces not allowed in real context and realizing imagination.

3. Could imagination be realized as a larger size of the p-adic sectors of WCW? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could the modes of WCW spinor fields for which 2-surfaces are extendable to space-time surfaces only in some p-adic sectors make sense? The real space-time surface for them be somehow degenerate, for instance, consisting of string world sheets only.

   Could imagination be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real preferred extremals? 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.

I have the feeling that this view allows respectable mathematical realization of imagination in terms of adelic quantum physics. It is remarkable that strong form of holography derivable from - you can guess, strong form of General Coordinate Invariance (the Big E again!), plays an absolutely central role in it.

Cognition at elementary particle length scales?

The success of p-adic mass calculations [K41, K14, K46] does not leave much room for the interpretations if one identifies p-adic physics as a physics of cognition: cognitive representations must be present already at elementary particle level. The adelic vision is the most elegant manner to describe the situation mathematically.

This means that the creation of zero energy states representing photons and perhaps even electrons and quarks could occur routinely in living matter. In the standard physics framework the interpretation would be as quantum fluctuations generating fermion pairs from vacuum. In TGD framework these quantum fluctuations become quantum states with precisely defined characteristics.

Intentional action could be present also in elementary particle length scales if the adelic vision makes sense. Time reversals should occur so often that the effects related to the arrow of time disappear on the average. The extreme situation is the each state function reduction occurs at opposite boundary of CD so that the life time of self is vanishingly short. In this case one cannot speak of any kind of intentional action or volition but already a sequence of few state function reductions generates self and can give rise to intentions.

What makes this hypothesis testable is the prediction that the time scales of CDs assignable to electron and quarks should define fundamental time scales of living matter. This seems to be the case. kHz neuronal synchrony is only one example. kHz frequency and 10 Hz frequency would be associated also with "dead" matter if cognition is present at elementary particle level. A particular prediction is the failure of second law below these time scales. This kind of failure has been indeed observed [D1] and the effect indeed involves millisecond and.1 second time scales [K45].

The experience has taught that physical system can be understood throughly only after the characteristic time and length scales have been understood. In case of biology the prevailing reductionistic attitude has led to the belief that living matter is a basic example of a "non-tidy" system so that the time and length scales associated with living matter are more or less accidental as also genetic code and the miracles of bio-chemistry. My own belief is that this attitude is wrong and explains why the progress in the theoretical understanding of living matter has been so slow.

Cognitive degeneracy and the survival of the fittest

Physical systems with large degeneracy would be favored since intuitively one expects this to give a high representational power. 4-D spin glass degeneracy suggests that these systems correspond to small deformations of vacuum extremals. If the final states of quantum jumps have roughly the same probabilities, this means that quantum jumps lead with highest probability to those states for which cognitive degeneracy is highest. The mere ability to imagine would mean winning in the fight for survival.

The hierarchy of Planck constants associated with the hierarchy of quantum criticalities involves degeneracy and its connection with conscious information in much more concrete manner. The density matrices for the outcomes of state function reductions are higher-dimensional projection operators and one can can assign to them negentropy and conscious information. The interpretation is as a consciously experienced abstraction or rule with its instances represented as state pairs in the superposition.

The emergence of symbols

p-Adic non-determinism gives rise to cognitive representations whereas the non-determinism of the real Kähler action gives rise to symbolic representations in terms of association sequences consisting of space like 3-surfaces with time like separations: the individual space like 3-surfaces play the role of words of sentence.

Conscious activities are indeed highly symbolic: a push of button can initiate a nuclear war. The reduction of the p-adic-to-real phase transitions to some fundamental level, perhaps to the level of nerve pulse transmission, indeed makes possible a build-up of very complex actions by using a repertoire of very simple basic actions serving p-adic memes translatable to symbols in case that system is initial value sensitive. Dark MEs with preferred frequencies inducing transitions provide an excellent candidate for the buttons.

This idea is developed concretely in the model of bio-photons as decay products of dark photons at flux tubes having $\hbar_{eff} = \hbar_{gr} = Gmm/v_0$ [K6, K58]. The cyclotron energies of charged particles are proportional to h_{gr}/m and thus independent of the mass of the particle. Therefore the cyclotron energy spectrum of emitted dark photons and bio-photons resulting from them is universal and in the range of visible and UV photons where also molecular transition energies are. Hence bio-photons define an optimal control too. This leads to a vision in which each biomolecule is symbolically represented by a collection of cyclotron frequencies characterizing its magnetic body and directed attention between molecules corresponds to a resonance interaction involving emission and absorption of cyclotron photons. This idea have been develop further in the geometric model of harmony leading to a proposal that genetic code is realized in terms of triplets of cyclotron frequencies for dark photons [K65]. Molecules - at least DNA and proteins- would be symbolically represented by "music pieces" consisting of sequence of 3-chords- somewhat like characters in Wagner's operas correspond to themes.

What cognitive representations are and how they develop?

It is far from clear what cognitive representations are and how they develop. The recent vision about generalized embedding space and about life as something in the intersection of real and p-adic worlds provides one possible answer to the question based on adelic physics supported also by p-adic mass calculations.

For a long time I believed that discretization of space-time by a subset of algebraic points and with cutoff makes sense at space-time and embedding space level: this vision was concretized in the proposal what p-adic manifolds as cognitive charges of real manifolds - now preferred extremals- could be [K98]. The intersection of realities and p-adic world was at the space-time level identified as discretized space-time surfaces with points having coordinates which are numbers in some algebraic extension of rationals. These discrete point sets were assumed to be continuable to preferred extremals of Kähler action containing them. This introduces a lot of non-uniqueness interpreted in terms of a finite measurement resolution.

The first problem is that this discretization is highly non-unique and one is forced to introduce preferred coordinates. Second problem was that there is a tension between symmetries and continuity. The identification via common rationals (or numbers in algebraic extension of rationals defining an extension of p-adic number fields) would respect symmetries represented by rational matrices but would be totally discontinuous. The canonical identification is continuous but does not respect symmetries. The proposal was a compromise involving pinary cutoffs.

The discretization at space-time level is abstracted to a discretization at the level of WCW reducing by strong form of holography to a discretization for the parameters characterizing partonic 2-surfaces and string world sheets. By conformal and modular invariances these parameters should corresponds to finite-dimensional space of conformal moduli (Teichmueller parameters and punctures representing intersections of string world sheets with partonic 2-surface [K14, K41]). As far as scattering amplitudes are considered, all calculations could be carried out at this level without continuation to 4-D space-time surfaces. p-Adic variant of Teichmueller space was actually used in p-adic mass calculations already two decades ago [K41].

The correspondence between real and p-adic space-time sheets would be induced by the continuation of string world sheets and partonic 2-surfaces to preferred extremals so that canonical identification is not needed. The tension between symmetries and continuity would disappear since there is no map from reals to p-adics or vice versa but only algebraic continuation from the intersection. Space-time discretization is not present except for partonic 2-surfaces but has purely physical meaning since the discrete points correspond physically to the ends of boundaries of string world sheets carrying fermions. Also measurement resolution can be formulated elegantly in terms of pinary cutoffs at this level.

The partonic 2-surfaces are in the intersection of realities and p-adicities in the sense that the parameters appearing in their mathematical representations are in extension of rationals so that they make sense both in real sense and p-adically. Restriction to algebraic points, which is clumsy at the level of space-time, occurs now at the level of "world of classical worlds" (WCW). These 2-dimensional objects would define the fundamental cognitive and symbolic representations at the same time.

One should answer several questions.

1. What are the basic types of cognitive representations? One can imagine two basic correspondences between reals and p-adics induced by common rationals and canonical identification or some map akin to it. One can ask whether self-representations could be induced by common rationals whereas representations of the external world could be induced by a proper

generalization of canonical identification mapping rationals to themselves up to some power of p. In both cases there is some pinary cutoff determining the goodness of the representation. For the identification based on common rationals or algebraics the geometry of the surfaces would dictate the resolution inherently.

More than decade after writing the above lines adelic view has replaced the original vision and the situation looks much simpler. Both real and p-adic space-time sheets are obtained as preferred extremals by strong form of holography from the partonic 2-surfaces and string world sheets in the intersection of reality and various p-adicities. Thus the representations are fixed to a high degree and provide kind of kaleidoscopic view about existence. How refined these representations are, depends on how complex the algebraic extension of rationals is. Evolution indeed corresponds to a gradual increase of the complexity of extension [K95].

2. How do cognitive representations in p-adic sectors relate to sensory representations in real sector? In the adelic view [K95] there is no step of this kind since p-adic and real sectors accompany automatically each other. p-Adic non-determinism might mean that p-adic preferred extremals depend on pseudo constants so that strong form of holography would not be highly non-unique in p-adic sectors. There could be large number of space-time surfaces associated with a given string world sheets and partonic 2-surfaces distinguished by different pseudo constants. This would mean that cognitive representations are not so trustworthy but does not seem to relate naturally to imagination.

3. Cognitive representations evolve in the sense that they become gradually more precise. What does this mean in the adelic vision? The complexity of the algebraic extension of rationals for the 2-surfaces in the intersection is the natural measure for a level of cognitive and symbolic representation. Evolution would involve a gradual increase of the complexity of the extension [K95] leading to the emergence of new preferred p-adic primes as ramified primes of the 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 [K52]. 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 the preferred primes satisfy p-adic length scale hypothesis or its generalization from $p = 2$ to small primes remains an open question.

   The value of effective Planck constant $h_{eff}/h = n$ corresponds to the number of sheets of some kind of covering space defined by the space-time surface. The discretization of the space-time surface identified as a monadic manifold [L17] with embedding space preferred coordinates in extension of rationals defining the adele has Galois group of extension as a group of symmetries permuting the sheets of the covering group. Therefore $n = h_{eff}/h$ would naturally correspondto the dimension of the extension dividing the order of its Galois group.

   Weak form of NMP would allow the emergence of highly negentropic entanglement, when the dimension of the projector for the outcome of projection is power of large prime. The phase transitions reducing quantum criticality and increasing h_{eff} would generate NE and extend the scale of macroscopic quantum coherence. The evolution would also involve the emergence of new strings connecting partonic 2-surfaces. These strings would carry super-symplectic Noether charges creating many-fermion states, which in turn would provide representation of Boolean algebra bringing in Boolean cognition.

4. What is the relationship to the memetics of Susan Blackmore [J69]? Susan Blackmore sees memes as independent objects using brain as a tool of replication.

   Memes could be identified as mental images able to utilize the metabolic energy resources associated with brains and to replicate themselves in communications. They must correspond to self-organization patterns able to induce the birth of their almost copies in communications. Selves have magnetic bodies and also memes should have them.

The replication of magnetic body - analogous to what happens in 3-vertex of Feynman diagram - is what induces the replication of biological sense in TGD inspired biology [K62]. The replication vertex is indeed the generalization of fundamental 3-vertex in TGD context. There is strong temptation to assume that also memes are magnetic bodies replicating in this concrete sense. Thus magnetic bodies serving as analogs of the morphic fields of Rubert Sheldrake [K62] would be the physical correlates for memes: this makes sense since they carry dark matter and NE, and can be said to act as an intentional agents using biological bodies as motor instruments and sensory receptors.

The original idea that p-adic cognitive representations could serve as the physical realization of memes is not feasible in the adelic framework. In the adelic picture p-adic cognitive representations are not independent elements but determined to a high extent by the string world sheets and partonic 2-surfaces as real sensory representations. One cannot say that p-adic representations use brain as at tool for the materialization and replication.

3.2.6 Quantization Phenomena In Psychophysics

p-Adicity might provide understanding of some phenomena of psychophysics related to the discrimination between different intensities of stimuli and to threshold phenomena of sensory perception.

When over-learning occurs in tasks involving temporal discrimination, the memory images about the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [J45] such that the plateaus where response remains constant are octaves of each other. This suggests that the memory image about the sensation depends only on the 2-adic norm of the 2-adic image of the ratio I/I_0 of the intensity of the stimulus to the threshold stimulus under canonical identification.

This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has 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 ELF selves 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.

3.3 Various Aspects Of Cognition

In the following various aspects of cognition are discussed further. The representation differs from the earlier one in some important aspects. Adelic view about sensory-cognitive representations replace the idea about weakly dependent sensory and cognitive representations: in the new view real and p-adic space-time sheets are determined by strong form of holography from string world sheets and partonic 2-surfaces - “space-time genes”. ZEO allows a precise formulation of various ideas related to time reversed cognition. The replication of magnetic bodies suggests itself as a counterpart for the replication of memes. The idea about quantum jumps transforming p-adic space-time sheets to real ones or vice versa is given as mathematically awkward one.

3.3.1 P-Adic Physics And Imagination

p-Adic non-determinism makes it natural to interpret p-adic space-time sheets as geometric correlates of cognitions. A natural guess is that p-adic physics is also physics of imagination but one must very carefully define what this means and whether it can make sense. The original idea that imagination corresponds to building of p-adic variants of the action transformed to real ones. This idea meets however grave mathematical difficulties and is un-necessary.

In the adelic picture the p-adic representations automatically accompany all physical systems, even elementary particles: this is consistent with the success of p-adic mass calculations.

One can also ask whether p-adic nondeterminism really plays any important role in imagination. One can of course imagine that the assignment of space-time surfaces to 2-D space-time genes is not unique due to the presence of pseudo-constants. But what this non-uniqueness could mean?

If sensory organs are the seats of the primary sensory qualia, one can understand imagined sensory experience as a perception, which does not start from the level of sensory organs but some higher level and gives rise only to cognitive representations. Dreaming and hallucinations would involve a feedback to the primary sensory organs "qualiafying" the cognitive representations. If motor action can be identified as a time reversal of the sensory perception in a relevant time scale for MEs then imagined motor actions would differ from real ones only in that they would be initiated from some higher level than muscles and proceed to brain and from brain to magnetic body. Imagined would be almost realized.

3.3.2 How Dreams And Hallucinations Relate To Sensory Experiences?

If primary sensory qualia are realized at the level of sensory organs, then dreams and hallucinations would be virtual sensory experiences with sensory input from magnetic body and brain instead of external world. Rapid eye movements and oto-acoustic sounds would be a signature of this process. Spontaneous movements during dreaming would in turn be the signature of the imagined motor activities. I have proposed this view about dreams already earlier and explains nicely the observations of Claude Rifat about lucid dreaming [J21]. The strange piecewise logical consistency of dreams is consistent with smaller value of Planck constant $h_{eff} = n \times h$ implying shorter time scale of memories and planned actions. The original interpretation was that it reflects p-adic non-determinism.

This view about dreaming is in accordance with the observations (reviewed in [J56]) that dreaming is not produced by random inputs from brain stem to cortex but is cognitive skill learned gradually during infancy. The most primitive dreams represent static pictures, then these pictures become dynamical, and at the age of about eight the dreamer becomes a participant of the dream. In lucid dreaming the dreamer has taken active role in transforming cognitive representations to sensory experiences.

One must actually distinguish between two kinds of "hallucinations": a genuine sharing of sensory mental images involving no "qualiafication" and interpretable as telepathy, and the receival of cognitive information, which is then qualiafied by the receiver like during dreaming. The presence/absence of a feedback to the sensory organs allows to discriminate between these options. The semitrance model for the bicameral mind [K75] relies on the idea that these experiences are communicated by higher levels of the self hierarchy during semitrance. This communication could be purely telepathic.

3.3.3 Cognition, Sensory Experience, And Boolean Mind

Thoughts have not color and pure thoughts seem to be free of emotions, with aesthetic experiences induced by abstract ideas being perhaps an exception. Pure thoughts involve often the experience that something is true or false but not beautiful or ugly or right or wrong. These simple observations provide tests for the identification of the p-adic physics as physics of cognition and for the model of sensory qualia, Boolean qualia, and emotions. These observations also suggest a concrete identification of the physical correlates for the Boolean algebras of ethics, aesthetics, and logics.

Are qualia number theoretically universal?

Sensory qualia were originally identified as averages of quantum number increments associated with the quantum jump sequence defining the sub-self representing sensory mental image. The recent view inspired first by the sensory capacitor model of qualia [K30, K23] and then suggested strongly by ZEO based definition of self reducing to the TGD inspired quantum measurement theory leads to a somewhat different view.

Qualia correspond to quantum number flows between subsystem defining sub-self and environment continuing as long as the mental image representing the qualia defined by quantum numbers of flowing particles. Quantum numbers of flowing particles instead of quantum number increments define qualia. There is high temptation to assume that qualia involve a transfer of negentropic entanglement. Also the flow of metabolic energy is proposed to involved it. This raises the question whether fundamental qualia are associated with metabolites- not only metabolic energy but also important bio-molecules carrying NE: certainly this would be very natural.

In the recent view all qualia related to fermions are number theoretically universal so that one cannot regard them a p-adic or real: this at least in the intersection of reality and p-adicities. Strong form of holography in any case demands that fermionic qualia can be assigned with string world sheets and partonic 2-surfaces at the fundamental level. The strong form of holography suggests that the qualia associated with quantum numbers in bosonic WCW degrees of freedom can be also localized to these 2-surfaces.

What about geometric qualia carrying geometric information? Do they make sense as it would seem? It is not at all clear whether sensory capacitor model applies to them. Rather, it would seem that string world sheets and partonic 2-surface define kind of conscious skeleton of space-time surface allowing conscious localization of various qualia. Does this mean that one can assign even geometric qualia to the 2-D objects - say their positions and velocities.

What is then the role of the space-time surfaces? How do they contribute to conscious experience? The answer to this question should be based on quantum classical correspondence realized as the analog of AdS/CFT correspondence in TGD. The zero modes of space-time surfaces provide a dual classical representation of quantum states necessary to interpret quantum measurements. The space-time surface generates correlations between the 2-surfaces otherwise absent and could bind the experiences to a coherent whole. Here quantum gravitational quantum coherence could play crucial role as the model for bio-photons as decay products of dark photons suggests. Could it be that cognition builds the 4-D representation from the 2-D representation as theoretical physicist might argue?

Here the question about uniqueness of the holographic correspondence becomes important. In particular, in p-adic case this could give rise to additional degeneracy which might however have interpretation as gauge degeneracy.

Does cognition involve emotions?

It is a fact of neuroscience that emotions and information are closely related [J22]. I have considered two views trying to mathematisize this finding.

1. Emotions could correlate with the rates of change for the negentropies associated with various quantum number increments in quantum jump sequence determining self. It seems that it is not possible to classify emotions or qualia to real and p-adic ones: number theoretical universality holds true.

2. Emotions could also correlate directly with the negentropy of the entanglement. Negentropic sub-selves would define mental images with positively colored emotions and entropic ones those with negatively colored emotions.

A naïve view about three dichotomies

Beautiful/ugly, right/wrong, and true/false dichotomies relate to the comparison of experience with some standard. Beautiful/ugly relates to sensory experience, right/wrong characterizes deeds, and true/false logical statements. What comes in mind that these dichotomies could be interpreted as Boolean qualia assignable to quantum jumps in purely fermionic degrees of freedom. The first guess is that these dichotomies could reduce to negentropic/entropic dichotomy.

1. Right/wrong relates to intentional actions - deeds - and therefore to the first quantum jump to the opposite boundary of CD in which old sub-self disappears and new one is born. This dichotomy could be understood in terms of weak form of NMP allowing free will and possible quantum correlates for ethics and moral [K93]. Strong form NMP would state that the reduction is always such that negentropy gain is maximal: the final state sub-space has a dimension for which the negentropic entanglement gain is maximal. Weak form of NMP allows also to choose some sub-space of any eigen-space of density matrix. Weak NMP

can also allow in some situations larger negentropy gain than the strong form of NMP and explains the generalized p-adic length scale hypothesis. The higher the negentropy gain, the more right the choice would be.

2. Beautiful-ugly dichotomy relates to sensory experience and should accompany the sequence of state function reductions at the same boundary of CD giving rise to self. What is interesting that the weak form of NMP impies that for a *fixed* fermionic Fock basis there are $2^n - 1$ sub-spaces, which can be selected in the reduction if the eigen-space is n-dimensional. This corresponds to a Boolean algebra with the physically non-realizable element (having empty set as set theoretic counterpart) thrown away. Could this give an emotional realization of Boolean algebra so that various choices would each give rise to some negentropy gain allowing to order them with respect to negentropy. Could this correspond to the aesthetic dimension? How to map this representation to a fermionic representation. Could the n-sheets of the singular covering of the space-time surface for which both ends collapse to single 3-surface carry the fermions and negative energy antifermions at the ends?

3. One should explain also the true-false aspect. Fermionic Fock states define Boolean basis and one can decompose it to independent states and their conjugates. True statements should correspond to some preferred basis with preferred direction of say fermion spin defining quantization axis.

3.3.4 Replication Of Memes, And Morphic Fields

What are the counterparts of memes in TGD framework? The identification of memes as zero energy states assignable to string world sheets and partonic 2-surfaces is one possible identification at fundamental level but so general that it does not say much. At the space-time level the magnetic bodies assignable to physical systems are a very natural candidates. String world sheets and partonic 2-surfaces accompany them and define the intersection of reality and p-adicities. The original idea was that p-adic space-time sheets could correspond to memes but it seems that memes corresponds to an entire adelic structure for which sensory-cognitive representations reside in the intersection.

Replication of sensory-cognitive representations

Memes are in central role in the theory of Susan Blackmore [J69] and magnetic bodies are excellent candidates for the space-time correlates memes understood in a more general sense. The replication of memes would reduce to a replication of 3-surfaces occurring at partonic 2-vertices and would be completely analogous to what happens in 3-vertex of Feynman diagram. This replication would also induce ordinary biological replication as visible matter self-organizes around the replicas of the magnetic body. This leads to a new view about genetic code as something realized at the level of dark magnetic bodies and becoming visible via this self-organization [K33].

Contrary to the vision of Susan Blackmore, memes would be conscious selves rather than unconscious deterministically behaving objects, and brain would not be an un-conscious machine used by memes but serving as a vehicle making possible for meme replication.

Although the notions of the meme and meme replication are very attractive, the mechanism of imitation is only partially known. The so called mirror neutrons are certainly an important of it. Learning by imitation could be understood as a process in which a sensory-cognitive representation as in sensory perception is formed as particular magnetic body and then replicates.

Time reversed cognition and reverse speech

Time reversed cognition and reverse speech are interesting phenomena allowing possibility to test these ideas.

1. *Time reversed cognition*

Time reflection yields time reversed and spatially reflected sensory-cognitive representations. When mental image dies it is replaced with its time-reversal at opposite boundary of its CD. The observation of these representations could serve as a test of the theory.

There is indeed some evidence for this rather weird looking time and spatially reversed cognition.

1. I have a personal experience supporting the idea about time reversed cognition. During the last psychotic episodes of my "great experience" I was fighting to establish the normal direction of the experienced time flow. Could this mean that for some sub-CDs the standard arrow of time had reversed as some very high level mental images representing bodily me died and was re-incarnated?

2. The passive boundary of CD corresponds to static observing self - kind of background - and active boundary the dynamical - kind of figure. Figure-background division of mental image in this sense would change as sub-self dies and re-incarnates since figure and background change their roles. Figure-background illusion could be understood in this manner.

3. The occurrence of [J55] is a well known phemonenon [J55] (my younger daughter was a reverse writer). Spatial reflections of MEs are also possible and the arrow of geometric time might determine the direction in mirror writing.

4. Reverse speech would be also a possible form of reversed cognition. Time reversed speech has the same power spectrum as ordinary speech and the fact that it sounds usually gibberish means that phase information is crucial for storing the meaning of speech. Therefore the hypothesis is testable.

2. Reverse speech

Interestingly, the Australian David Oates claims that so called reverse speech is a real phenomenon [J13], and he has developed entire technology and therapy (and business) around this phenomenon. What is frustrating that it seems impossible to find comments of professional linguistics or neuro-scientists about the claims of Oates. I managed only to find comments by a person calling himself a skeptic believer but it became clear that the comments of this highly rhetoric and highly arrogant commentator did not contain any information. This skeptic even taught poor Mr. Oates in an aggressive tone that serious scientists are not so naïve that they would even consider the possibility of taking seriously what some Mr. Oates is saying. The development of science can often depend on ridiculously small things: in this case one should find a shielded place (no ridiculing skeptics around) to wind tape recorder backwards and spend few weeks or months to learn to recognize reverse speech if it really is there! Also computerized pattern recognition could be used to make speech recognition attempts objective since it is a well-known fact that brain does feature recognition by completing the data into something which is familiar.

The basic claims of Oates are following.

1. Reverse speech contains temporal mirror images of ordinary words and even metaphorical statements, that these words can be also identified from Fourier spectrum, that brain responds in unconscious manner to these words and that this response can be detected in EEG. Oates classifies these worlds to several categories. These claims could be tested and pity that no professional linguist nor neuroscientist (as suggested by web search) has not seen the trouble of finding whether the basic claims of Oates are correct or not.

2. Reverse speech is complementary communication mode to ordinary speech and gives rise to a unconscious (to us) communication mechanism making lying very difficult. If person consciously lies, the honest alter ego can tell the truth to a sub-self understanding the reverse speech. Reverse speech relies on metaphors and Oates claims that there is general vocabulary. Could this taken to suggest that reverse speech is communication of right brain whereas left brain uses ordinary speech? The notion of semitrance used to model bicameral mind suggests that reverse speech could be communication of higher levels of self hierarchy dispersed inside the ordinary speech. There are also other claims relating the therapy using reverse speech, which sound rather far-fetched but one should not confuse these claims to those which are directly testable.

Physically reverse speech corresponds to phase conjugate sound waves which together with their electromagnetic counterparts can be produced in laboratory [D2, D4]. Phase conjugate waves have rather weird properties due the fact that second law applies in a reversed direction of geometric time. For this reason phase conjugate waves are applied in error correction. TGD based description of both electromagnetic and sound wave phase conjugation is based on negative energy space-time sheets representing classically electromagnetic fields and Z^0 fields [K24].

Negative energy topological light rays are in a fundamental role in the TGD based model for living matter and brain. The basic mechanism of intentional action would rely on time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) utilizing the TGD counterparts of phase conjugate waves producing also the nerve pulse patterns generating ordinary speech. If the language regions of brain contain regions in which the the arrow of psychological time is not always the standard one, they would induce phase conjugates of the sound wave patterns associated with the ordinary speech and thus reverse speech.

ZEO based quantum measurement theory, which is behind the recent form of TGD inspired theory of consciousness, provides a rigorous basis for this picture. Negative energy signals can be assigned with sub-CDs representing selves with non-standard direction of geometric time and every time when mental image dies, a mental images with opposite arrow of time is generated. It would be not surprising if the reverse speech would be associated with these time reversed mental images.

A connection with the ideas of Sheldrake

In [K72, K44] I have discussed a possible TGD based justification of Sheldrake's ideas about learning at the level of species.

If one assumes that memes correspond to magnetic bodies, that the replication of memes by topological replication of magnetic bodies is possible [K44], and that MEs involved can have even sizes of order Earth size and are associated with cyclotron transitions at magnetic bodies, it is not too difficult to imagine how species memory could be realized. Magnetic bodies cold take the role of the morphic fields in TGD framework and represent habits, skills, ideas, ... Susan Blackmore would call these morphic fields memes but basically only a naming convention and generalization is in question (amusingly, skeptics regard Sheldrake as a pseudoscientist but Blackmore as a serious scientist, perhaps because she has emphasized her skepticism in the publicity!).

The meme associated with the development of a particular skill could be realized in a particular brain and replicate itself. When the magnetic replicas would encounter other brains of the same species, the skill could be manifested as a real action and lead to learning without direct sensory communication.

Sheldrake's theory thus generalizes memetics and would thus make Sheldrake pseudo scientist! Labels are dangerous: needless to add that certainly Blackmore has not been using them. That a given meme could be realized only in brains of the same species might be understood in this framework by using resonance argument: morphic resonance is the notion used by Sheldrake which could reduce to cyclotron resonance for dark photons with frequencies in say EEG range but energies in the range of bio-photons and therefore maximally bio-active. The precise cyclotron frequencies - that is precise values of magnetic fields associated with the parts of magnetic body- would characterize species and make possible resonant communication restricted within species.

It is also possible that stochastic resonance [D3] to be discussed later in more detail could be involved with the morphic resonance. The individuals that learned the habit first, need not even live anymore since c memes remain and replicate even when the physical body dies.

3.4 Frontal Lobes And TGD

Negentropic entanglement (NE) is possible and is stable against self measurement if NMP holds true. Even weak form of NMP is enough and strongly favoured. This very encouraging finding suggests that cognition involves the p-adic aspects in an essential manner. For instance, number theoretic entanglement entropy would make it possible to understand what it is to understand! To have an experience of understanding is to have a sub-self (cognitive mental image) with a positive entanglement negentropy.

Frontal lobes are regarded as seats of the highest mental functions such as cognition, intention, volition, attention, evaluation of actions, self model, and perception of and reaction to social situations. Long term memory and language are largely independent of frontal lobes whereas working memory can be located to the dorsolateral parts of prefrontal lobes. Thus the concrete model both the p-adic aspects of the physics of sensory experience, intention, and cognition might boil down to a model of frontal lobe function. Of course, also the notions of field body and magnetic body are needed to understand the highest levels of the control. In particular, social control could be performed basically by the multi-brained collective selves by activation of social habit routines as suggested by the fact that the persons who have lost these routines are able to deduce the correct social behaviour.

3.4.1 Basic Functional Anatomy Of Frontal Lobes

Frontal lobes involve the most complex association networks of brain. In fact so complex, that the diagnostics based on simple reflex schema and the idea about exact locations of mental functions applied to subjects having serious frontal lobe damage suggested that frontal lobes have no function at all! Only a view in which brain is regarded as self-regulating and self-organizing system allowed to develop diagnostic tools revealing the effects of frontal lobe damage.

Dorsolateral frontal lobes seem to be specialized with various aspects of cognition such as problem solving, judgement, reasoning, and discrimination. In particular, what is identified usually as working memory is located here. These areas are also involved with imagination and corresponding loops extend to sensory areas. In TGD framework dreams can be seen as a particular kind of imagination in which imagined sensory features are mapped to the magnetic sensory canvas.

The medial and ventral frontal lobes are involved with intention, planning, volition, and attention. These regions are also crucial for the routine perception of and reaction to social situations. Affect and motivation are crucial concepts here and the complex circuits connecting frontal lobes, amygdala/brain stem and cortex are essential for planning and decision making. Salience detection or rather, selective amplification of those aspects of percepts which are significant seems to be basic function of these loops. The lesion for these loops implies effective loss of volition as well as emotional flatness.

Phineas P. Gage is a classic example of a person with serious damage for the circuits. He did not lose either his intellectual abilities nor memory but lost the ability of planning and the access the previously acquired social conventions and rules, and became childish and irresponsible. Gage was also well aware that he did was not anymore able to react emotionally. Gage was also able to use to theoretically deduce what would be the appropriate behaviour in social situations but in everyday life this was impossible.

These findings suggest that frontal lobes perform high level control and habit routines are the basic tools of cognition and planning, and that frontal lobes both active, generate, modify and replace these habit routines by new ones. Using brain as computer metaphor one might say that working memory provides the initial values of the parameters of the habit routines.

3.4.2 Some Neurophysiological Findings Related To The Functioning Of Frontal Lobes

The notion of cortical tone characterizes the state of cortex and is maintained by CNS. In so called inhibitory phase state the tone is low and brain responds with similar response to both strong and weak stimuli. This phase is also called equalization phase. In paradoxal phase weak stimuli can give rise to strong responses and vice versa. In this state no organized thought appears and selective associations are replaced by non-selective and more or less random associations. REM sleep is regarded as an example of paradoxal phase. The interaction between medial frontal lobes, reticular activating system and cortex controls the cortical tone.

Gray Walter found that any expectation elicits characteristic slow waves emanating from frontal lobes and spreading to other regions. Expectancy wave diminishes if the probability of expected signal diminishes. When the instruction that elicited the expectation states is negated, the wave ceases. Similar wave phenomenon is detected during concentration, say during an attempt to solve a complex mathematical problem. The interpretation as a correlate for binding by quantum entanglement suggests itself.

Orienting reaction is a vegetative and electrophysiological reaction to stimulus. Constriction of the vascular system to the arms, dilation of the vascular system to the head, galvanic skin changes and alpha wave amplitude reduction are involved. Habituation to the stimulus reduces orienting reaction. Orienting reaction can be however increased and stabilized by verbal instruction that links meaning to the stimulus. If frontal lobe lesion affects attention, the orienting reaction fails to be stabilized by this mechanism. The interpretation is that for polar, medial and mediobasal section of the frontal lobe, the physiological tools for the regulation of attention are deranged.

3.4.3 TGD Based View About Frontal Lobes

The TGD based model for how frontal lobes cognize forces some new interpretations of classic experiments. Also a new view about working memory is unavoidable.

Paper, pencil, and eraser metaphor

The inability to modify existing routines or replace them with new ones rather than loss of these routines seems to accompany the lesions of ventromedial frontal lobes. Or more precisely, new routines can be acquired but instantaneous replacement of active routines with new ones is not possible. In a classic experiment already performed by Pavlovian school a person having a frontal lobe lesion in the ventromedial area started to plane a plank and continued until there was no plank anymore and continued to plane of the bench. In the so called Wisconsin card sorting test the subject is presented with a series of stimulus cards and a deck of response cards. The cards bear coloured geometric patterns and can be matched by categories such as colour, form or number. The experimenter selects category but does not inform subject person who guesses rapidly the category by trial and error. After ten cards experimenter changes the category without informing the subject person about the change. Patient is not able to revise his strategy and continues to make wrong guesses.

These persons can adopt strategy but cannot change it. This is something very essential. The proposed interpretation is however that these persons do not have motor imagination and therefore cannot construct new habit routine. This seems to be wrong since in the beginning card experiment the subject was able to achieve this. Something more delicate is involved: patient is not able to replace an activated strategy with a new one instantaneously The activated strategy however becomes deactivated spontaneously sooner or later.

This leads to pencil, paper, and eraser metaphor as a model for what frontal lobes are doing. Creation of habit routines is creation of symbolic representations and frontal lobes both create and erase habit routines just as we do when we do our calculations or type text to computer file. The patient with dorsolateral frontal lobe lesion must wait until the erasure happens spontaneously to establish a new habit routine. Of course, sticking into habit routines seems to a part of human condition, in particular at the old age.

Interestingly, during psychedelic experiences frontal lobes are very active. Habit routines are what one gets rid in these experiences and also during meditation. The interpretation would thus be that a very intense erasure of old and generation of new habit routines is going on.

Working memory quantum mechanically

The notion of working memory does not seem to be an appropriate concept in TGD framework. The proper interpretation seems to be as erasure and replacement mechanism for habit routines. Short term geometric and subjective memories are automatic side products. Mirror mechanism is also now the natural mechanism for geometric memories but one cannot exclude the interpretation of working memory as subjective memory. Note that it does not make sense to construct long term memory representations of all intermediate stages of habit routine construction (just as it does not make sense to publish all intermediate and often erratic stages of a long mathematical calculation).

Erasure and replacement mechanism corresponds in spin glass metaphor to the kicking of the system out from the bottom of a potential well. In quantum framework this means a formation of a de-localized state in zero modes followed by a localization to the bottom of some other potential well representing the new habit routine. Delocalized states in zero modes are however not possible. Rather, a generation of a bound state implying a temporary transformation of the zero modes in question to quantum fluctuating macroscopic quantum degrees of freedom is required. This is the TGD counterpart of Penrose-Hameroff mechanism. State of oneness, quantum computing macro-temporally quantum coherent system, moment of consciousness effectively lasting very many quantum jumps: all these characterizations apply to the resulting state.

The creation of new habit routine might even mean the changing synaptic connections. This would mean a multiverse state of multineuron system with different synaptic strengths such that one of these states is selected when the bound state decays. Interestingly, it is known that the synaptic connections related to the somatosensory representations of rat's whiskers change in an incredibly short millisecond time scale. The explanation as a macroscopic quantum effect strongly suggests itself.

Also quantum superposition of entangled axons with varying membrane potentials near axonal hillock and thus with a varying firing probability could be considered. Also the ends of axons might be in entangled quantum superposition: Ca^{++} waves and sol-gel transition might be involved.

Cognitive quantum computation like processes at neurolevel

If one assumes that an eigenstate of the density matrix or of the negentropy operator results in self measurement, the system must end up to an entangled state corresponding to some eigenspace of the density matrix. The requirement that the increase of entanglement negentropy is maximal, fixes this eigenspace uniquely. For the resulting state density matrix is proportional to unit matrix and entanglement negentropy is maximal $N_R = Nlog(p)$, when the number of states is $n = p^N n_0$, n_0 not divisible by p, $N > 0$: otherwise it vanishes. Quantum computers indeed operate with systems for which entanglement probabilities are identical. A very strong prediction is that the dimension of the state space should be divisible by p^N.

A possible neurolevel realization of a cognitive quantum computation is following.

1. Information is represented as a sequence of p-adic and real memetic qupits along axon. If the effective phase velocity ofME is sufficiently low quite high number of qupits can be realized as already found. Incoming p-adic and real memetic codewords can be taken to be identical un-entangled sequences of p-adic and real memetic codewords. The unitary time development is discrete with a time step of 1/1270 seconds and lasts an integer multiple of $T_2(127) = .1$ seconds (127 steps). Thus the minimal quantum computation involves $2^{127} - 1$ quantum jumps effectively glued to a single quantum jump by macro-temporal quantum coherence. The outcome of the cognitive self-measurement is a pair of memetic codewords representing the initial memetic codeword and the result of the cognitive quantum computation.

2. A conscious experience results, when the spin directions of the real oddball qubits flip to the direction of the external magnetic field at the cell membrane space-time sheet. The spatial sequences of qubits in the direction of the magnetic field are excluded because these states do not give rise to any spin flips. In this manner a quantum computer with $p = 2^{127} - 1$ results. The spin flips of the real qubits induce MEs which in turn induce membrane oscillations and perhaps even nerve pulses.

3.4.4 Goal Structures And Emotions

Daniel Pouzzner has proposed quite an interesting theory of emotions relating most emotions to cognitive models and goal structures [L32]. Goal structures are also cognitive models assumed to have correlates at the level of neurophysiology.

Quite many emotions originate basically from comparisons of expectations or goals with reality and Pouzzner's model of emotions relates emotions to the dynamics of the goal structure. The failure to reach a goal or giving up a goal is accompanied by a disappointment or sadness; realization of a goal is accompanied by a feeling of success; fear or rage is experienced when the achievement of a goal is threatened. The failure of a model is accompanied by a surprise; the success of a model, which has been questioned by experience involves a feeling of relief; etc..

There are of course exceptions: for instance, physical pain and pleasure, excitement, love and perhaps also pure rage without any object. The basic question is whether the comparison type emotion accompanies inherently comparison or whether emotions as such have nothing to do with comparisons and brain has only evolved to associated emotions to comparison results to guide the behaviour. In the model of Pouzzner the latter view is adopted and various neurotransmitters are identified as correlates of emotions. The problem is to understand how cognitive models and goals could be represented in real physics.

In TGD framework negative emotions relate to the increase of the entropies associated with various quantum number and zero mode increments defining qualia and are automatically generated in state function reductions in which sub-self representing mental image dies and re-incarnates at opposite boundary of CD. Contrary to the original believes one cannot assign emotions to any specific number field since they are number theoretically universal. Positively colored emotions relate to the increasing negentropies. The formation of negentropic generating sub-selves are obviously excellent candidates for quantum correlates of positive emotions. The challenge is two-fold.

1. Construct a concrete model for intentions and goal structures analogous to the model of long term memories. In fact, the two structures might differ only by time orientation and be represented by the active boundary of CD whereas the passive boundary would represent the self, kind of background to a figure.

2. Develop a model for the comparison process explaining why a quantum coherent sub-self results if the mental images about the predicted and actual states of the world are nearly identical and de-cohering sub-self results if these mental images are too different. Fractality of TGD Universe basically to quantum criticality allows to have scaled variants of sub-selves. The intelligent system must be able build scaled variants of its sub-selves having basically similar goal structures, and test statistically the average outcome of reduction to the opposite boundary from them. If the outcome of the real reduction is very different from that for the simulated reduction in shorter time scale, the outcome is disappointment or joy. In the simplest situation the goal is to yield negentropy and in this case the comparison between predicted and real events is simple.

A model of goal structures

The models for geometric memories and intentions should be very symmetrical the basic difference being that geometric past is replaced with the geometric future in the model for intentions: intentions are memories about geometric future in very precise sense. The new elements of the model are due to ZEO based notion of self. The static background contribution to self consciousness comes from the passive boundary of CD and the rest - such as intentions and memories - comes from the changing active boundary of CD.

Intention does not have p-adic space-time sheet as its correlate as the original idea went but something assignable to the evolution of sub-self by repeated state function reductions at passive boundary and involves both emotional and cognitive (real and p-adic) aspects. NMP forces the state function reduction to the opposite boundary to occur eventually and NMP must in some sense force the development of intention. Weak form of NMP however allows free choice. The one who chooses is the higher level self possessing the sub-self for which the state function reduction to opposite boundary occurs. We are gods of our mental images.

1. The content of intention or goal corresponds to the second member for the pair formed by the positive and negative energy parts of the zero energy state. Intentions and goals might also involve time like NE between the opposite boundaries of CD say that between the brain of the geometric now with the brain of the geometric future: in this case the intention involves abstraction. Whether the time like NE is necessary aspect of intention is not clear. NE between opposite boundaries of CD is would reflect finite measurement resolution and the degeneracy would be related to quantum criticality. M-matrix defined as a product of square root of S-matrix and real diagonal density matrix decomposing to a sum projection operators of various dimensions multiplied by real numbers would realize time-like NE.

2. It should be possible to speak about intention fields as analogs of perceptive fields and memory fields - characterizing various brain cells according to how long is the temporal distance T to the event of the geometric future representing the intention. The cells corresponding to the highest values of T should be found in frontal lobes. The value of T would correlate with quantum criticality and the value of $h_{eff} = n \times h$ and would be highest for frontal lobes defining kind of intelligence quotient. Large h_{eff} means that the size of the super-symplectic algebra represented as gauge symmetries is smaller so that the resolution of sensory and cognitive experience is better. It would seem that large value of h_{eff} must be assigned with the magnetic bodies of the cells, rather than cells and could be achieved by a large number of "deaths" and re-incarnations for the self assignable to he magnetic body.

In TGD cognitions and intentions should appear also at brain level and have definite correlates. A good guess is that cognitive representations are realized using memetic code in terms of MEs (of course, also em MEs might be involved). The model of music harmony and of genetic code provides a very concrete realization of this idea [K65].

How comparison type emotions could result?

What is needed is a concrete model for the comparison proces? One must answer several subquestions. What characterizes typical goals? What comparison means? What generates the positive or negative emotion in the comparison process? What is the fundamental quantum correlate of emotional coloring?

The challenge is to understand how comparison type emotions could result from the comparison of a sensory-cognitive model of reality with the reality. The model could be for a sub-self representing goal or ensemble of sub-selves representing scaled down variants of the sub-self. Fundamental goal helps self to say alive. Hence the death of goal sub-self must generate maximal negentropy gain to make NMP happy. Primary goal is expected to be such that its realization by a state function reduction at opposite boundary generates maximal negentropy gain meaning that it gives for self good changes to continue before the fatal state function reduction forced eventually by NMP, who wants NE by any means. There are also secondary goals formulated as concrete outcomes of state function reduction. There are hopes to achieve this if the achieved goal corresponds to a large negentropy gain.

1. The the mental image representing is sub-self whereas the prediction of the model is represented by scaled down variants sub-selves in shorter time scales. p-Adic length scale hierarchy and hierarchy of Planck constants allow to realize the scaling. Contrary to the original expectations p-adic space-time sheets are not in special role although they are essential part in adelic picture.

2. The members of the modelling ensemble of sub-selves are born and die and generate some average negentropy. If this average negentropy is large, there are good hopes that the goal assigned with sub-self can be realized. If this is not the case, self can modify the sub-self representing the goal to make it more realistic. Eventually the goal sub-self dies and generates the attempt to realize the goal. It the negentropy gain is smaller than expected, disappointment results. If its is higher, self has reasons to be happy. A more precise comparison would require a more precise characterization of the contents of goal.

3.4.5 Figure-Background Rivalry

The classical demonstration of figure-background rivalry (`http://tinyurl.com/y7nojvey`) is a pattern experienced either as a vase or two opposite faces. This phenomenon is not the same thing as bi-ocular rivalry in which the percepts associated with left and right eyes produced by different sensory inputs are rivalling. This phenomenon is not the same thing as bi-ocular rivalry in which the percepts associated with left and right eyes produced by different sensory inputs are rivalling. There is also an illusion in which one perceives the dancer to make a pirouette in either counter-clockwise or clockwise direction although the figure is static. The direction of pirouette can change. In this case time-reversal would naturally change the direction of rotation.

Figure-background rivalry gives a direct support for the TGD based of self relying on ZEO if the following argument is accepted.

1. In ZEO the state function reduction to the opposite boundary of CD means the death of the sensory mental image and birth of new one, possibly the rivalling mental image. During the sequence of state function reductions to the passive boundary of CD defining the mental image a boundary quantum superposition of rivalling mental images associated with the active boundary of CD is generated.

   In the state function reduction to the opposite boundary the previous mental image dies and is replaced with new one. In the case of bin-ocular rivalry this might be the either of the sensory mental images generated by the sensory inputs to eyes. This might happen also now but also different interpretation is possible.

2. The basic questions concern the time reversed mental image. Does the subject person as a higher level self experience also the time reversed sensory mental image as sensory mental image as one might expect. If so, how the time reversed mental image differs from the mental image? Passive boundary of CD define quite generally the background - the static observer - and active boundary the figure so that their roles should change in the reduction to the opposite boundary. In sensory rivalry situation this happens at least in the example considered (vase and two faces).

   I have also identified motor action as time reversal of sensory percept. What this identification could mean in the case of sensory percepts? Could sensory and motor be interpreted as an exchange of experiencer (or sub-self) and environment as figure and background?

If this interpretation is correct, figure-background rivalry would tell something very important about consciousness and would also support ZEO. Time reversal would permute figure and background. This might happen at very abstract level. Even subjective-objective duality and first - and third person aspects of conscious experience might relate to the time reversal of mental images. In near death experiences person sees himself as an outsider: could this be interpreted as the change of the roles of figure and background identified as first and third person perspectives? Could the first moments of the next life be seeing the world from the third person perspective?

An interesting question is whether right- and left hemispheres tend to have opposite directions of geometric time. This would make possible metabolic energy transfer between them making possible kind of flip-flop mechanism. The time-reversed hemisphere would receive negative energy serving as metabolic energy resource for it and the hemisphere sending negative energy would get in this manner positive metabolic energy. Deeper interpretation would be in terms of periodic transfer of negentropic entanglement. This would also mean that hemispheres would provide two views about the world in which figure and background would be permuted.

A further interesting question relates to near death experiences (NDEs). In biological death the roles of boundaries of CD are changed and figure becomes background and vice versa. This could also mean that third person perspective becomes first person perspective and vice versa. In NDEs one indeed sees ones's own body from outside. Could this mean that in the beginning of reincarnation third person perspective dominates. One can go even further and ask whether the habit of children to talk about themselves as third person could relate to the dominance of third person perspective.

Quantum TGD brings in also other new elements.

1. In the conceptual framework of the standard quantum mechanics there is no known mechanism making possible macroscopic quantum coherence in the time scales involved. If dark matter with large h_{eff} is involved with the formation of conscious percept there is no problem in understanding the time scales in question. Actually a hierarchy of rivalries of various kinds in various time scales is predicted corresponding to the p-adic time scale hierarchy and hierarchy of Planck constants.

2. Another ingredient which is new from the point of view of standard quantum mechanics is that the hierarchy of Planck constants implies self hierarchy. The fractal structure of state function reduction process means that it is possible have macroscopic quantum behavior in given time scale but dissipative self-organization in shorter time scales.

   This is actually not new: in hadron physics hadrons are described as quantum systems whereas parton dynamics in the shorter time scales is assumed to be dissipative. In the recent case this means the possibility of quantum superposition of dissipative self-organization processes involved with the formation of neuronal correlates of percepts and proceeding in time scales of order milliseconds considerably shorter than the time scale of binocular rivalry.

3.4.6 Experimental Support For Binocular Rivalry As A Quantum Phenomenon

For years ago I constructed a quantum model for binocular rivalry and generalized it to a general model of volitional act as a quantum jump selecting not only between alternative motor actions but also between percepts. In this model different alternatives were represented as superpositions of neural firing patterns. The model allows to see sensory perception as an active volitional process (at some level of hierarchy of selves) and explains sensory rivalry as a quantum phenomenon.

The work of Efstratios Manaosakis

I learned from New Scientist [J77] that physicist Efstratios Manousakis has now published an interesting work [J29] about binocular rivalry providing experimental support for this model.

Recall that the classical demonstration of binocular rivalry [J3] is using different sensory inputs to left and right eye: figures can have different color or shape or be just different. Subject person does not see a superposition of figures but either or them. The two percepts alternate with some frequency and it is not possible to consciously experience both patterns simultaneously. This has led Manousakis to consider the idea that binocular rivalry could provide direct evidence for the notion of quantum consciousness. The obvious idea is that either of the percepts results by a state function reduction from the superposition of both percepts. As already explained this phenomenon need not have anything to do with figure-background rivalry.

The model predicts that the flip rate correlates with neuronal firing rate. The prediction is confirmed by using as subjects persons who have a reduced firing rate due to the use of LSD. The work of Manousakis might turn out to be an important step of progress in the development of theories of quantum consciousness and might help also main stream physicists to get rid of their atavistic fears relating quantum consciousness.

Justification for the model in TGD framework

TGD based model for rivalry and its generalization

The TGD based quantum model for binocular rivalry relies on the idea that the formation of quantum superposition of competing percepts is somewhat analogous to quantum computing in which large number of quantum parallel computations are carried out and one computation is selected as the computation halts. TGD however brings in also some new elements.

1. In ZEO the state function reduction in question means the death of the sensory mental image and birth of new one, possibly the rivalling mental image. During the sequence of state function reductions to the passive boundary of CD defining the mental image a boundary quantum superposition of rivalling mental images associated with the active boundary of CD is generated. In the state function reduction to the opposite boundary the previous mental image dies and is replaced with itself or with rivalling mental images and is assignable to the opposite boundary.

2. One could think that the two percepts correspond to two different quantum stats at active boundary of CD: the attention of self is directed to either left or right sensory input and superposition of these states is possible at active boundary of CD whereas at passive boundary either one is selected. This would make possible considerable metabolic economy since metabolic costs would be halved.

   The proposal for the space-time correlate of directed attention is flux tubes connecting the perceiver and perceived and involving resonant transfer of dark cyclotron photons. Different configurations of connecting and active flux tubes would serve as a concrete correlate for left and right-attention.

3. As proposed the opposite boundaries of CD would naturally correspond to figure and background. What could this mean in the case of sensory mental images in the case of bin-ocular rivalry?

The formation of quantum superposition of right and left percepts has evolutionary advantages which suggest also a generalization to a model of volitional action as a selection between neural firing patterns leading to alternative motor actions. As a matter fact, in ZEO motor actions and sensory percepts as mental images are time reversals of each other so that the suggestion is a prediction of ZEO.

1. The formation of superposition would be metabolically advantageous. In the classical world one should form both right and left percept simultaneously. The associated self-organization process requires a metabolic energy feed. When only single brain hemisphere forms the percept and one has quantum superposition of right and left percepts metabolic energy feed is reduced by factor 1/2. A highly synchronous neural firing distinguishes the perceived stimulus from non-perceived so that a quantum superposition of patterns of two neural firing patterns would be in question.

2. This picture leads naturally to a proposal that one function of sleep is to make possible quantum superposition of large number of neural firing patterns via quantum entanglement with external systems (perhaps other sleeping brains) so that sleep would be a process analogous to quantum computation.

3. The formation of alternative percepts would have an obvious evolutionary advantage in a situation in which several percepts are consistent with the sensory input. For instance, bipolar mood disorders seem to involve sticking of consciousness to either hemisphere. This generalizes also to cognition: of course, percepts actually consist of sensory input plus cognition.

4. This framework is behind TGD based model of volitional action applying to both motor actions and selection of sensory percepts. For a brain living in jungle it would be highly advantageous to develop in a difficult situation a quantum superposition of alternative motor actions and select the proper one only at the eleventh moment.

5. Sensory rivalry is analogous to an ability to move fluently between - say - skeptic and new age views about world. There is also a parallel at the level of society and in TGD framework the rivalry of various views (religions, political parties, competing scientific theories, ...) might perhaps be seen as counterpart of binocular rivalry at the level of collective consciousness. The complete dominance of only single view - be it religious or materialistic world view, market economy or communism, or super-string model or loop quantum gravity - would be something comparable to a bimodal mood disorder.

Alternative TGD based model for binocular rivalry

Science Alert reported an interesting result from neuroscience. The title of the popular article was"A New Brain Experiment Just Got Closer to The Origins of Consciousness" (see `http://tinyurl.com/y9n9mbjm`). The original article "Human single neuron activity precedes emergence of conscious perception" is published in Nature [J32] (see `http://tinyurl.com/y7rhklsr`).

The researchers in Tel Aviv University studied people suffering from epilepsy: the epilepsy as such is however not relevant for the research interests. During more than 20 sessions the volunteers stared at a pair of images. Each image was located in front of one eye. Because each eye saw only one image, the brains couldn't fuse the images into single picture. Instead, the brain choose one image to deal with at a time. This process is known as binocular rivalry. The article claims that this process allows to separate visual stimulation and conscious seeing for each other. I would however argue that the outcome of the experiment relates to binocular rivalry rather than generation of conscious percept itself.

The finding was that medial-frontal lobe becomes active two seconds before the subject sees the picture. A second zone becomes active second later in medial-temporal lobe (that is 1 second before the conscious visual percept). These time scales are rather long as compared to time scale of 0.08-.1 seconds associated with sensory mental images - one might call this time scale a duration of sensory chronon.

As article explains, these experiments differ from the usual experiments studying the behavior of medio-temporal neurons in response to various modifications of the sensory input (flashing a different image to the other eye; backward masking, in which a briefly presented image is suppressed by the immediate presentation of a mask image; and the attentional blink, in which the second of two target stimuli appearing in close succession is often not perceived). Also these experiments study what happens at brain level as the visual percept changes but the change is now induced externally rather than internally as in binocular rivalry. The response of MTL neurons started about .2-.3 seconds after the external manipulation. There was no activation before the change.

If I understood correctly, the interpretation of the finding was based on computational paradigm. According to this interpretation it takes about 2 seconds to compute the new visual percept when the decision about new percept is made. One might however argue that this computation should take 2 seconds also in the case of externally induced change of percept. Actually the time for the emergence of the percept is .2-.3 seconds and there was no activation before the change.

In TGD framework this longer time scale would naturally correspond to a higher level in self hierarchy. In self hierarchy mental images correspond to sub-selves and self is sub-self of self at the higher level of the hierarchy. Each level is characterized by time scale and the higher the level in the hierarchy, the longer the time scale.

1. Could a higher level self direct its attention to alternative percepts in bio-ocular rivalry in more or less random manner? Could this re-directing of attention be seen as a motor action at some level of self hierarchy? This is the case when I turn my gaze from one object of the perceptive field to another one.

2. In TGD picture motor based on zero energy ontology (ZEO) [L29] motor actions are identified as sensory percepts in opposite time direction: a signal is sent to geometric past and initiates neural processing leading to the motor action. This explains Libet's finding that motor action is preceded by a neural activity beginning a fraction of second before the conscious decision about motor action. Could the situation be the same now except that the time scale would be now longer? The longer time scale would suggest that the decision maker is not "me" characterized by a fraction of second time scale but some higher level in the hierarchy of selves associated with my biological and magnetic body.

3.4.7 Quantum Cognition

The talks in the conference Towards Science of Consciousness 2015 held in Helsinki produced several pleasant surprises, which stimulated more precise views about TGD inspired theory of consciousness. Some of the pleasant surprises were related to quantum cognition. It is a pity that I lost most of the opening talk of Harald Atmanspacher (`http://tinyurl.com/pvb36jq`).

The general idea is to look whether one could take the formalism of quantum theory and look whether it might allow to construct testable formal models of cognition. Quantum superposition, entanglement, and non-commutativity, are the most obvious notions to be considered. The problems related to quantum measurement are however present also now and relate to the basic questions about consciousness.

1. For instance, non-commutativity of observables could relate to the order effects in cognitive measurements. Also the failure of classical probability to which Bell inequalities relate could have testable quantum cognitive counterpart. This requires that one should be able to speak about the analogs of quantization axis for spin in cognition. Representation of Boolean logic statements as tensor product of qubits would resolve the problem and in TGD framework fermionic Fock state basis defines a Boolean algebra: fermions would be interpretation as quantum correlates of Boolean cognition.

2. The idea about cognitive entanglement described by density matrix was considered and the change of the state basis was suggested to have interpretation as a change of perspective.

Here I was a little bit puzzled since the speakers seemed to assume that density matrix rather than only its eigenvalues has an independent meaning. This probably reflects my own assumption that density matrix is always assignable to a system and its complement regarded as subsystems of large system in pure state. The states are purifiable - as one says. This holds true in TGD but not in the general case.

3. The possibility that quantum approach might allow to describe this breaking of uniqueness in terms of entanglement - or more precisely in terms of density matrix, which in TGD framework can be diagonalized and in cognitive state function reduction reduces in the generic case to a 1-D density matrix for one of the meanings. The situation would resemble that in hemispheric rivalry or for illusions in which two percepts appear as alternatives. One must be of course very cautious with this kind of models: the spoken and written language do not obey strict rules. I must however admit that I failed to get the gist of the arguments completely.

One particular application discussed in the conference was to a problem of linguistics.

1. One builds composite words from simpler ones. The proposed rule in classical linguistics is that the composites are describable as unique functions of the building bricks. The building brick words can however have several meanings and meaning is fixed only after one tells to which category the concept to which the world refers belongs. Therefore also the composite word can have several meanings.

2. If the words have several meanings, they belong to at least $n = 2$ two categories. The category associated with the word is like spin $n = 2$ and one can formally treat the words as spins, kind of cognitive qubits. The category-word pairs - cognitive spins- serve building bricks for 2 composite worlds analogous to two-spin systems.

3. A possible connection with Bell's inequalities emerges from the idea that if word can belong to two categories it can be regarded as analogous to spin with two values. If superpositions of same word with different meanings make sense, the analogs for the choice of spin quantization axis and measurement of spin in particular quantization direction make sense. A weaker condition is that the superpositions make sense only for the representations of the words. In TGD framework the representations would be in terms of fermionic Fock states defining quantum Boolean algebra.

   (a) Consider first a situation in which one has two spin measurement apparatus A and B with given spin quantization axis and A′ and B′ with different spin quantization axis. One can construct correlation functions for the products of spins s_1 and s_2 defined as outcomes of measurements A and A′ and s_3 and s_4 defined as outcomes of B and B′. One obtains pairs 13, 14, 23, 24.

   (b) Bell inequalities give a criterion for the possibility to model the system classically. One begins from 4 CHSH inequalities (`http://tinyurl.com/y6ua44dk`) follow as averages of inequalities holding for individual measurement always (example: $-2 \leq s_1s_3 + s_1s_4 + s_2s_3 - s_2s_4 \leq 2$) outcomes by *assuming* classical probability concept implying that the probability distributions for s_is_j are simply marginal distributions for a probability distribution $P(s_1, 2_2, s_3, s_4)$. CHSH inequalities are necessary conditions for the classical behavior. Fine's theorem (`http://tinyurl.com/y8c8r22s`) states that these conditions are also sufficient. Bell inequalities follow from these and can be broken for quantum probabilities.

   (c) Does this make sense in the case of cognitive spins? Are superpositions of meanings really possible? Are conscious meanings really analogous to Schrödinger cats? Or should one distinguish between meaning and cognitive representation? Experienced meanings are conscious experiences and consciousness identified as state function reduction makes the world look classical in standard quantum measurement theory. I allow the reader to decide but represent TGD view below.

What about quantum cognition in TGD framework? Does the notion of cognitive spin make sense? Do the notions of cognitive entanglement and cognitive measurement have sensible meaning? Does the superposition of meanings of words make sense or does it make sense for representations only?

1. In TGD quantum measurement is measurement of density matrix defining the universal observable leading to its eigenstate (or eigen space when NE is present in final state) meaning that degenerate eigenvalues of the density matrix are allowed). In the generic case the state basis is unique as eigenstates basis of density matrix and cognitive measurement leads to a classical state.

   If the density matrix has degenerate eigenvalues situation changes since state function can take place to a sub-space instead of a ray of the state space. In this sub-space there is no preferred basis. Maybe "enlightened" states of consciousness could be identified as this kind of states carrying negentropy (number theoretic Shannon entropy is negative for them and these states are fundamental for TGD inspired theory of consciousness. Note that p-adic negentropy is well-defined also for rational (or even algebraic) entanglement probabilities but the condition that quantum measurement leads to an eigenstate of density matrix allows only projector as a density matrix for the outcome of the state function reduction. In any case, in TGD Universe the outcome of quantum measurement could be enlightened Schrödinger cat which is as much dead as olive.

   Entangled states could represent concepts or rules as superpositions of their instances consisting of pairs of states. For NE generated in state function reduction density matrix would be a projector so that these pairs would appear with identical probabilities. The entanglement matrix would be unitary. This is interesting since unitary entanglement appears also in quantum computation. One can consider also the representation of associations in terms of entanglement - possibly negentropic one.

2. Mathematician inside me is impatiently raising his hand: it clearly wants to add something. 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 unitary entanglement 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.

3. Can one really have superposition of meanings in TGD framework where Boolean cognitive spin is represented as fermion number (1,0), spin, or weak isospin in TGD, and fermion Fock state basis defines quantum Boolean algebra.

   In the case of fermion number the superselection rule demanding that state is eigenstate of fermion number implies that cognitive spin has unique quantization axis.

For the weak isopin symmetry breaking occurs and superpositions of states with different em charges (weak isospins) are not possible. Remarkably, the condition that spinor modes have a well-defined em charge implies in the generic case their localization to string world sheets at which classical W fields carrying em charge vanish. This is essential also for the strong form of holography, and one can say that cognitive representations are 2-dimensional and cognition resides at string world sheets and their intersections with partonic 2-surfaces. Electroweak quantum cognitive spin would have a unique quantization axes?

But what about ordinary spin? Does the presence of Kähle magnetic field at flux tubes select a unique quantization direction for cognitive spin as ordinary spin so that it is not possible to experience superposition of meanings? Or could the rotational invariance of meaning mean SU(2) gauge invariance allowing to rotate given spin to a fixed direction by performing SU(2) gauge transformation affecting the gauge potential?

4. A rather concrete linguistic analogy from TGD inspired biology relates to the representation of DNA, mRNA, amino-acids, and even tRNA in terms of dark proton triplets. One can decompose ordinary genetic codons to letters but dark genetic codons represented by entangled states of 3 linearly order quarks and do not allow reduction to sequence of letters. It is interesting that some eastern written languages have words as basic symbols whereas western written languages tend to have as basic units letters having no meaning as such. Could Eastern cognition and languages be more holistic in this rather concrete sense?

3.5 P-Adic Cognition And Various Codes

I learned from Tidjani Negadi about some new ideas related to the attempt to understand the basic numbers of the genetic code [A24]. Some of these ideas stimulated some speculations about genetic code and its relationship to cognition and led to a discovery of two number theoretical miracles related to the realization of cognition at DNA and protein level. I have done a lot of work with genetic code [K32, K2, K92, K65] and the ideas below correspond to arelatively old layer in this work.

3.5.1 Symmetry Breaking Generates Conscious Information

What is very attractive in Negadi's approach is the interpretation of the reduction of the entropy in the symmetry breaking as information [A23]. This kind of a philosophy fits nicely with the general TGD based view about the generation of the macro-temporal quantum coherence and hierarchy of quantum criticalities and super-symplectic symmetry breakings as a source of negentropic entanglement and correlate for evolution.

The recent vision about fractal hierarchy of quantum criticalities brings the breaking of super-symplectic symmetries as gauge symmetries central element of evolution. The phase transitions reducing the sub-algebra of this algebra acting as gauge symmetries occur spontaneously and generate negentropic entanglement if weak form of NMP is accepted as the basic variational principle. The sub-algebras are characterized by an integer n telling that the conformal weights for its generators are n-ples of those for the full algebra isomorphic to the sub-algebra. A very detailed view reducing evolution to the hierarchy of algebraic extensions of rationals defining in turn those of p-adic numbers emerges from this picture. Preferred p-adic primes can be identified as so called ramified primes of the algebraic extension of rationals and also the generalization of p-adic length scale hypothesis emerges from the weak form of NMP.

In strong form of holography 2-surfaces are algebraically continued to preferred extremals. 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 [K52]. 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.

What this picture implies at space-time level is yet an open question. Certainly the representations of Galois groups are important but are realized rather abstractly at the level of conformal invariants parameterizing string world sheets and partonic 2-surfaces rather than space-time surfaces. The discretization is at the level of this space and means that common points ore reality and p-adicities are at the level of parameter space.

Co-dimension 2 rule holds true for the discretization. Space-time is discretized in terms of string world sheets and partonic 2-surfaces (this is just strong form of holography implied by strong form of General Coordinate Invariance). Partonic 2-surfaces are discretized as discrete sets of points common the real and p-adic variants of the partonic 2-surface belonging to the algebraic extension of rationals in question. This means also discretization at space-time level and one might hope that some preferred very simple discrete geometries could be dynamically favored.

Weak form of NMP generalizes p-adic length scale hypothesis. p-Adic primes, which are near but below powers of prime are favored. The original form of p-adic length scale hypothesis states that the primes $p \simeq 2^k$ are preferred. Mersenne primes are the primes nearest to power of two and in this sense unique. For odd powers of primes this criterion cannot be satisfied so accurately as for Mersennes. The model for the hierarchy of codes containing also genetic code relies on Combinatorial Hierarchy $M(n+1) = M_{M(n)}$, $M(1) = 3$, giving rise to Mersenne primes $3, 7, 127, 2^{127} - 1$. The remaining numbers in the hierarchy could but need not be Mersenne primes. $M_7 = 127$ corresponds to genetic code and M_{127} to what I have called memetic code possibly assignable to electron. If cognition is fundamental aspect of TGD present already at elementary particle length scales as already p-adic mass calculations and the adelic vision about tGD [K95] suggest, one indeed expects that the Universe is full of cognitive codes - even at the level of elementary particles. They would however correspond to the “dark” aspects of matter not observable by the existing experimental methods and related to the hierarchy of Planck constants predicted by TGD.

The considerations related to codes discussed in the sequel are written much before the emergence of this picture and I cannot guarantee full consistency with the proposed picture.

3.5.2 Cognitive Codes As A Realization Of The Information Generated By DNA-Protein SymmetryBreaking?

One can argue that before the establishment of the genetic code the assignments of DNA triplets to amino-acids are random. This would mean that the symmetry group is a direct product of the permutation groups permuting 64 DNA triplets and 20 amino-acids. The symmetry entropy is logarithm about the number of elements of the symmetry group

$$S_{max} = log(w) \ , \quad w = 64! \times 20! \ . \tag{3.5.1}$$

One obtains $S_{max} \simeq 4 \times 61.8789$.

The work of Negadi inspired the question about whether one could interpret protein-DNA symmetry breaking as a process in which the information $I = S_{max} - S$ is generated and represented in a concrete manner as an additional conscious cognitive information associated with DNA and protein sequences.

In case of DNA sequences the symmetry breaking would be maximal so that one has $I = S_{max}$. In case of protein sequences symmetry breaking would be partial and $I = S_{max} - S$, where S corresponds to the entropy due to the fact that DNA triplets coding for the same amino-acid are equivalent from the view point of protein: DNA sequences carry more cognitive information than protein sequences.

Weak form of NMP provides additional clues.

1. Unitary entanglement between two state spaces of dimension kp^N (in the sense that entanglement matrix is proportional to a unitary matrix) gives rise to negentropic entanglement with p-adic prime p [K45]. These dimensions are favored by weak form of NMP as highly negentropic (the maximum of number theoretic negentropy corresponds to p-adic prime p).

2. If p is Mersenne prime: $p = M_k = 2^k - 1$, temporal sequences of k spin directions /qubits could provide a concrete mechanism of quantum computation (for $k = 127$ associated with the memetic code at least. This suggests that DNA triplets or amino-acids could be accompanied by $p = M_k$-fold degeneracy resulting from the assignment of a sequence of k qubits to each DNA triplet and/or amino-acid.

3. This representation of information should relate somehow to the realization of the memetic code in terms of DNA and amino-acid sequences. In the model of the memetic code sequences of 21 DNAs are a natural candidate for the realization of the memetic code words since the number of different sequences is $64^{21} = 2^{126}$, which is the number of the memetic code words representing maximal number of forming a set theoretic inclusion hierarchy and logical implication hierarchy in the Boolean algebra represented by sequences of 127 bits. These statements correspond also to all statements consistent with a fixed atomic statement fixing the value of one bit. The sequences of 21 proteins are a natural candidate for defining the memetic counterpart of the DNA-protein translation if one assumes that the translation of genetic code induces directly the translation of the memetic code to proteins. A test is to find whether sequences of 21 DNAs/proteins might appear in the tertiary structure of DNAs/proteins.

4. The argument above suggests that one should try to find a representation of the cognitive information by assigning a temporal sequence of $p = M_k$ spin directions to each DNA/protein in the the sequence of 21 DNAs/proteins. This representation makes sense if the condition

$$I = 21 \times log(M_k) \simeq 21 \times k \times log(2) \tag{3.5.2}$$

giving

$$k = \frac{I}{21 \times log(2)} \ , \tag{3.5.3}$$

is satisfied for k Mersenne prime. The condition is obviously extremely restrictive and a number theoretical miracle is required since k has exponential sensitivity to the value of I. Even more, this miracle is required to occur twice: for both DNA and proteins! The value of I can be calculated for both DNA and proteins and one can check whether the mircacle occurs. That it indeed occurs gives a support for the realization of memetic code in terms of sequences of 21 DNAs and proteins.

3.5.3 Peptides As Molecules Of Emotion

The view about peptides and proteins as cognizing and intentional entities allows to translate to TGD language often used expressions like "emotions are expressed", "blocked emotions are released", "emotions are stored to the body as traumatic body memories", "peptides are molecules of emotion and information molecules". Most importantly, a concrete code for cognition emerges in which elementary intention represents inhibition or facilitation of gene expression.

Unasked questions

The interactions of the information molecules involve the formation of receptor-information molecule complex either at cell surface or in the cell plasma inside cell. Receptor-information molecule complex inside cell can move to genome and induce gene transcription. In case that the complex is formed at the surface of cell, second messenger action is involved. One can also speak about N: th messenger action. There are many poorly understood aspects related to the mechanisms of information molecule action [I10].

1. There are only few second messenger pathways and relatively few receptors but large number of different functions. This phenomenon is known as pleiotropy or multi-functionality. For instance, given second messenger causes different effects depending on the hormone that activated it (the phenomenon is somewhat analogous to the phenomenon in which message can be understood in several ways depending on the state of receiver).

At purely chemical level the problem is how second messenger knows what hormone activated it? In steroid action the complex formed by information molecule and receptor in turn activates some gene. Now the question is: How the activated RNA polymerase knows which gene has to be activated? Pleiotropy appears also at level of hormones. Same hormone can have multiple effects and the border between hormone, neuropeptide or even neurotransmitter is unclear. For instance, a hormone which by definition transmits long distance communications, can have effects in nearby cells and thus acts like a neuropeptide. How hormone knows what function it must perform? Also drugs and treatments can have different effects and side effects.

2. There is also functional redundancy: the same function is performed by several second messenger molecules. For instance, glucagon, growth hormone, adrenaline and corticosteroids elevate glucose levels. This suggests that there is deeper level of communication involved and that second messenger molecules are more like computer passwords than subprogram calls. Now the question is: What these subprogram calls do correspond physically?

3. Biological functions can be initiated also in non-chemical manner. The phenomena of healing by touch and the effects of meditation and biofeedback are examples of biological self-organization processes are initiated in non-chemical manner. Even other treatments like massage, acupuncture or meditation can decrease or inhibit pain. These observations suggest that chemical level is not the deepest level involved with biological functions and the question is: What is this deeper control level?

Simple lock and key mechanism cannot provide answer to the questions raised above. If information molecules carry p-adic intentions about say gene level expression of emotions, situation changes since additional information transfer is involved.

The code of emotions

The expressions of emotions are usually symbolic. What it means that peptides are responsible for the expression of emotions? Perhaps information molecules transfer the information about the emotions to be expressed at molecular level between body parts. It is indeed known that nervous system, immune system, and endocrine system are in an intense information exchange using information molecules.

The original naïve speculation was that p-adic physics might be concretely involved here. The recent view is however more mundane looking.

1. The emotional expression - in fact all signalling in biosystems - involves pairs of magnetic flux tubes connecting the sender of the control signal and the target and serving as a correlate for directed attention. The reconnection of U-shaped flux tubes emanating from sender and the receptors of the target gives rise to the connecting pair of flux tubes. The connections would be between information molecules. For instance, messenger molecules would be connected to the sender and receptor of the target in this manner. Hormones and neurotransmitters would have similar connections.

2. The signal itself is transmitted along the flux tube pair and realized as dark photons propagating along massless extremals (MEs) parallel to flux tubes. Dark photons would have frequencies selecting only special targets by resonance mechanism. Dark photons would be cyclotron photons with a universal energy spectrum assignable to bio-photons in visible and UV range resulting as dark photons transform to ordinary photons. Universal energy spectrum is obtained if the value of h_{eff} satisfies $h_{eff} = h_{gr}$, where $\hbar_{gr} = GMm/v_0$ is so called gravitational Planck constant [K58] being proportional to the mass m of the charged particle appearing in cyclotron condensate so that cyclotron energy proportional to h_{eff}/m does not depend on the mass of the charged particle. The independence of gravitational Compton length on the mass of charged particle makes possible macroscopic gravitational quantum coherence.

The model for the music harmony and genetic code [K65] leads to a more detailed model for the representation of DNA codons and amino-acids in terms of “3-chords” defined by 3 frequencies.

Since music represents and generates emotions, it is natural to consider the possibility that this representation provides correlates for emotions.

1. DNA sequences and proteins correspond to sequences of 3-chords, music pieces one might say and are represented by a characteristic musical theme. An analogous dark photon representation could apply to all important biomolecules and serve as its name. What is interesting that 256 different harmonies defined by the possible 3-chords emerge. They could provide correlates for various kinds of moods at bio-molecular level and assignable to magnetic bodies carrying dark matter, which would represent completely new information processing level distinguishing biochemistry from the ordinary chemistry.

2. The model involves only 3-chords playing the role of passwords, and can be seen as a particular realization of the genetic code. Password code could be enough but the temporal patterns of the signal analogous to temporal coding of bit sequences make possible an additional message much like in the ordinary communications between computers. The signal could be sent using higher level code in a hierarchy of codes.

3. Combinatorial Hierarchy containing at least the primes $3, 7, 127, 2^{127} - 1$ could define such a sequence of codes having interpretation as a hierarchy of statements about statements. Above the genetic code with 6 bits would be memetic code with 126 bits, which could be assigned to dark electrons if the flux tube connecting the wormhole contacts involved corresponds to $h_{eff} = M_{127} \times h$. Electron could have dark side invisible using recent measurement technology but crucial for understanding biology - the size scale of electron CD is .1 seconds, the fundamental biorhythm.

4. An interesting question is whether DNA sequences consisting of 21 DNA triplets realizing memetic code could have some special role in the control part of the genome. The sequences of $10 \times n$ DNA triplets are special in that the net helical rotation along the sequence is a multiple of 2π. This suggests a connection with $p = 5$ finite geometry realized in terms of pentagon and involved also with the finite geometry defined by icosahedron characterizing genetic code. Could the sequences of 20 DNA and thus also of 20 amino-acids serve as units of genetic information? Note that the sequence of 21 DNA codons realizing memetic codon corresponds to same twist modulo 2π tetrahedron as single DNA nucleotide. 10 memetic codons correspond to full multiple of 2π twist: is there some kind of fractality involved?

   Clearly, the number 5 is the key number of genetic code and $p = 5$ finite geometries dimension 1 and 2 seem to be involved. The challenge is to undertand the full picture.

Of course, any code based on Mersenne primes and on prime near but below a power of prime p_1 might be involved. $p_1 = 2, 3, 5$ correspond to finite geometries realizable as Platonic solids and are especially interesting candidates in this respects. All primes are realizable as regular polygons. Since $h_{eff} = h_{gr}$ is proportional to the mass of charged particle, each charged particle would have its own frequency scale analogous to a user specific frequency band used in radio communications so that the communications would not interfere with each other. Temporal code could have several variations. Frequency modulation is however strongly suggested by the model for cell membrane as generalized Josephson junction [K66].

What could happen in information-molecule receptor complex?

I have considered at the general level the question about what might happen in receptor complex in [K86].

The general idea is that the receptor serves as a relay station. The attachment of U-shaped flux tube emanating from the sender to a receptor generates a flux tube connection between sender and target analogous to that generated by a tele-operator. The connection can be very long ranged since the size scale of the magnetic body can e very large as compared to that of biological body from the fact that time scale of .1 seconds defining universal biorhythm assignable to electrons corresponds to the size scale of the Earth.

In [K86] I have discussed a speculative model for the effect of psychedelics on consciousness considering the possibility that the claimed encounters with representatives of other civilizations might be actually real remote sensory experience involving genuine communication rather than mere hallucination. The basic objection that the finite light velocity makes these encounters impossible is circumvented in ZEO. I do not of course expect that the reader would take this kind of speculation seriously. What however remains is the possibility that receptors would serve as kind of tele-operators at which the flux tubes can attach so that remote connection is generated.

It is known that membrane proteins serving as receptors are in a helical conformation such that the number of proteins in the portion connecting the cell exterior and interior is 20 [I5]. This is not quite 21, which is the number of DNA codons representing single memetic codon ($126 = 21 \times 6$ bits). What could this mean?

1. Could the number 20 relate somehow to the number of triangular faces of icosahedron playing a key role in the model of music harmony and genetic code?

Cell membrane receptors are especially important receptors. The active parts of the cell membrane receptors corresponds to the parts of the membrane proteins traversing the cell membrane. Often the receptors are proteins, which traverse the cell membrane many times and the interpretation would be that each portion of 20 amino-acids defines one elementary signal unit defining a portion of DNA sequence to be translated and initiating a process leading to an expression of some gene(s). 7-bit code suggests that the codeword activates control genes which promote or disfavor the expression of some gene(s).

Micro-tubular cytoskeleton which is piezoelectric structure claimed to allow 64 bit code [I4], [J28] could mediate the electric electric signal to the nucleus and activate the desired genes. Massless extremals could be involved. The generation of the second messenger would represent a standardized part (there are relatively few second messenger pathways) of the process of realizing gene expression now responsible for the transfer of the intention.

Failure to express emotions

The expression of emotions can fail at several levels. The intention to express emotion is not realized as action. No state function reduction to the opposite boundary of CD for the corresponding sub-self would take place so that the mental image representing emotion would become very long-lived. By NMP the death of the emotional mental image is however required in order to generate negentropic entanglement. The unexpressed emotion is stored to the body as kind of tension.

Second failure is that the information molecules are sent but fail to bind to their receptors for some reason or the transfer of information inside the receiving cell fails for some reason. In this case the emotion is expressed at the primary level but the desired effect is not achieved.

An important function of sleep and dreams might be the expression of the un-expressed emotions of the geometric past. Also meditation and various therapies might have the same effect. Neuropharmacological approach, as long as it tries to affect only the geometric now, cannot change the geometric past and would not seem therefore very useful healing method for emotional traumas. My own rather traumatic academic past provides a good testing ground for this hypothesis. As a scientific heretic I lost my academic human rights for long time ago. It became clear that if I react to this, I will be labelled as an asocial paranoid. Apart from few exceptions, when the psychic pain was simply too intolerable, I managed to avoid this. This left a lot of unexpressed emotion to my geometric past and the reward for a civilized behavior was a label of a stupid sissy. Gradually it became also clear that there is no hope: the academic decision makers have unlimited power. It is hard to imagine a more effective mechanism for generating deep frustration and long term depression! Gradually I however realized that the coin had also the other side: the role of an academic zombie gave me an unlimited intellectual freedom which those professors did not possess and I had actually ideal circumstances for carrying out my mission optimally. Besides the incredible stupidity of the academic power holders I have been wondering second strange phenomenon during these years. Why do I spend practically all my dream time in my past? Could a partial answer be that I have been busily trying to express these un-expressed emotions: during sleep it is easier to break the academic etiquette.

3.6 About Molecular Cognitive And Sensory Representations?

The challenge of understanding how intentions and cognitions are realized at the molecular level is a fascinating and potentially very rewarding challenge. The work with genetic and memetic codes based on the notion of Combinatorial Hierarchy [K32, K40, K65] represents first steps in this direction but does not yet involve p-adic aspects. The ideas of preceding section provide a lot of additional insight but do not provide any general theory. This section is devoted to an attempt to say something about the general theory of cognitive and symbolic representations at the molecular level assuming that even molecular structures have intentions and cognition and are able to transform intentions to actions.

The basic hypothesis is that molecules provide both static and dynamic symbolic representations for cognitive codes. Cognitive codes would be characterized by the symmetry groups of finite geometries and their projective counterparts. The requirement that cognitive quantum computation is possible raises the primes defining Mersenne primes to a preferred position. The symmetry groups of finite geometries are assumed to act as the symmetries of the molecular structures responsible for the symbolic representations. This leads to strong predictions as some examples treated below demonstrate and one might even speak about Golden Road to the understanding of cognition and intentionality at molecular level.

3.6.1 Number Theoretical Ideas

The predictive power of the model to be proposed derives basically from number theoretical constraints. Mersenne primes are in a unique position as far as p-adic quantum computation is considered. One can imagine a good reason for why Gaussian Mersennes should have a unique role. Fibonacci numbers characterize often the structure of biological systems, and there are reasons to believe that they might relate very intimately also to the evolution of cognitive representations.

Mersenne primes an cognitive hierarchies

The findings about new cognitive codes initiated by the idea of symmetry entropy of DNA-protein system can be compressed to a generalized notion of abstraction hierarchy, which was introduced years earlier. Any Mersenne prime M_p, p prime defines an abstraction hierarchy containing at most two levels. The 2^p-1 elements of the finite field $G(M_p,1)$ represent all possible statements about p basic statements except the one which is not representable for some physical reason. Hierachies start from some prime which is $2,5,13,17,19,31,89,107$ in the range of p-adic time scales of interest and can have several levels.

1. Combinatorial hierarchy $p=2,3,7$ (single base pair), 127 (genetic code), M_{127} (memetic code whose mutually consistent statements are realized also as sequences of 21 DNAs) is the longest hierarchy. It is not known whether $M_{M_{127}}$ is prime: Hilbert conjecture states the entire infinite hierarchy consists of Mersenne primes. This would mean that universe possesses infinite ability of cognitive abstraction.

2. The next hierarchy starts from prime 5 and contains three levels $p=5$, M_5=31, and $M_{31}=2^{31}-1\simeq 2\times 10^9$.

3. The remaining known to me hierarchies are two-step hierarchies and any Mersenne prime defines such a hierarchy. The largest Mersenne prime hierarchy of this kind relevant for human consciousness is M_{127} which is the p-adic prime characterizing electron and memetic code. M_{521} is the next Mersenne prime and corresponds to a completely super-astrophysical time scale.
   i) The first abstraction pair (p,M_p) corresponds to $p=13$. Micro-tubuli are excellent candidates for the realization of M_{13}^{13} representations with $13^2=169$ bits of information (recall that $k=169$ characterizes the p-adic length scale associated with neutrinos!).
   ii) Next Mersenne M_p prime corresponds to $p=17$ and was deduced by the argument relating to the information gain in complete symmetry breaking of the DNA-protein system.
   iii) Also the Mersenne primes M_p associated with $p=19,31,61,89,107$ should be there.

The beauty of Mersenne representations is that one can construct from them product representations containing M_p^k cognitive states and bits replaced by pinary digits M_p. Furthermore, by fractality any time scale $2^{pm/2}T_{M_p}$ is possible for sufficiently small primes p so that these representation can be present in and a wide spectrum of time scales ranging from the time scales relevant for the conformational dynamics of molecules to the time scales relevant for neural activity and EEG and even time scales measured in years.

What about Gaussian Mersennes?

The Gaussian Mersennes $G_n = (1+i)^n - 1$, n some prime, are expected to be also of fundamental importance and one expects that they give rise to complex cognitive representations. The Gaussian Mersennes possibly relevant to life correspond to primes $n = 2, 3, 5, 7, 11,\ 19, 29, 47, 73, 79, 113, 151, 157, 163, 167,\ 239, 241, 283$. The length scale range between cell membrane thickness and size of small bacterium contains only scaled up Compton lengths of electron for Gaussian Mersennes: they are $n = 151, 157,\ 163, 167$. The norm squared of the Gaussian Mersenne $G_{n=2k+1}$ is $p_n = 2^{21+1} + 2^{k+2} + 1$ and larger than 2^n.

One might guess that the number of Gaussian integers with norm smaller than the norm squared of Gaussian prime G_n defines the number of states in this kind of representation and that this number must be prime. Some very beautiful cognitive structures might be involved with Gaussian Mersennes and it remains to be found what this structure is. Obviously the idea that one could use sequences of n bits to realize $p_n = 2^n - 1$ points as phase transitions by spontaneous magnetization to an analogous representation of $p_{n=2k+1} = 2^{2k+1} + 2^{k+1} + 1$ points. One can write p_n in a form which gives hints about what kind of physics this representation might require:

$$p_{n=2k+1} \equiv N_1 + N_2 + N_3 \ ,$$

$$N_1 = 2^{2k+1} - 1 \ , \qquad N_2 = 2 \times 2^k - 1 \ , \quad N_3 = 2 \times 2 - 1 \ .$$

p_n is sum over numbers of magnetization phase transitions for three phases of the fermion system. N_1 corresponds to a system of $2k+1$ fermions. N_2 corresponds to a system consisting of one fermion plus k Cooper pairs: by the indistinguishability of fermions the combinatorial factor k is absent from N_2. N_3 corresponds to a system consisting of one fermion and a Bose-Einstein condensate of all k Cooper pairs behaving like a single particle. Neutrinos at $k = 169$ space-time sheet suggest themselves strongly as a realization of this phase.

Fibonacci numbers and the evolution of cognition

Fibonacci numbers proliferate living matter (logarithmic spirals) and emerge in the simplest models of growth: living matter is full of logarithmic spirals and also micro-tubular structure involves the sequence $3, 5, 8, 13$ of Fibonacci numbers. The natural guess is that Fibonacci numbers are also involved with cognitive growth and evolution: especially so if this biological growth is basically intentional and involves growth of plans from rough sketches to more detailed ones and if this development is seen in the structure of intention. In particular, 21 DNA/protein codeword could decompose to ordered hierarchy of subsequents of $1, 2, 3, 5, 8, 13, 21$ DNAs and these sequences with increasing length gradually give better and better representation of codeword. The development of the full cognitive code word or intention, would be like an interactive growth of a population of 21 cognitive organisms, primitive intentions associated with single DNA. Older unit intentions react to the presence of new ones by generating new unit of intention each. When, say, a generation consisting of 5=2+3 unit has been established, 3 units of previous generation generate new units (5+3=8) as a response to the presence of new 2 units.

For intance, single micro-tubule would represent only the 13 first DNAs and would not give faithful coding of the codeword. The wall of a double micro-tubule with 21 tubulin strands at its wall would do it. Interestingly, triple micro-tubules seem to contain the total of 33 or 34 micro-tubules, whether the number is 34=21+13, the next Fibonacci in the micro-tubular series, is not clear on basis of material that I have seen. Because of its Fibonacci structure of micro-tubule could automatically represent 5, 8 and 13 DNA approximations to the full intention represented by a sequence of 21 DNAs.

3.6.2 Representations

Representations are fundamental notions in geometry and physics and, as it seems, also sensory, symbolic, and cognitive representations make sense. The basic idea is that Nature codes its mathematical cognition to various kinds of symbolic representations. The fascinating possibility is that practically every bio-structure which results in genetic expression represents some cognitive/intentional structure somehow. We have been used to think that our theories represent those structures we see: it might be fruitful to see the situation as just the opposite! DNA and proteins would be only particular hardware realization of finite geometries associated with cognition. This view might be general enough and certainly practical: one can deduce the symmetry groups associated with various structures and look whether one can assign them to finite geometries or their projective counterparts and thus to p-adic cognition.

Various types of representations

One can distinguish between several kinds of representations.

1. There are cognitive representations in terms of temporal sequences of p-adic neutrinos. Sequences of 21 DNA triplets could realize any representation defined by Mersenne prime since the temporal character of the sequences means that the density of neutrinos needed does not depend on the Mersenne prime. Thus there is no really deep reason for making too restrictive assumptions at this stage.

2. The symbolic representations can transform further to dynamical representations as either nerve pulses or oscillations of membrane potential. This representation generalizes: what is needed are two-state systems in an external field which forces a process analogous to spontaneous magnetization.

3. One can also consider the possibility of static geometric representations in terms of molecular geometry. These kind of representations could be realized for any prime p and in case that M_p is Mersenne prime, the structure characterized by p parts related by a cyclic symmetry Z_p could serve as a template for dynamical representations obtained by attaching a two-state system at every unit of the system. For instance, DNA triplets realize statically the set of 64 statements consistent with an atomic statement (single bit fixed) for $M_7 = 127$ cognitive representation and single DNA triplet could realize $M_3 = 7$ representation if each basepair can be in two states. Clathrin molecule gives 12-fold product of $p = 5$ representation in terms of 12 disjoint pentagon faces whose vertices carry a two-state system (the polarization of the triskelion protein could define the two states).

The basic principle for realizing dynamical representations

According to TGD inspired theory qualia, primitive qualia correspond to spin flips, and more generally, to phase transitions changing the direction of spin or some other quantity characterizing the state of the two-state system. In case of neutrino representations the essential elements are the presence of magnetic field, the fact that the neutrino is a two-state system which flips in the direction of externa magnetic field, and the fact that the number of representable states is $M_n = 2^n - 1$ rather than 2^n states since the state in which all spins are parallel does not give rise to spontaneous magnetization and conscious experience.

The replacement of single particle states with say spontaneously magnetized states guarantees rigidity and robustness. Spin glass type phase is optimal for the representative purposes and TGD universe is indeed a quantum spin glass. Dynamic representations can be realized in terms of molecular conformations instead of using fields. Micro-tubule representations provide a fundamental example but there are a lot of others. If magnetic flux tubes and electrets are indeed fundamental building blocks of living systems (they represent fundamental solutions of field equations of TGD), living system should be a huge fractal collection of these representations. Also cell membrane is expected to carry representations of this kind.

What this means is that the projective finite geometry with $M_n+1 = 2^n$ points is represented dynamically by n two state systems such that the point at infinity is not realizable as spin flip pattern since it corresponds to the spontaneous magnetization or electret state in which all n two-state systems have spin /polarization/... direction parallel to external field and nothing happens. This is indeed what is required by the realization of qualia as quantum number increments. At the level of set theoretical Boolean algebra representation the point at infinity corresponds to the empty set.

If the strength of the background field can be controlled, the representation could be generated by weakening the field temporarily so that there results either a spin glass phase at criticality optimal for the storage of bits or a phase above criticality optimal for signal propagation. The transformation inducing "spontaneous magnetization" responsible for the conscious experience could be generated by increasing the strength of the magnetic/electric field to its original value. For instance, in case of micro-tubular conformational representations reading would result by introducing strong electric field forcing the conformations to ground state conformations.

Magnetic flux tubes and their electric duals provide these background fields. In case of magnetic flux tubes cyclotron transitions are these transitions and spins of Cooper pairs define the bits. This allows a deeper understanding of also sensory representations.

Fractal hierarchy of time scales

The beauty of the realization of cognitive representation in terms of Mersenne primes is that all fractal powers $T(p,n) = p^{(n-1)/2}T_p$ of p-adic time scale T_p are a priori possible and correspond in good approximation to the square roots of the octaves of the fundamental time scale. The first implication is that the entire span of biologically relevant time scales can be realized using relatively few fundamental time scales defined by small Mersenne primes. This means also that for large Mersenne primes corresponding to relatively long time scales there can be several small Mersenne representations with essentially the same time scale. The signatures for these time scales are resonance frequencies corresponding to the time scales defining the duration of the codeword and also the duration of single bit. How much the duration of the codeword can vary around the p-adic time scale is still an open and important question: the width of alpha band suggests that the variation is about $\pm$ 20 per cent.

Is evolution 3-adic?

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" [I8, I9].

The observation challenging Darwinian dogma is that the moments for evolutionary breakthroughs - according to Faixat's observation - seems to come in powers of 3 for some fundamental time scale. There would be precise 3-fractality and accompanying cyclicity - something totally different from Darwinian expectations.

By looking at the diagrams demonstrating the appearance of powers of 3 as time scales of evolution, it became clear that the interpretation in terms of underlying 3-adicity could make sense. I have speculated with the possibility of small-p p-adicity. In particular, p-adic length scale hypothesis stating that primes near powers of 2 are especially important physically could reflect underlying 2-adicity. One can indeed have for each p entire hierarchy of p-adic length scales coming as powers of $p^{1/2}$. $p = 2$ would give p-adic length scale hypothesis. The observations of Faixat suggest that also powers p=3 are important - at least in evolutionary time scales.

Note: The p-adic primes characterizing elementary particles are gigantic. For instance, Mersenne prime $M_{127} = 2^{127} - 1$ characterizes electron. This scale could relate to the 2-adic scale $L_2(127) = 2^{127/2} \times L_2(1)$. The hierarchy of Planck constants coming as $h_{eff} = n \times h$ also predicts that the p-adic length scale hierarchy has scaled up versions obtained by scaling it by n.

The interpretation would be in terms of p-adic topology as an effective topology in some discretization defined by the scale of resolution. In short scales there would be chaos in the sense of real topology: this would correspond to Darwinian randomness. In long scales p-adic continuity would imply fractal periodicities in powers of p and possibly its square root. The reason is that in p-adic topology system's states at t and $t + kp^n$, $k = 0, 1, ...p - 1$, would not differ much for large values of n.

A possible interpretation relies on p-adic fractality [K51] (http://tgdtheory.fi/figu.html). p-Adic fractals are obtained by assigning to real function its p-adic counterpart by mapping real point by canonical identification

$$\sum_n x_n p^n \rightarrow \sum_n x_n p^{-n}$$

to a p-adic number, assigning to it the value of p-adic variant of real function with a similar analytic form and mapping the value of this function to a real number by the inverse of the canonical identification, the powers of p correspond to a fractal hierarchy of discontinuities.

A possible concrete interpretation is that the moments of evolutionary breakthroughs correspond to criticality and the critical state is universal and very similar for moments which are p-adically near each other.

The amusing coincidence was that I have been working with a model for 12-note scale [L8], [K65, K92] (http://tinyurl.com/y7csuxaw), which to my opinion is highly interesting from the point of view of consciousness theory. Already the mathematicians of ancient Greece speculated with a connection with the geometry of Platonic solid and music scale [J66].

The basic observation is that icosahedron is a Platonic solid containing 12 vertices. The scale is represented as a closed non-self-intersecting curve - Hamiltonian cycle - connecting all 12 vertices: octave equivalence is the motivation for closedness. The cycle consists of edges connecting two neighboring vertices identified as quints - scalings of fundamental by factor 3/2 in Platonic scale. What is amusing that scale is obtained essentially powers of 3 are in question scaled down (octave equivalence) to the basic octave by a suitable power of 2. There is of course slight discrepancy due to the fact that $(3/2)^{12} = 2^7$ is not quite true. This motivated the transition to the well temperated scale with half note corresponding to the scaling by $2^{1/12}$.

The faces of icosahedron are triangles and define naturally basic 3-chords. Triangle can contain either 0, 1, 2 edges of the cycle meaning that the 3-chords defined by faces and defining the notion of harmony contain 0, 1, or 2 quints. One obtains large number of different harmonies partially characterized by the numbers of 0-, 1-, and 2-quint icosahedral triangles since the total number of Hamiltonian cycles at icosahedron is 2^{10}. One must howe$h_{eff} = n \times h$ver notice that those related by an isometry of icosahedron are equivalent.

The connection with 3-adicity comes from the fact that Pythagorean quint cycle is nothing but scaling by powers of 3 followed by suitable downwards scaling by 2 bringing the frequency to the basic octave so that 3-adicity might be realized also at the level of music!

There is also another strange coincidence. Icosahedron has 20 faces, which is the number of amino-acids. This suggests a connection between fundamental biology and 12-note scale. This leads to a concrete geometric model for amino-acids as 3-chords and for proteins as music consisting of sequences of 3-chords. Amino-acids can be classified into 3 classes using polarity and basic - acid/neutrality character of side chain as basic criteria. DNA codons would would define the notes of this music with 3-letter codons coding for 3-chords. One ends up also to a model of genetic code relying on symmetries of icosahedron from some intriguing observations about the symmetries of the code table.

At the level of details the icosahedral model is able to predict genetic code correctly for 60 codons only, and one must extend it by a fusion it with a tetrahedral code. The fusion of the two codes corresponds geometrically to the fusion of icosahedron with tetrahedron along common face identified as punct (punct) and coded by 2 stopping codons in icosahedral code and 1 stopping codon in tetrahedral code. Tetrahedral code brings in 2 additional amino-acids identified as so called 21st and 22nd amino-acid discovered for few years ago and coded by stopping codons. These stopping codons certainly differ somehow from the ordinary ones - it is thought that context defines somehow the difference. In TGD framework magnetic body of DNA could define the context.

The addition of tetrahedron brings one additional vertex, which correlates with the fact that rational scale does not quite closed. 12 quints gives a little bit more than 7 octaves and this forces to introduce 13 note for instance, A_b and $G_\#$ could differ slightly. Also micro-tubular geometry involves number 13 in an essential manner.

3.6.3 Finite Geometries And Cognition

Finite geometries defined by Galois fields $G(p,n)$ with p^n elements and identifiable as integers in an algebraic extension of p-adic numbers modulo p and corresponding projective geometries are the natural mathematical framework for simplest cognition. The primes p defining Mersenne primes $M_=2^p-1$ and Gaussian Mersennes and these primes themselves are preferred primes for the reasons already explained.

1. The evolution of mathematics represents the evolution of cognition if ontogeny recapitulates phylogeny also at the level of cognition. This means that ancient mathematicians constructed also models for the basic structures of cognition. The Platonic solids could represent basic cognitive structures rather than only vice versa as it is usually thought.

2. Symmetry group characterizes a given geometry. This group is cyclic group Z_p for the simplest finite geometries defined by finite fields $G(p,1)$, p prime, and finite projective group for for their projective counterparts obtained by adding the point at infinity.

3. One can interpret spatial and temporal sequences of quark magnetization directions as representing points of finite geometries or their projective counterparts defined by Mersenne primes. The point at infinity corresponds to all spins in the direction of magnetic field so that no membrane oscillation is generated: infinity is un-reachable. Operational infinity is something which one is not able to achieve or perceive. This finding generalizes to a more general representational principle using two-state systems in an external field which forces the two-state systems to the same state. The cognitive state is coded to a conscious experience resulting in the phase transition to the ground state. If there are p two-state systems such that M_p is Fermat prime this system codes the points of the finite geometry M_p to conscious experiences.

Primes $p=2,3,5$ define especially interesting finite geometries and they correspond to Platonic solids. These Platonic solids appear in the molecular physics of living matter abundantly and this suggests that the p-adic length scale hierarchies associated with this primes are of special importance. There is indeed evidence for this as will be found.

If this view is correct, the mathematicians were studying their own cognitive consciousness when they were proving theorems about Platonic and Archimedean solids or doing ruler and compass constructions. In fact, I realized for years ago that Pythagorean triangles which pop up naturally in p-adic context, represent the very early view about world as mere rational numbers. The simplest mathematical cognition relies on finger counting: amusingly, decimal code pops up already at the level of DNA: 10 DNA triplets correspond to a helical twist which is minimal multiple of 2π.

Finite geometries

Ordinary finite geometry understood as having a structure of number field involves only a set of p (prime) ordered points defining the finite field $G(p,1)$ and subsets of points of this geometry. The projective counterpart involves also the point at infinity and contains thus $p+1$ points. Also the algebraic extensions $G(p,n)$ of $G(p,1)$ containing p^n points are possible but not discussed here. The symmetry group of the finite geometry $G(p,1)$ is cyclic group Z_p and the sequences of magnetization directions of p quark blocks represent the subsets of $G(p,1)$ as ordered sets. In case of projective finite geometry containing also the point infinity projective transformations induced by 2×2 unimodular matrices

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \tag{3.6.1}$$

induce projective transformations via the formula

$$x \rightarrow \frac{ax+b}{cx+d} \quad . \tag{3.6.2}$$

By studying the unimodularity condition $ad-bc=1$ in finite field one easily finds that the number of elements in the projective group is

$$N = (p-1)\times[(p-1)\times(p-2)+4\times(p-1)+2]/2 \ . \tag{3.6.3}$$

For $p=5$ one obtains $N=60$ corresponding to the number of vertices in truncated icosahedron representing thus the symmetry group of 6-point projective finite geometry consisting of the group A_5 of even permutations of five objects. For $p=3$ the number of elements is $N=224$ and corresponds to the group S_4 of permutations of four objects whereas for $p=2$ the number of elements is $N=6$ and corresponds to the group S_3 of the permutations of three objects.

The projective transformations of finite projective geometries are counterparts of Lorentz transformations. One can assign to finite geometries also a spinor structure. Spinors have two-components and the action of the projective transformation on the spinor is by matrix multiplication. It was actually this finding which led to the realization that there might be a deep connection between cognitive representations using fermion sub-CDs and finite (projective) geometries.

Representations of finite geometries

An interesting question is what finite geometries can be realized as polygons in plane or as Platonic or Archimedean solids. This requires that the symmetry group of the finite geometry or of its projective counterpart acts as a subgroup of the rotation group $O(3)$. For finite geometries having Z_p as a symmetry group regular polygons of plane with p vertices and edges provide this realization. At molecular level a realization by helical twisting is natural. If the number of units corresponding to a full helical twist of multiple of 2π is p or power of p one has a geometric realization of a finite geometry.

1. *Polygons obtainable by ruler and compass construction*

Of special interest are the polygons which can be constructed using only ruler and compass: for these structures lengths of various edges are either integers or involve iterated square roots of integers. The well-known theorem of Euler states that the only structures of this kind correspond to regular polygons with n vertices and sides of identical length having vertices at circle. The allowed values of n are given by

$$n = 2^k \prod_k F_k \ ,$$

where k is any non-negative integer and F_k is Fermat prime

$$F_k = 2^{2^k}+1 \ , \ \ k=1,2,3,4 \ .$$

The list of Fermat primes is $3,5,17,287,2^{16}+1$. Interestingly, the lowest three Fermat primes define Mersenne primes M_{F_k} so that they are expected to be of special interest from the point of view of cognition. These structures are not finite geometries but could be regarded as Cartesian products of finite geometries $G(2,k)$ and $G(F_i,1)$. These structures can be seen as Cartesian products of finite geometries.

A possible geometric representation of these structures is based on many-sheeted space-time concept (see **Fig. ??** in the appendix of this book) so that various factors in the decomposition correspond to different space-time sheets characterized by appropriate p-adic topology (also real space-time sheets are characterized by p-adic prime). The hierarchical helical structures containing helices inside helices correspond to many-sheeted space-time structures and the numbers of basic units corresponding to single period at various levels could correspond to the prime factors appearing in the decomposition.

Bio-systems are full of helical structures. Five finger code and decimal code are included as almost simplest codes. 10 DNA molecules define a structures for which the total helical winding is multiple of 2π. Perhaps here is linear realization of the decimal code: that twist is multiple of 2π indeed says that one can form from DNA a loop where that cyclic group of 10 elements acts. One should look systematically through all helical structures and find the number of units which correspond to a minimal multiple of 2π rotation to see whether ruler and compass codes are realized.

2. Quantized Planck constant, dark matter, and Fermat polygons

One ends up with Fermat polygons from the quantization of Planck constant as $\hbar = \lambda\hbar_0$. Number theoretical arguments suggest a general formula for the allowed values of λ [K26] as $\lambda = n$ where the integer n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K96]. 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 $F_0 = 3, F_1 = 5, F_2 = 17, F_3 = 257, F_4 = 2^{16} + 1$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales.

The p-adic vision about cognition suggests that algebraic extensions of p-adic numbers define a cognitive hierarchy and the lowest levels of this hierarchy correspond to algebraic extensions of p-adic numbers involving only iterated square root operation. These should emerge first in the evolution and therefore dark matter systems assignable to Fermat polygons should be the most abundant ones.

There is a lot of evidence for the presence of integers characterizing Fermat integers in living systems. For instance, the so called scaling law of [I1] [K33] states that radiation with frequency f_l is accompanied by a radiation with frequency $f_h \simeq 2 \times 10^{11} f_l$. The scaling factor 2×10^{11} corresponds with 1.5 per cent accuracy to the integer $n_F = 2^{36} \times 3 \simeq 2.03 \times 10^{11}$ defining a Fermat polygon. This suggests an interpretation in terms of a decay of dark photon with a given wave-length to a bundle of n_F ordinary photons with the same wavelength. The energy of the dark photon would be by a factor n_F higher. This process could serve as an effective tool of bio-control. Dark photon could also transform to an ordinary photon with wavelength shorter by factor $1/n_F$. Quite generally, integers n_F defining Fermat polygons are a reasonable guess for the generalization of the scaling law of homeopathy and the search for these scaling factors could provide an experimental means of identifying the values of Planck constant relevant for living matter.

Even the time units of everyday life could reflect the properties of the dark matter hierarchy responsible for the control of living matter, in particular those of the sub-hierarchy defined by Fermat polygons. Indeed, one year corresponds to $n_F = 4 \times 3$ months, one month to $n_F = 2 \times 3 \times 5$ days, one day to $n_F = 8 \times 3$ hours, one hour to $n_F = 60 = 4 \times 3 \times 5$ minutes, and one minute to $n_F = 60$ seconds.

3. Chromosomes and exotic quarks?

Helices within helices could give rise to hierarchies of cognitive representations. Magnetic flux tubes can have complex helices inside helices hierarchies and in this case the number of units basically consisting of super-conducting ions or of their Cooper pairs per single period at given level of hierarchy should be prime for a given loop.

Chromosomes are characterized by this kind of hierarchy of coiling and looping which helps to pack chromosome DNA (about 2 meters in humans) in a small volume. This hierarchy could give also make possible a hierarchy of cognitive codes corresponding to the space-time sheets defining the hierarchy. What makes this hierarchy so interesting is that the p-adic length scales in question correspond to the miracle length scales defined by Gaussian Mersennes corresponding to $k = 151, 157, 163$ and 167. The diameter of the largest structure involved with chromosomes is about .7 micrometers whereas the smallest structure has diameter of 11 nanometers. Thus all three primary p-adic scaled up electron Compton lengths ($k = 151, 157, 163$) could be realized and three levelled hierarchy is possible.

1. If the principle of realization is same as for the memetic code based on the pair $k = 127, 120$ (electron CD containing a sequence of quark CDs), the following picture suggests itself. $k = 157$ codon has $n = 2^{157-151} = 64$ bits of duration $T(2, 151)$, $k = 163$ codon has $n = 64$ bits of duration $T(2, 157)$, and $k = 167$ codon has $n = 2^{167-163} = 4$ bits of duration $T(2, 163)$.

   The realization in terms of exotic light quarks quarks would involve only temporal sequences of n sub-CDs. The secondary p-adic time scales determining the time scale of the corresponding CD and thus the time duration of codon are rather long: about 2×10^6 s for $k = 151$ and 10^8 seconds for $k = 157$. A test for this idea is whether the numbers of the basic units per period of helix at various levels are given $n = 32, 32$, and 8 DNA nucleotides (not that these numbers do not correspond to full number of codons).

2. The realization analogous to genetic code would involve $n = 157 - 151 = 6$ bits (genetic code), $n = 163 - 57 = 6$ bits, and $167 - 163 = 4$ bits.

3. One can also consider the possiblity that the number of bits is determined by the p-adic prime characterizing the space-time sheet involved and thus equal to $k = 151, 157, 163$. In this case the duration of bit would not correspond to a secondary p-adic time scale as it does for the memetic code.

Realization of finite projective geometries using Platonic and Archimedean solids

For projective geometries the realization as Platonic solids in the sense that the projective symmetry group acts as group of symmetries of the Platonic solid are possible only for $p = 2, 3, 5$ cases. The 5 Platonic solids are tetrahedron, cube and octhedron, and icosahedron and dodecahedron. The basic transformation is duality changing faces and vertices. tetrahedron (4 vertices and 4 faces) is self dual whereas cube (8 vertices and 6 faces) and octahedron (6 vertices and 8 faces) are duals of each other, as are also icosadedron (12 vertices and 20 faces) and dodecahedron (20 vertices and 12 faces). The number of edges is fixed by the Euler characteristic of sphere (solids are topologically spheres) given in terms of the numbers of vertices, edges, and faces by $V - E + F = 2$ and one has $E = V + F - 2$ giving for the number of edges $E = 6, 12, 30$ in the three cases respectively. Archimedean solids allow different types of faces and hexagons, octagons and decagons are possible (note that the number of vertices for faces is not prime anymore). Archimedean solids have same symmetry groups as Platonic solids from which they are obtained by "truncations".

It is interesting to look how the symmetry groups of finite geometries can be realized as symmetries of Platonic and some Archimedean solids.

1. For $p = 2$ the group of projective symmetries corresponds to the 6-element group S_3 of permutations of three objects acting on triangle and being generated by 2- and 3-fold symmetries. The 3 vertices represent the 3 points of the projective geometry and the generator of Z_2 acts as a reflection permuting any pair of these points with the third point representing the point at infinity. The three faces of tetrahedron give rise to a representation of $p = 2$ finite geometry too. By assigning to each of these vertices a two-state system one obtains a representation for M_2. Tetrahedron allows M_2^2 representation with information content of 4 bits.

2. $p = 3$ projective geometry has four points and has the permutation group S_4 of four objects as a symmetry group. This group is the symmetry group of tetrahedron and the vertices of any face realize the finite geometry with three points with the fourth vertex taking the role of the point at infinity. Also octahedron and cube having symmetry group generated by 2-, 3- and 4-fold symmetries allow realization of the $p = 3$ finite geometry but not an isometric realization of the projective geometry since the tetrahedron defined by the 3 vertices nearest to a given vertex is not regular. 3-fold symmetries are rotations along diagonals. M_3 cognitive representation results by assigning to the 3 vertices of triangle, tetrahedron or cube two-state systems.

3. The symmetry group of $p = 5$ finite projective geometry and thus also the geometry are represented by dodecahedron and icosahedron which are dual to each other by vertex-face transformation, as well as by a truncated icosahedron, "bucky ball", having 60 vertices and directly representing the projective group associated with the corresponding finite geometry [A6]. This group is isomorphic with the group A_5 of even permutations of 5 objects and contains 2-, 3-, and five-fold elements. The coset space of $A_5/Z_2 \times Z_5$ represents the projective space and consists of 6 pairs of opposite and disjoint pentagons representing the points of the finite projective geometry.

The points of the finite geometry are represented by a single pentagon as is clear from the fact that the cyclic group Z_5 acts on these pentagons) M_5 representation results by assigning to the vertices of any pentagon a two-state system. System allows actually much more: there are 12 disjoint pentagons so that M_5^{12} code can be realized with information content of 60 bits! Thus truncated icosahedron has an exceptional capacity for coding intentions and this might be the reason for why it is the geometry of the clathrin molecules which take care of logistics in cellular systems.

All platonic solids except tetrahedron allow also lattice structures. Therefore cognitive structures allowing symbolic representations in terms of molecular and lattice structures based on Platonic solids are expected to be of fundamental importance. These correspond to correspond to 2, 3, and 5 bit codes and Mersennes M_2, M_3, M_5. M_2 corresponds to geometry of a line interval/triangle, M_3 to triangle/tetrahedron, and M_5 to pentagon/icosahedron, dodecahedron or truncated icosahedron depending on whether one requires projective extension or not. The codes would be represented by assigning to the substructures representing the finite geometry a two-state system. For instance, electric polarization of the protein structure in electric field at larger space-time sheet could define the spinlike variable. By using lattice like structure formed by basic units one obtains products of representations of type M_n^k.

Finite geometries appear naturally in p-adic context and Platonic solids suggests that the primes $p = 2, 3, 5$ and corresponding p-adicities are in special position. Generalized p-adic length scale hypothesis implied by NMP suggests that also the primes new powers of these primes are important. What is intriguing that the times assignable to jumps in biological evolution seems to correspond to powers of 3 for fundamental time scale (`http://tinyurl.com/ycesc5mq`) [I9]. The appearance of Golden mean in biology in turn suggests that 5-adicity is also present. Note however that Golden Mean requires algebraic extension of rationals containing $\sqrt{5}$. What is especially interesting that the model of music harmony and genetic code to be discussed in following involves icosahedron, which corresponds to $p = 5$ finite geometry.

Icosahedral model for music harmony and genetic code

The model for music harmony and genetic code [K65] represents the most recent work, which could be possibly interpreted in terms of discrete 2-D geometries assignable to partonic 2-surfaces. Platonic solids represent the most symmetric discrete geometries assignable to sphere. Icosahedron and tetrahedron represent two Platonic solids and appear in the model.

The work relies on two observations. The number of notes of 12-note scale is same as the number of vertices of icosahedron. Icosahedron has 20 faces, which is the number of amino-acids in standard genetic code. There are however some non-standard features: 2 additional amino-acids appear in Nature and the coding of stop codons is not always the same - as if two codes were present or code is context dependent.

So called quint rule allows to represent 12-note scale as a sequence of 3/2 scalings for the fundamental frequency of the scale. Nearest neighbors at the icosahedron would differ by quint as notes which would mean 3-adic notion of distance for frequencies. There is however a little problem: 12 scalings give 7 slightly more than 7 octaves. Well-tempered scale solves the problem but those with absolute ear like Pythagorean scale. The problem can be also solved by allowing 13:th note very near to one of the 12 notes.

The proposal is that 12-note scale corresponds to a self-non-intersecting closed (by octave equivalence) curve at icosahedron connecting neighboring points. Geometrically non-equivalent curves would correspond to different harmonies defined by the 3-chords assignable to the 20 faces of the icosahedron. These 20 faces would also correspond to amino-acids and also 20 DNAs which indeed consists of 3 nucleotides. The closed curves in question are known as called Hamiltonian cycles and there are 17 cycles altogether. 6 cycles do not have any symmetries. The remaining cycles have symmetry groups $Z_6, Z_4, Z_{2,rot}, Z_{2,refl}$ and their total number is 1+ 2+3+ 5=11.

60 DNAs can be regarded as a fusion of 3-harmonics corresponding to Z_6, Z_4 and Z_2 symmetry groups and one obtains 256 different bio-harmonies having possibly interpretations as correlates for emotional moods (music harmony both represents and generates emotions). It is proposed that the DNA codons are represented as chords defined by dark photon triplets and having frequency spectrum in the same region as ordinary music notes. The transformation between these two representation could take place routinely in living matter.

4 DNAs and also the 2 additional amino-acids are obtained in two ways. By fusing tetrahedron along its face to icosahedron and fusing the codes - this corresponds to adding 13:th note to the 12-note scale - or by keeping icosahedron and tetrahedron as distinct. One would have two separate genetic codes and this would explain the non-uniqueness of genetic code in some situations

as well as the 2 additional amino-acids. An interesting possibility is that the two DNA strands talk different languages so that the two codes would correspond to the two DNA strands!

Clathrin molecule and cognition

Icosahedral structure representing $p = 5$ finite geometry populate biology. Water molecular clusters have icosahedral structure or its dual dodecahedral structure defining also $p = 5$ finite geometry. Chlatrin molecule is a further example.

Clathrin molecule [J67] is involved with the transfer of various kinds of cargo through the cell membrane and also through intracellular membranes. Even viruses use clathrin molecule coating. Clathrin molecule induces a pit in the cell membrane and membrane pinches so that clathrin molecule providing coating for a piece of cell membrane and containing the cargo ends up to the cell interior. An area of cell membrane of football plane corresponding to that contained by entire brain is generated during one hour when clathrins coat cell membrane containing receptors and take it inside the cell. The generation of new cell membrane with this gigantic rate should involve huge dissipative losses unless macro-temporal quantum coherence is involved in the process.

Perhaps this argument alone convinces one day anyone about the presence of macro-temporal quantum coherence in brain. Clathrin molecule has the geometry of a truncated icosahedron, also the geometry of the soccer ball and fullerene or buckyball molecule C_{60} containing 60 carbon atoms arranged to the vertices of the truncated icosahedron. In clathrin molecule carbon atoms are replaced by three-legged triskelion molecules consisting of proteins. It is interesting to take a more careful look on the geometry of truncated icosahedron defining the geometry of the clathrin molecule, if not anything else, the for the purpose to get a glimpse about the amazing number theoretical regularities of this structure. Truncated icosahedron has 60=59+1 vertices, 90=89+1 lines, and 12=11+1 pentagonal and 20=19+1 hexagonal faces. Pentagonal faces are disjoint. 6 pentagonal face pairs can be naturally interpreted as points of a finite projective geometry associated with finite field $G(5, 1)$.

What it is interesting is that all these numbers are of form $p + 1$, p prime. With one exception (59) these primes also define Mersennes of Gaussian Mersennes. As a matter fact, the number of faces, edges, and vertices are of this form for all Platonic solids and also for several Archimedean solids. The interpretation in terms of a finite projective geometries suggests itself but the requirement that the symmetries of finite geometry are realizable as rotations excludes this interpretation since these substructures are not representations of the corresponding projective group realized in terms of rotations. Of course, one must keep mind open for the possibility that the embedding of the symmetry group to rotation group is not necessary.

Clathrin molecule is an excellent candidate for a very effective realization of molecular cognition. If the triskelion proteins at the vertices of disjoint pentagons are electrically polarizable, a dynamical M_5^{12} representation with information content of 60 bits becomes possible by controlling the electric field at the space-time sheet at which the triskelions are condensed at. This information could relate to the basic function of clathrin molecules but also the idea that clathrin molecules transfer also information besides matter must be considered. For instance, this representation could be involved with the transfer of not only the neurotransmitters but also of (micro-tubular?) information from post- to pre-synaptic neurons.

3.6.4 Application Of Ideas To Micro-Tubuli And Clathrin Molecules

The proposed general principle allow to develop detailed views about what kind of cognitive representations that various molecular structure can accommodate. There is a considerable freedom concerning the choice of the representative system and spin flips or analogous transitions can be amplified to magnetization type quantum phase transitions at higher levels of the self hierarchy.

Micro-tubular representations

Micro-tubuli [J28, J67] are formed as hexagonal lattices of tubulin dimers on cylinder. The two conformations of a tubulin dimer define the two states of the micro-tubular representations. In an external electric field along micro-tubule at the larger space-time sheet the second tubulin conformation is unstable and the codeword is realized as a phase transition leading to the ground state. Spontaneous electric polarization of all tubulins in the same direction forced by an electric field in the direction of the micro-tubule defines the ground state. The ground state itself cannot give rise to conformational flips and thus cannot define a codeword and one obtains M_{13} rather than 2^{13} codewords realizable as a signal resulting in the flip to the ground state.

1. Basic picture Micro-tubuli have helical structure: there are two helical strands with 13-

micro-tubule periodicity. A full 2π twist for a tubulin dimer strand corresponds to 13 dimers and corresponds to vertical distance of 8 resp. 5 micro-tubules for the two arrays involved. Thus a full 2π twist defines naturally the codeword and corresponds to 13-bit M_{13} codeword. Each tubulin dimer strand defines a codeword: M_{13}^{13} representations with an information content of $13^2 = 169$ bits associated with single 13-plet of codewords results.

The small value of $p = 13$ means an extreme flexibility concerning the duration of the cognitive code word. All $2^{13k/2} \sim 90.51^k$ multiples of T_{13} are possible. An interesting working hypothesis is that the number N of the tubulin strands contributing to the codeword defined by single connected structure defines the duration of the codeword as $T(N) = 2^{N\times 13/2}T_{13}$.

1. If the $k = 21$ micro-tubules at the wall of micro-tubule doublet contribute give rise to the DNA representation, this rule would predict the duration of the code word to be $T = 2^{(21-13)\times 13/2}T(169) \simeq 67.7$ seconds with the duration of bit about 5.6 seconds, which is somewhat longer than the mysterious time scale of 5 seconds associated with the Comorosan effect [K99]. $k = 20$ would give a codeword with a duration of .8 seconds and with the duration of bit about 62 milliseconds. DNA should control the behavior of micro-tubules in a rather long time scale (translation of single amino-acid takes 1/20 seconds) and these timescales sound rather reasonable.

2. For triplets of micro-tubuli the number of tubuli in the wall is something like 29 and the rule would predict completely unrealistic duration of the codeword about 10^7 years. It seems that the time scale should be same as for doublet: note that only pairs of tubuli have direct contact in the triplet.

3. Micro-tubular representation would correspond to the duration $T(13^2) = T(169)$ the cognitive codeword which is about 1.7×10^{-14} seconds, which is much shorter than the time scale of conformational dynamics and corresponds to the time scale of infrared transitions. This time scale is considerably shorter than the time scale $\sim .1$ nanoseconds associated with the protein conformational dynamics so that some other spin or rpolarization type variable should define the representation if it is realized at all. Neutrino spin is an excellent candidate in this respect. By increasing $k = 13$ to $k = 15$ gives time scale of order.1 nanoseconds. It seems that the working hypothesis could give rough ideas about orders of magnitude but cannot be taken literally.

2. Cilia and centriole

Centriole resp. cilia are arrangements of micro-tubules containing 9 bundles of 3 resp. 2 micro-tubules at the boundary of cylinder like structure and possibly also a doublet of micro-tubuli in the center [J67].

Micro-tubule doublets are associated with cilia crucial for the movement of monocellulars. Cilia consists of nine micro-tubule doublets at the surface of cylinder and one doublet in the center: also two separate micro-tubules are possible in the center. Some tubulin strands (usually three) are lacking from the second fused micro-tubule. According to some sources, the total number of tubulin dimer strands in doublet is 24 and 21 at the outer surface of doublet. 21 is Fibonacci number associated with the micro-tubular sequence of Fibonacci numbers and also the number of DNA triplets in cognitive codes. The complex of 21 tubulin dimer strands would be ideal for coding of M_{13}-bit sequences possibly associated with DNA or amino-acid sequences of 21 units and containing $21 \times 13 = 273$ bits of information. The code words associated with the wall of the cilium define $M_{13}^{9\times 21}$ representation with $13 \times 9 \times 21 = 2457$ bits.

Centriole are crucial for the control of the movement of the cell and are present only in motile cells (not in plants). If nucleus controls the movement of cell, centrioles and cilia should communicate with DNA in both directions in the act of transforming intentions to actions. T shaped centriole form an ideal antenna structure and could communicate both classically and quantally in terms of MEs. Centriole have 9 micro-tubule triplets at the boundary of a cylinder. Various sources give different values for the total number of strands but it seems that the total number of tubulin strands is about 33-34 and outer wall contains about 4 strands. Perhaps it deserves to be noticed that the total number of strands is near to Fibonacci number 34 associated with the micro-tubular sequence of Fibonacci numbers. In case of centriole the 9 fused triplets of micro-tubules at the boundary each triplet containing about 33 tubulin dimer strands should give rise to a representation $M_{13}^{9\times 33}$ with $13 \times 9 \times 33 = 3861$ bits. Huge amounts of information are involved.

3. Neuronal micro-tubuli

Neurons, which are not motile cells, do not have the usual T shaped centriole structure. Micro-tubuli are however there and start from the region near nucleus and connect this region to the dendrites and to the end of the axon. The micro-tubuli associated with the axons can be very long, up to millimeters and are connected together by MAPs, micro-tubule associated proteins. This strongly suggests that micro-tubuli participate in an essential manner to neuronal communications or to short term information storage. For instance, the propagation of the nerve pulse could alter the electric field of the micro-tubule space-time sheet temporarily and give rise to spin glass state and thus induce representations of cognitive states in terms of tubulin conformations. The return of the membrane potential to the normal value would induce the conscious reading of the resulting representations. The minimal reason for this would be that axonal micro-tubules are responsible for the transfer of neurotransmitters to the axonal end and they must be cognizant about the overall nerve pulse activity.

Against the impressive representational capacity of micro-tubules the idea that nerve pulse involves the transfer of only single bit of information seems weird. Rather, the picture about micro-tubules would suggest that nerve pulse propagation are accompanied by a propagation of conformational spin glass state in the depolarized portion of the axon carrying information, and that one important function of the nerve pulse is to allow the propagation of the conformational wave carrying the information. Of course, also cell membrane could carry informational wave by same mechanism and one could see the events in the axonal membrane also as a realization of p-adic intentions basically. An objection against this view is related to the problem how the micro-tubular signal is transferred between micro-tubuli at MAPs. This is obviously needed if information from micro-tubuli is transferred to postsynaptic neuron. One must seriously consider the possibility is that the information is received only by micro-tubuli and their form an essential part of the conscious sensory pathway. This would explain why the lengths of micro-tubuli associated with sensory pathways are maximized (the information from given side of the body goes to the opposite brain hemisphere).

What about cell membrane?

Cell membrane electric field makes it ideal for the realization of cognitive representations. Lipid molecules and membrane proteins are natural good candidates for representing the bit sequences represented as two different electric polarizations of proteins. The propagation of nerve pulse could generate a representation during de-polarization phase which would be read when membrane potential has returned to its original value. The function of the nerve pulse would be thus to inform entire axon consciously.

3.7 Cognition And Number Theory

The identification of p-adic physics as physics of cognition and intention suggests strongly connections between cognition, intentionality, and number theory. The new idea is that also real transcendental numbers can appear in the extensions of p-adic numbers which must be assumed to be finite-dimensional at least in the case of human cognition. This idea, when combined with a more precise model for how intentions are transformed to actions, leads to a series of number theoretical conjectures. Also new insights about the number theoretical origin of the universal dynamics of conformally invariant critical systems emerge. The earlier approaches to the proof of Riemann hypothesis can be understood in a unified manner and the assumption that Riemann Zeta exists in all number fields when finite extensions are allowed for p-adic numbers leads to the view that the zeros of Riemann Zeta correspond to the universal number theoretically quantized spectrum of scaling momenta associated with critical conformally invariant systems.

3.7.1 Conceptual And Technical Problems Related To P-Adicization

The following two ideas serve as guide lines in the attempt to relate cognition and number theory to each other so that number theory would allow to construct a more detailed view about the realization of intentionality and cognition.

One must face also several technical problems stimulating in turn ideas and in the following some of them are discussed.

1. Real and p-adic number fields form and adelic book like structure with pages represented by number fields glued together along rationals forming the rim of the book. For the extensions of p-adic numbers further common points result and the book becomes fractal if all possible extensions are allowed. This picture generalizes to the level of the embedding space and allows to see space-time surfaces as consisting of real and p-adic space-time sheets belonging to various extensions of these numbers. Gluing of the sheets to a book-like structure is however carried out at the level of parameter space defined by an algebraic extension of rationals. This generalized view about numbers gives hopes about an un-ambigious definition of what some number, say e, appearing in an extension of p-adic numbers really means.

   It is now clear that adelic view is the only mathematically feasible one and is made possible by the strong form of holography [K95]. The key notion is what I have called intersection of reality and various p-adicities. This intersection can be identified as string world sheets and partonic 2-surfaces parameterized by numbers in some algebraic extension of rationals. These extensions define a cognitive hierarchy since fermions reside at these 2-surfaces already from the condition that electric charge is well-defined.

   Discretization and real-p-adic correspondence via canonical identification as already in p-adic mass calculations for various group invariants - in particular the Lorentz invariants appearing in the scattering amplitudes - takes therefore therefore at more abstract level than originally thought. This allows to circumvent problems with various symmetries encountered if one maps real space-time surfaces to their p-adic counterparts locally. Only for partonic 2-surfaces the concrete discretization by common points in algebraic extension for real and partonic 2-surfaces makes sense.

   The roughest parametrization for the algebraic extension of rationals is by the degree of the polynomial defining it and the so called ramified primes. These parameters have a physical meaning too, and are expected to central for the understanding of cognitive hierarchy. Ramified primes indeed correspond to preferred p-adic primes for which additional degrees of freedom emerge.

   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 [K52]. 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 the preferred primes satisfy p-adic length scale hypothesis or its generalization from $p = 2$ to small primes remains an open question.

   The value of effective Planck constant $h_{eff}/h = n$ corresponds to the number of sheets of some kind of covering space defined by the space-time surface. The discretization of the space-time surface identified as a monadic manifold [L17] with embedding space preferred coordinates in extension of rationals defining the adele has Galois group of extension as a group of symmetries permuting the sheets of the covering group. Therefore $n = h_{eff}/h$ would naturally correspond to the dimension of the extension dividing the order of its Galois group.

2. The first new idea is roughly that the discovery of notion of any algebraic or transcendental number x (such as Φ or e) involves a quantum jump in which there is generated a p-adic space-time sheet for which the existing finite-dimensional extension of p-adic numbers is replaced by a finite-dimensional extension involving also x. Also some higher powers of the number are involved. For instance, for e $p-1$ powers are necessarily needed (e^p exists p-adically).

3. The points of M^4_+ with integer valued Minkowski coordinates using CP_2 length related fundamental length scale as a basic unit is a good guess for the subset of M^4_+ defining the rational points of the M^4_+ involved. CP_2 coordinates as functions of M^4_+ coordinates should be rational or belong to some finite-dimensional extension of p-adics. Of course, also rational points of M^4_+ are possible, and the evolution of cognition should correspond to the increase of the algebraic dimension of the extension.

4. A very powerful hypothesis is that the p-adic and real functions have the same analytic form. This makes possible to construct scattering amplitudes by algebraic continuations from the intersection of reality and p-adicities (the back of the book-like structure defined by 2-surfaces with parameters in algebraic extension of rationals). This assumption favors functions which allow at some point (most naturally origin) a Taylor series with rational valued Taylor coefficients.

Is e an exceptional transcendental?

Neper number is obviously the simplest one and only the powers e^k, $k=1,...,p-1$ of e are needed to define p-adic counterpart of e^x for $x=n$. In case of trigonometric functions deriving from e^{ix}, also e^i and its $p-1$ powers must belong to the extension.

An interesting question is whether e is a number theoretically exceptional transcendental or whether it could be easy to find also other transcendentals defining finite-dimensional extensions of p-adic numbers.

1. Consider functions $f(x)$, which are analytic functions with rational Taylor coefficients, when expanded around origin for $x>0$. The values of $f(n)$, $n=1,...,p-1$ should belong to an extension, which should be finite-dimensional.

2. The expansion of these functions to Taylor series generalizes to the p-adic context if also the higher derivatives of f at $x=n$ belong to the extension. This is achieved if the higher derivatives are expressible in terms of the lower derivatives using rational coefficients and rational functions or functions, which are defined at integer points (such as exponential and logarithm) by construction. A differential equation of some finite order involving only rational functions with rational coefficients must therefore be satisfied (e^x satisfying the differential equation $df/dx=f$ is the optimal case in this sense). The higher derivatives could also reduce to rational functions at some step ($log(x)$ satisfying the differential equation $df/dx=1/x$).

3. The differential equation allows to develop $f(x)$ in power series, say in origin

$$f(x)=\sum f_n\frac{x^n}{n!}$$

such that f_{n+m} is expressible as a rational function of the m lower derivatives and is therefore a rational number.

The series converges when the p-adic norm of x satisfies $|x|_p\leq p^k$ for some k. For definiteness one can assume $k=1$. For $x=1,...,p-1$ the series does not converge in this case, and one can introduce and extension containing the values $f(k)$ and hope that a finite-dimensional extension results.

Finite-dimensionality requires that the values are related to each other algebraically although they need not be algebraic numbers. This means symmetry. In the case of exponent function this relationship is exceptionally simple. The algebraic relationship reflects the fact that exponential map represents translation and exponent function is an eigen function of a translation operator.

The necessary presence of symmetry might mean that the situation reduces always to either exponential action. Also the phase factors $exp(iq\pi)$ could be interpreted in terms of exponential symmetry. Hence the reason for the exceptional role of exponent function reduces to group theory.

Also other extensions than those defined by roots of e are possible. Any polynomial has n roots and for transcendental coefficients the roots define a finite-dimensional extension of rationals. It would seem that one could allow the coefficients of the polynomial to be functions in an extension of rationals by powers of a root of e and algebraic numbers so that one would obtain infinite hierarchy of transcendental extensions.

Does the integration of complex rational functions lead to rationals extended by a root of e and powers of π?

These cold showers suggest that the best one might hope is that the numbers like $log(p)$ and $log(\Phi)$ could be proportional to some power π with a coefficient which belongs to a finite extension of p-adic numbers containing e. This might make it possible to continue the theory to p-adic context and also make very strong predictions.

The elementary differential and integral calculus provides important hints for as how to proceed. Derivation takes rational functions to rational functions unlike integration since the integrals of $1/x$ and and $1/(1+x^2)$ give $log(x)$ and $arctan(x)$ leading outside the realm of rational numbers. One can go to complex plane and consider the integrals of complex rational functions with complex rational coefficients and here one encounters integrals over closed curves and between two points. The rational approach is to consider rational complex plane, and first restrict to Gaussian integers which allow primes.

1. The first observation is that residy calculus for rational functions gives always integrals which are of form $2\pi iq$, q a rational number.

2. The integral $I=\int_a^b dz/z$, $a=m_1+in_1$, $b=m_2+in_2$ in turn gives

$$I = log(a/b) = \frac{1}{2}\left(log(m_2^2+n_2^2) - log(m_1^2+n_1^2)\right)$$
$$+i(arctan(n_2/m_2) - arctan(n_1/m_1)) \ .$$

1. The strongest hypothesis would be that logarithm and arctan are also rationally proportional to π so that all integrals of this kind lead to an infinite-dimensional transcendental extension of p-adic numbers containing π. The strong hypothesis cannot be correct. Consider arcus tangent as an example. $arctan(m/n) = r\pi/s$ would imply $tan(r\pi/s) = m/n$, and this cannot hold true since it would imply that s: th powers of Gaussian integer $n+im$ would give an ordinary integer. This would be also true for Gaussian primes and the decomposition of Gaussian integers as products of Gaussian primes would become non-unique. There is this kind of uniqueness but this is due the units $exp(i\pi/4)$ and its powers. Indeed, $arctan(1) = \pi/4$ and proportional to π.

2. One can overcome this difficulty by replacing the ansatz with

$$arctan(q) = e^{q_1(q)}q_2\pi$$

such that $q_1(q)$ is non-vanishing for $q \neq \pm 1 \pm i$ corresponding to the units of Gaussian primes. This ansatz is completely analogous to the ansatz for $log(p)$. The beauty of this ansatz would be that the imaginary parts for the integral of $1/(z-z_0)$ between complex rational points would be proportional to π irrespective of whether the integration is over a closed or open curve. The real parts of complex integrals in turn would be proportional to $1/\pi$ of $log(p) \propto 1/\pi$ ansatz holds true.

The requirement that complex integrals are powers of π could also mean quantization of topology in TGD framework. For instance, the conformal equivalence classes of Riemann surfaces of genus g are represented by period integrals of 1-forms defining elements of cohomology group H^1 over the circles representing the elements of homology group H_1. Restricting the cohomology to a rational cohomology, the periods with standard normalization would be quantized to complex rationals multiplied by a power of π. For surfaces characterized by a given power of π one might perhaps perform the p-adicization finite-dimensionally by suitable normalizations by powers of π.

3.7.2 Should One Allow Also Transcendentals In The Extensions Of P-Adic Numbers?

TGD inspired theory of consciousness leads to the identification of p-adic physics as physics of cognition. This identification leads to a rather fascinating new ideas concerning the characterization of intentional systems.

The basic ingredient is the new view about numbers: real and p-adic number fields are glued together like pages of a book along common rationals representing the rim of the book. This generalizes to the extensions of p-adic number fields and the outcome is a complex fractal book like structure containing books within books. This holds true also for manifolds and one ends up to the view about many-sheeted space-time realized as 4-surface in 8-D generalized embedding space and containing both real and p-adic space-time sheets. The transformation of intention to action corresponds to a quantum jump in which p-adic space-time sheet is replaced with a real one.

One implication is that the rationals having short distance p-adically are very far away in real sense. This implies that p-adically short temporal and spatial distances correspond to long real distances and that the evolution of cognition proceeds from long to short temporal and spatial scales whereas material evolution proceeds from short to long scales. Together with p-adic non-determinism due the fact that the integration constants of p-adic differential equations are piecewise constant functions this explains the long range temporal correlations and apparent local randomness of intentional behavior. The failure of the real statistics and its replacement by p-adic fractal statistics for time series defined by varying number N of measurements performed during a fixed time interval T allows very general tests for whether the system is intentional and what is the p-adic prime p characterizing the "intelligence quotient" of the system. The replacement of $log(p_n)$ in the formula $S = -\sum_n p_n log(p_n)$ of Shannon entropy with the logarithm of the p-adic norm $|p_n|_p$ of the rational valued probability allows to define a hierarchy of number theoretic information measures which can have both negative and positive values.

Since p-adic numbers represent a highly number theoretical concept one might expect that there are deep connections between number theory and intentionality and cognition. The discussions with Uwe Kämpf in CASYS′2003 conference in Liege indeed stimulated a bundle of ideas allowing to develop a more detailed view about intention-to-action transformation and to disentangle these connections. These discussions made me aware of the fact that my recent views about the role of extensions of p-adic numbers are perhaps too limited. To see this consider the following arguments.

1. Pure p-adic numbers predict only p-adic length scales proportional to $p^{n/2}l$, l CP_2 length scale about 10^4 Planck lengths, $p \simeq 2^k$, k prime or power of prime. As a matter fact, all positive integer values of k are possible. This is however not enough to explain all known scale hierarchies. Fibonacci numbers $F_n : F_n + 1 = F_n + F_{n-1}$ behave asymptotically like $F_n = kF_{n-1}$, k solution of the equation $k^2 = k+1$ given by $k = \Phi = (1+\sqrt{5})/2 \simeq 1.6$. Living systems and self-organizing systems represent a lot of examples about scale hierarchies coming in powers of the Golden Mean $\Phi = (1+\sqrt{5})/2$. According to Selvam [H1] also meteorological phenomena involve spiral waves characterized by Golden Mean.

   By allowing the extensions of p-adics by algebraic numbers one ends up to the idea that also the length scales coming as powers of x, where x is a unit of algebraic extension analogous to imaginary unit, are possible. One would however expect that the generalization of the p-adic length scale hypothesis alone would predict only the powers $\sqrt{x}p^{n/2}$ rather than $x^k p^{n/2}$, $k = 1, 2, ...$ Perhaps the purely kinematical explanation of these scales is not possible and genuine dynamics is needed. For sinusoidal logarithmic plane waves the harmonics correspond to the scalings of the argument by powers of some scaling factor x. Thus the powers of Golden Mean might be associated with logarithmic sinusoidal plane waves.

2. Physicist Hartmuth Mueller has developed what he calls Global Scaling Theory [B2] based on the observation that powers of e (Neper number) define preferred length scales. These powers

associate naturally with the nodes of logarithmic sinusoidal plane waves and correspond to various harmonics (matter tends to concentrate on the nodes of waves since force vanishes at the nodes). Mueller talks about physics of number line and there is great temptation to assume that deep number theory is indeed involved. What is troubling from TGD point of view that Neper number e is not algebraic. Perhaps a more general approach allowing also transcendentals must be adopted. Indeed, since e^p is ordinary p-adic number in R_p, a finite-dimension transcendental extension containing e exists.

3. Classical mathematics, such as the theory of elementary functions, involves few crucially important transcendentals such as e and π. This might reflect the evolution of cognition: these numbers should be cognitively and number theoretically very special. The numbers e and π appear also repeatedly in the basic formulas of physics. They however look p-adically very troublesome since it has been very difficult to imagine a physically acceptable generalization of such simple concepts as exponent function, trigonometric functions, and logarithm resembling its real counterpart by allowing only the extensions of p-adic numbers based on algebraic numbers.

4. Number theoretic entropies measured in bits are proportional to $log(p)/log(2)$. The idea that these entropies are rational fractions of bit is attractive and implies that $log(p)$ for all primes is proportional to the same transcendental number. This would mean that logarithm of the rational number field would be a transcendental multiple of rationals.

These considerations stimulate the question whether, besides the extensions of p-adics by algebraic numbers, also the extensions of p-adic numbers involving e, and perhaps even $\pi andother$ transcendentals might be needed. The intuitive expectation motivated by the finiteness of human intelligence is that these extensions might have finite algebraic dimensions. On the other hand, if one is only interested in quantities derived from phases $exp(i2\pi/n)$, a finite-dimensional algebraic extension is enough. π is needed only if one wants to deal with say length of circle's circumference in the p-adic context, and one could argue that p-adic Riemann geometry is local and only about angles and infinitesimal distances.

Second question is whether there might be some dynamical mechanism allowing to understand the hierarchy of scalings coming in powers of some preferred transcendentals and algebraic numbers like Golden Mean. Conformal invariance implying that the system is characterized by a universal spectrum of scaling momenta for the logarithmic counterparts of plane waves seems to provide this mechanism. This spectrum is determined by the requirement that it exists for both reals and all p-adic number fields assuming that finite-dimensional extensions are allowed in the latter case. The spectrum corresponds to the zeros of the Riemann Zeta if Zeta is required to exist for all number fields in the proposed sense, and a lot of new understanding related to Riemann hypothesis emerges and allows to develop further the previous TGD inspired ideas about how to prove Riemann hypothesis [L1] , [H2].

3.7.3 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.

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 $m_BX/s_F + n_Bs_F$, $X = \prod_i p_i$ (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 might generalize to quaternionic and even 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.

A connection with infinite primes?

Infinite primes are one of the mathematical outcomes of TGD [K83]. There are two kinds of infinite primes. There are the analogs of free many particle states consisting of fermions and bosons labelled by primes of the previous level in the hierarchy. They correspond to states of a supersymmetric arithmetic quantum field theory or actually a hierarchy of them obtained by a repeated second quantization of this theory. A connection between infinite primes representing bound statesandirreducible polynomials is highly suggestive.

1. The infinite prime representing free many-particle state decomposes to a sum of infinite part and finite part having no common finite prime divisors so that prime is obtained. The infinite part is obtained from "fermionic vacuum" $X = \prod_k p_k$ by dividing away some fermionic primes p_i and adding their product so that one has $X \to X/m + m$, where m is square free integer. Also $m = 1$ is allowed and is analogous to fermionic vacuum interpreted as Dirac sea without holes. X is infinite prime and pure many-fermion state physically. One can add bosons by multiplying X with any integers having no common denominators with m and its prime decomposition defines the bosonic contents of the state. One can also multiply m by any integers whose prime factors are prime factors of m.

2. There are also infinite primes, which are analogs of bound states and at the lowest level of the hierarchy they correspond to irreducible polynomials $P(x)$ with integer coefficients. At the second levels the bound states would naturally correspond to irreducible polynomials $P_n(x)$ with coefficients $Q_k(y)$, which are infinite integers at the previous level of the hierarchy.

3. At the lowest level the polynomials defined by infinite primes correspond to irreducible polynomials characterizing irreducible algebraic extensions. Infinite bound state integers in turn would characterize non-irreducible extensions. Since the algebraic extensions of rationals define a hierarchy identified as giving rise to evolutionary hierarchy based on increasing algebraic complexity and increasing representative capacity, there indeed would be a connection with the infinite primes at the first level of hierarchy at least.

4. What is remarkable that bound state infinite primes at any level of hierarchy would define maximally ramified algebraic extensions at previous level. One indeed has infinite hierarchy of infinite primes since the infinite primes at given level are infinite primes in the sense that they are not divisible by the primes of the previous level. The formal construction works as such. Infinite primes correspond to polynomials of single variable at the first level, polynomials of two variables at second level, and so on. Could the Langlands program could be generalized from the extensions of rationals to polynomials of complex argument and that one would obtain infinite hierarchy?

5. Infinite integers in turn could correspond to products of irreducible polynomials defining more general extensions. This raises the conjecture that infinite primes for an extension K of rationals could code for the algebraic extensions of K quite generally. If infinite primes correspond to real quantum states they would thus correspond the extensions of rationals to which the parameters appearing in the functions defining partonic 2-surfaces and string world sheets.

   This would support the view that partonic 2-surfaces associated with algebraic extensions defined by infinite integers and thus not irreducible are unstable against decay to partonic

2-surfaces which corresponds to extensions assignable to infinite primes. Infinite composite integer defining intermediate unstable state would decay to its composites. Basic particle physics phenomenology would have number theoretic analog and even more.

6. According to Wikipedia, Eisenstein's criterion (`http://tinyurl.com/47kxjz`) allows generalization and what comes in mind is that it applies in exactly the same form also at the higher levels of the hierarchy. Primes would be only replaced with prime polynomials and the there would be at least one prime polynomial $Q(y)$ dividing the coefficients of $P_n(x)$ except the highest one such that its square would not divide P_0. Infinite primes would give rise to an infinite hierarchy of functions of many complex variables. At first level zeros of function would give discrete points at partonic 2-surface. At second level one would obtain 2-D surface: partonic 2-surfaces or string world sheet. At the next level one would obtain 4-D surfaces. What about higher levels? Does one obtain higher dimensional objects or something else. The union of n 2-surfaces can be interpreted also as $2n$-dimensional surface and one could think that the hierarchy describes a hierarchy of unions of correlated partonic 2-surfaces. The correlation would be due to the preferred extremal property of Kähler action.

   One can ask whether this hierarchy could allow to generalize number theoretical Langlands to the case of function fields using the notion of prime function assignable to infinite prime. What this hierarchy of polynomials of arbitrary many complex arguments means physically is unclear. Do these polynomials describe many-particle states consisting of partonic 2-surface such that there is a correlation between them as sub-manifolds of the same space-time sheet representing a preferred extremals of Kähler action?

This would suggest strongly the generalization of the notion of p-adicity so that it applies to infinite primes.

1. This looks sensible and maybe even practical! Infinite primes can be mapped to prime polynomials so that the generalized p-adic numbers would be power series in prime polynomial - Taylor expansion in the coordinate variable defined by the infinite prime. Note that infinite primes (irreducible polynomials) would give rise to a hierarchy of preferred coordinate variables. In terms of infinite primes this expansion would require that coefficients are smaller than the infinite prime P used. Are the coefficients lower level primes? Or also infinite integers at the same level smaller than the infinite prime in question? This criterion makes sense since one can calculate the ratios of infinite primes as real numbers.

2. I would guess that the definition of infinite-P p-adicity is not a problem since mathematicians have generalized the number theoretical notions to such a level of abstraction much above of a layman like me. The basic question is how to define p-adic norm for the infinite primes (infinite only in real sense, p-adically they have unit norm for all lower level primes) so that it is finite.

3. There exists an extremely general definition of generalized p-adic number fields (see `http://tinyurl.com/y5zreeg`). One considers Dedekind domain D, which is a generalization of integers for ordinary number field having the property that ideals factorize uniquely to prime ideals. Now D would contain infinite integers. One introduces the field E of fractions consisting of infinite rationals.

   Consider element e of E and a general fractional ideal eD as counterpart of ordinary rational and decompose it to a ratio of products of powers of ideals defined by prime ideals, now those defined by infinite primes. The general expression for the p-adic norm of x is $x^{-ord(P)}$, where n defines the total number of ideals P appearing in the factorization of a fractional ideal in E: this number can be also negative for rationals. When the residue field is finite (finite field G(p,1) for p-adic numbers), one can take c to the number of its elements ($c = p$ for p-adic numbers.

   Now it seems that this number is not finite since the number of ordinary primes smaller than P is infinite! But this is not a problem since the topology for completion does not depend on the value of c. The simple infinite primes at the first level (free many-particle states) can be mapped to ordinary rationals and q-adic norm suggests itself: could it be that infinite-P p-adicity corresponds to q-adicity discussed by Khrennikov [A4]. Note however that q-adic numbers are not a field.

3.7.4 Cognition, Logic, And P-Adicity

There seems to be a nice connection between logic aspects of cognition and p-adicity. In particular, p-valued logic for $p = 2^k - n$ has interpretation in terms of ordinary Boolean logic with n "taboos" so that p-valued logic does not conflict with common sense in this case. Also an interpretation of projections of p-adic space-time sheets to an integer lattice of real Minkowski space M^4 in terms of generalized Boolean functions emerges naturally so that M^4 projections of p-adic space-time would represent Boolean functions for a logic with n taboos.

2-adic valued functions of 2-adic variable and Boolean functions

The binary coefficients f_{nk} in the 2-adic expansions of terms $f_n x^n$ in the 2-adic Taylor expansion $f(x) = \sum_{n=0} f_n x^n$, assign a sequence of truth values to a 2-adic integer valued argument $x \in \{0, 1, ..., 2^N\}$ defining a sequence of N bits. Hence $f(x)$ assigns to each bit of this sequence a sequence of truth values which are ordered in the sense that the truth values corresponding to bits are not so important p-adically: much like higher decimals in decimal expansion. If a binary cutoff in N: th bit of $f(x)$ is introduced, B^M-valued function in B^N results, where B denotes Boolean algebra fo 2 elements. The formal generalization to p-adic case is trivial: 2 possible truth values are only replaced by p truth values representable as $0, ..., p - 1$.

p-Adic valued functions of p-adic variable as generalized Boolean functions

One can speak of a generalized Boolean function mapping finite sequences of p-valued Boolean arguments to finite sequences of p-valued Boolean arguments. The restriction to a subset $x = kp^n$, $k = 0, ..., p - 1$ and the replacement of the function $f(x)$ with its lowest pinary digit gives a generalized Boolean function of a single p-valued argument. If $f(x)$ is invariant under the scalings by powers of p^k, one obtains a hologram like representation of the generalized Boolean function with same function represented in infinitely many length scales. This guarantees the robustness of the representation.

The special role of 2-adicity explaining p-adic length scale hypothesis $p \simeq 2^k$, k integer, in terms of multi-p-acidic fractality would correlate with the special role of 2-valued logic in the world order. The fact that all generalizations of 2-valued logic ultimately involve 2-adic logic at the highest level, where the generalization is formulated would be analog of p-adic length scale hypothesis.

$p = 2^k - n$-adicity and Boolean functions with taboos

It is difficult to assign any reasonable interpretation to $p > 2$-valued logic. Also the generalization of logical connectivesandOR is far from obvious. In the case $p = 2^k - n$ favored by the p-adic length scale hypothesis situation is however different. In this case one has interpretation in terms B^k with n Boolean statements dropped out so that one obtains what might be called $\hat{B^k}$. Since n is odd this set is not invariant under Boolean conjugation so that there is at least one statement, which is identically true and could be called taboo, axiom, or dogma: depending on taste. The allowed Boolean functions would be constructed in this case using standard Boolean functionsandOR with the constraint that taboos are respected: in other words, both the inputs and values of functions belong to $\hat{B^k}$.

A unique manner to define the logic with taboos is to require that the number of taboos is maximal so that if statement is dropped its negation remains in the logic. This implies $n > B^k/2$.

Some calculational details

In the following the details of p-adic non-determinism are described for a differential equation of single p-adic variable and some comments about the generalization to the realistic case are given.

1. *One-dimensional case*

To understand the essentials consider for simplicity a solution of a p-adic differential equation giving function $y = f(x)$ of one independent variable $x = \sum_{n \geq n_0} x_n p^n$.

1. p-Adic non-determinism means that the initial values $f(x)$ of the solution can be fixed arbitrarily up to $N+1$: th pinary digit. In other words, $f(x_N)$, where $x_N = \sum_{n_0 \leq n \geq N} x_n p^n$ is a rational obtained by dropping all pinary digits higher than N in $x = \sum_{n \geq n_0} x_n p^n$ can be chosen arbitrarily.

2. Consider the projection of $f(x)$ to the set of rationals assumed to be common to reals and p-adics.

   (a) Genuinely p-adic numbers have infinite number of positive pinary digits in their non-periodic expansion (non-periodicity guarantees non-rationality) and are strictly infinite as real numbers. In this regime p-adic differential equation fixes completely the solution. This is the case also at rational points $q = m/n$ having infinite number of pinary digits in their pinary expansion.

   (b) The projection of p-adic x-axis to real axis consists of rationals. The set in which solution of p-adic differential equations is non-vanishing can be chosen rather freely. For instance, p-adic ball of radius p^{-n} consisting of points $x = p^M y$, $y \neq 0$, $|y|_p \leq 1$, can be considered. Assume $N > M$. p-Adic nondeterminism implies that $f(q)$ for $q = \sum_{M \leq n \leq N} x_n p^n$, can be chosen arbitrarily. For $M \geq 0$ q is always integer valued and the scaling of x by a suitable power of p always allows to get a finite integer lattice at x-axis.

   (c) The lowest pinary digit in the expansion of $f(q)$ in powers of p in defines a pinary digit. These pinary digits would define a representation for a sequence of truth values of p-logic. $p = 2$ gives the ordinary Boolean logic. It is also interpret this pinary function as a function of pinary argument giving Boolean function of one variable in 2-adic case.

2. Generalization to the space-time level

This picture generalizes to space-time level in a rather straight forward manner. y is replaced with CP_2 coordinates, x is replaced with M^4 coordinates, and differential equation with field equations deducible from the Kähler action. The essential point is that p-adic space-time sheets have projection to real Minkowski space which consists of a discrete subset of integers when suitable scaling of M^4 coordinates is allowed. The restriction of 4 CP_2 coordinates to a finite integer lattice of M^4 defines 4 Boolean functions of four Boolean arguments or their generalizations for $p > 2$. Also the modes of the induce spinor field define a similar representation.

3.8 Cognitive representations for partonic 2-surfaces, string world sheets, and string like objects

Cognitive representations are identified as points of space-time surface $X^4 \subset M^4 \times CP_2$ having embedding space coordinates in the extension of of rationals defined by the polynomial defined by the M^8 pre-image of X^4 under $M^8 - H$ correspondence [L24, L25, L48, L43, L42, L38]. Cognitive representations have become key piece in the formulation of scattering amplitudes [L45] . One might argue that number theoretic evolution as increase of the dimension of the extension of rationals favors space-time surfaces with especially large cognitive representations since the larger the number of points in the representation is, the more faithful the representation is.

One can pose several questions if one accepts the idea that space-time surfaces with large cognitive representations are survivors.

1. Preferred p-adic primes are proposed to correspond to the ramified primes of the extension [L50]. The proposal is that the p-adic counterparts of space-time surfaces are identifiable as imaginations whereas real space-time surfaces correspond to realities. p-Adic space-time surfaces would have the embedding space points in extension of rationals as common with

real surfaces and large number of these points would make the representation realistic. Note that the number of points in extension does not depend on p-adic prime.

Could some extensions have an especially high number of points in the cognitive representation so that the corresponding ramified primes could be seen as survivors in number theoretical fight for survival, so to say? Galois group of the extension acts on cognitive representation. Galois extension of an extension has the Galois group of the original extension as normal subgroup so that ormal Galois group is analogous to a conserved gene.

2. Also the type of extremal matters. For instance, for instance canonically imbedded M^4 and CP_2 contain all points of extension. These surfaces correspond to the vanishing of real or imaginary part (in quaternionic sense) for a linear octonionic polynomial $P(o) = o$! As a matter of fact, this is true for all known preferred extremals under rather mild additional conditions. Boundary conditions posed at both ends of CD in ZEO exclude these surfaces and the actual space-time surfaces are expected to be their deformations.

3. Could the surfaces for which the number of points in cognitive representation is high, be the ones most easily discovered by mathematical mind? The experience with TGD supports positive answer: in TGD the known extremals [K5] are examples of such mathematical objects! If so, one should try to identify mathematical objects with high symmetries and look whether they allow TGD realization.

4. One must also specify more precisely what cognitive representation means. Strong form of holography (SH) states that the information gives at 2-D surfaces - string world sheets and partonic 2-surfaces - is enough to determine the space-time surfaces. This suggests that it is enough to consider cognitive representation restricted to these 2-surfaces. What kind of 2-surfaces are the cognitively fittest one? It would not be surprising if surfaces with large symmetries acting in extension were favored and elliptic curves with discrete 2-D translation group indeed turn out to be assigable string world sheets as singularities and string like objects. In the case of partonic 2-surfaces geodesic sphere of CP_2 is similar object.

All known extremals, in particular preferred extremals, are good candidates in this respect because of their high symmetries. By strong form of holography (SH) partonic 2-surfaces and string world sheets are expected to give rise to cognitive representations. Also cosmic strings are expected to carry them. Under what conditions these representations are large?

3.8.1 Partonic 2-surfaces as seats of cognitive representations

One can start from SH and look the situation more concretely. The situation for partonic 2-surfaces has been considered already earlier [L49, L41] but deserves a separate discussion.

1. Octonionic polynomials allow special solutions for which the entire polynomial vanishes. This happens at 6-sphere S^6 at the boundary of 8-D light-cone. S^6 is analogous to brane and has radius $R = r_n$, which is a root of the real polynomial with rational coefficients algebraically continued to the octonionic polynomial.

   S^6 has the ball B^3 of radius r_n of the light-cone M^4_+ with time coordinate $t = r_n$ as analog of base space and sphere S^3 of E^4 with radius $R = \sqrt{r_n^2 - r^2}$, r the radial coordinate of B^3 as an analog of fiber. The analog of the fiber contracts to a point at the boundary of the light-cone. The points with B^3 projection and E^4 coordinates in extension of rationals belong to the cognitive representation. The condition that $R^2 = x_i x^i = r_n^2 - r^2$ is square of a number of extension is rather mild and allows infinite number of solutions.

2. The 4-D space-time surfaces X^4 are obtained as generic solutions of $Im(P(o)) = 0$ or $Re(P(o)) = 0$. Their intersection with S^6 - partonic 2-surface X^2 - is 2-D. The assumption is that the incoming and outgoing 4-D space-time surfaces representing orbits of particles in topological sense are glued together at X^2 and possibly also in their interiors. X^2 serves as an analog of vertex for 3-D particles. This gives rise to topological analogs of Feynman diagrams.

   In the generic case the number of points in cognitive representation restricted to X^2 is finite unless the partonic 2-surface X^2 is special - say correspond to a geodesic spere of S^6.

3. The discrete isometries and conformal symmetries of the cognitive representation restricted to X^2 possibly represented as elements of Galois group might play a role. For $X^2 = S^2$ the finite discrete subgroups of $SO(3)$ giving rise to finite tessellations and appearing in ADE correspondence might be relevant. For genera $g = 01, 2$ conformal symmetry Z_2 is always possible but for higher genera only in the case of hyper-elliptic surfaces- this used to explain why only $g = 0, 1, 2$ correspond to observed particles [K14] whereas higher genera could be regarded as many-particle states of handles having continuous mass spectrum. Torus is an exceptional case and one can ask whether discrete subgroup of its isometries could be realized.

4. In TGD inspired theory of consciousness [L29, L41] the moments $t = r_n$ corresponds to "very special moments in the life of self". They would be also cognitively very special - kind of eureka moments with a very large number of points in cognitive representation. The question is whether these surfaces might be relevant for understanding the nature of mathematical consciousness and how the mathematical notions emerge at space-time level.

3.8.2 Ellipticity

Surfaces with discrete translational symmetries is a natural candidate for a surface with very large cognitive representation. Are their analogs possible? The notions of elliptic function, curve, and surface suggest themselves as a starting point.

1. Elliptic functions (`http://tinyurl.com/gpugcnh`) have 2-D discrete group of translations as symmetries and are therefore doubly periodic and thus identifiable as functions on torus.

   Weierstrass elliptic functions $\mathcal{P}(z; \omega_1, \omega_2)$ (`http://tinyurl.com/ycu8oa4r`) are defined on torus and labelled by the conformal equivalence class $\lambda = \omega_1/\omega_2$ of torus identified as the ratio $\lambda = \omega_1/\omega_2$ of the complex numbers ω_i defining the periodicities of the lattice involved. Functions $\mathcal{P}(z; \omega_1, \omega_2)$ are of special interest as far as elliptic curves are considered and defines an embedding of elliptic curve to CP_2 as will be found.

   If the periods are in extension of rationals then values in the extension appear infinitely many times. Elliptic functions are not polynomials. Although the polynomials giving rise to octonionic polynomials could be replaced by analytic functions it seems that elliptic functions are not the case of primary interest. Note however that the roots r_n could be also complex and could correspond to values of elliptic function forming a lattice.

2. Elliptic curves (`http://tinyurl.com/lovksny`) are defined by the polynomial equation

$$y^2 = P(x) = x^3 + ax + b \ . \tag{3.8.1}$$

   An algebraic curve of genus 1 allowing 2-D discrete translations as symmetries is in question. If a point of elliptic curve has coordinates in extension of rationals then 2-D discrete translation acting in extension give rise to infinite number of points in the cognitive representation. Clearly, the 2-D vectors spanning the lattice defining the group must be in extension of rationals.

One can indeed define commutative sum $P + Q$ for the points of the elliptic curve. The detailed definition of the group law and its geometric illustration can be found in Wikipedia article (`http://tinyurl.com/lovksny`).

1. Consider real case for simplicity so that elliptic curve is planar curve. $y^2 = P(x) = x^3+ax+b$ must be non-negative to guarantee that y is real. $P(x) \geq 0$ defines a curve in upper (x, y) plane extending from some negative value x_{min} corresponding to $y^2 = P(x_{min}) = 0$ to the right. Given value of y can correspond to 3 real roots or 1 real root of $P_y(x) = y^2 - P(x)$. At the two extrema of $P_y(x)$ 2 real roots coincide. The graph of $y = \pm\sqrt{P(x)}$ is reflection symmetric having two branches beginning from $(x_{min}, y = 0)$.

2. The negative $-P$ is obtained by reflection with respect to x-axis taking y_P to $-y_P$. Neutral element O is identified as point a infinity (assuming compactification of the plane to a sphere) which goes to itself under reflection $y \to -y$.

3. One assigns to the points P and Q of the elliptic curve a line $y = sx + d$ containing them so that one has $s = (y_p - y_Q)/(x_P - x_Q)$. In the generic case the line intersects the elliptic curve also at third point R since $P_{y=sx+d}(x)$ is third order polynomial having three roots (x_P, x_Q, x_R). It can happen that 2 roots are complex and one has 1 real root. At criticalityfor the transiton from 3 to 1 real roots one has $x_Q = x_R$.

   Geometrically one can distinguish between 4 cases.

   - The roots P, Q, R of $P_{y=sx+d}(x)$ are different and finite: one defines the sum as $P+Q = -R$.
   - $P \neq Q$ and $Q = R$ (roots Q and R are degenerate): $P + Q + Q = O$ giving $R = -P/2$.
   - P and Q are at a line parallel to y-axis and one has $R = O$: $P + Q + O = O$ and $P = -Q$.
   - P is double root of $P_{y=sx+d}(x)$ with tangent parallel to y-axis at the point $(x_{min}, y = 0)$ at which the elliptic curve begins so that one has $R = O$: $P+P+O = O$ gives $P = -P$. This corresponds to torsion.

4. Elliptic surfaces (see `http://tinyurl.com/yc33a6dg`) define a generalization of elliptic curves and are defined for 4-D complex manifolds. Fiber is required to be smooth and has genus 1.

3.8.3 String world sheets and elliptic curves

In twistor lift of TGD space-time surfaces identifiable as minimal surfaces with singularities, which are string world sheets and partonic 2-surfaces. Preferred extremal property means that space-time surfaces are extremals of both Kähler action and volume action except at singularities.

Are string world sheets with very large number of points in cognitive representation possible? One has right to expect that string world sheets allow special kind of symmetries allowing large, even infinite number of points at the limit of large sheet and related by symmetries acting in the extension of rationals. If one of the points is in the extension, also other symmetry related points are in the extension. For a non-compact group, say translation one would have infinite number of points in the representation but the finite size of CD would pose a limitation to the number of points.

String world sheets are good candidates for the realization of elliptic curves.

1. The general conjecture is that preferred extremals allow what I call Hamilton-Jacobi structure for M^4 [K73]. The distribution of tangent spaces having decomposition $M^4(x) = M^2(x) \times E^2(x)$ would be integrable giving rise to a family of string world sheets Y^2 and partonic 2-surfaces X^2 more general than those defined above. X^2 and Y^2 are orthogonal to each other at each point of X^4. One can introduce local light-cone coordinates (u, v) for Y^2 and local E^2 complex coordinate w for X^2.

2. Space-time surface itself would be a deformation of M^4 with Hamilton-Jacobi structure in CP_2 direction. w coordinate as function $w(z)$ of CP_2 complex coordinate z or vice versa would define the string world sheet. This would be a transversal deformation of the basic string world sheet Y^2: stringy dynamics is indeed transversal.

3. The idea about maximal cognitive representation suggests that $w \leftrightarrow z$ correspondence defines elliptic curve. One would have $y^2 = P(x) = x^3 + ax + b$ with either $(y = w, x = z)$ or $(y = z, x = w)$. A natural conjecture is that for the space-time surface corresponding to a given extension K of rationals the coefficients a an b belong to K so that the algebraic complexity of string world sheet would increase in number theoretic evolution [L47]. The orbit of a algebraic point at string world sheet would be lattice made finite by the size of CD. Elliptic curves would define very special deformed string world sheets in space-time.

4. It is interesting to consider the pre-image of given point y ($y = w$ or $y = z$) covering point x. One has $y = \pm\sqrt{u}$, $u = P(x)$ corresponding to group element and its negative: there are two points of covering given value of u. $u = P(x)$ covers 3 values of x. The values of x would belong to 6-fold covering of rationals. The number theoretic interpretation for the effective Planck constant $h_{eff} = nh_0$ states that n is the number of sheets for space-time surface as covering.

   There is evidence that $h_{eff} = h$ corresponds to $n = 6$ [L14]. Could 6-fold covering of rationals be fundamental since it gives very large cognitive representation at the level of string world sheets?

   For extensions K of rationals the x coordinates for the points of cognitive representation would belong to 6-D extension of K.

5. Ellipticity condition would apply on the string world sheets themselves. In the number theoretic vision string world sheets would correspond at M^8 level to singularities at which the quaternionic tangent space degenerates to 2-D complex space. Are these conditions consistent with each other? It would seem that the two conditions would select cognitively very special string world sheets and partonic 2-surfaces defining by strong form of holography (SH) space-time surface as a hologram in SH. Consciousness theorist interested in mathematical cognition might ask whether the notion of elliptic surfaces have been discovered just because it is cognitively very special. In the case of partonic 2-surfaces geodesic sphere of CP_2 is similar object.

3.8.4 String like objects and elliptic curves

String like objects - cosmic strings - and their deformations, are fundamental entities in TGD based cosmology and astrophysics and also in TGD inspired quantum biology. One can assign elliptic curves also to string like objects.

1. Quite generally, the products $X^2 \times Y^2 \subset M^4$ of string world sheets X^2 and complex surfaces Y^2 of CP_2 define extremals that I have called cosmic strings [K5].

2. Elliptic curves allow a standard embedding to CP_2 as complex surfaces constructible in terms of Weierstrass elliptic function $\mathcal{P}(z)$ (`http://tinyurl.com/ycu8oa4r`) satisfying the identity

$$[\mathcal{P}'(z)]^2 = [\mathcal{P}(z)]^3 - g_2\mathcal{P}(z) - g_3 \quad . \tag{3.8.2}$$

   Here g_2 and g_3 are modular invariants. This identity is of the same form as the condition $y^2 = x^3 + ax + b$ with identifications $y = \mathcal{P}'(z), x = \mathcal{P}(z)$ and $(a = -g_2, b = -g_3)$. From the expression

$$y^2 = x(x-1)(x-\lambda) \tag{3.8.3}$$

   in terms of the modular invariant $\lambda = \omega_1/\omega_2$ of torus one obtains

$$g_2 = \frac{4^{1/3}}{3}(\lambda^2 - \lambda + 1 \quad , \quad g_3 = \frac{1}{27}(\lambda+1)(2\lambda^2 - 5\lambda + 2) \quad . \tag{3.8.4}$$

   Note that third root of a appears in the formula. The so called modular discriminant

$$\Delta = g_2^3 - 27g_3^2 = \lambda^2(\lambda-1)^2 \quad . \tag{3.8.5}$$

   vanishes for $\lambda = 0$ and $\lambda = 1$ for which the lattice degenerates.

3. The embedding of the elliptic curve to CP_2 can be expressed in projective coordinates of CP_2 as

$$(z^1, z^2, z^3) = (\xi^1, \xi^2, 1) = (\frac{\mathcal{P}'(w)}{2}, \mathcal{P}(w), 1) \ . \tag{3.8.6}$$

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Chapter 4

Philosophy of Adelic Physics

4.1 Introduction

I have developed during last 39 years a proposal for unifying fundamental interactions which I call "Topological Geometrodynamics" (TGD). During last twenty years TGD has expanded to a theory of consciousness and quantum biology and also p-adic and adelic physics have emerged as one thread in the number theoretical vision about TGD.

Since Quantum TGD and physical arguments have served as basic guidelines in the development of p-adic ideas, the best way to introduce the subject of p-adic physics, is by describing first TGD briefly.

In this article I will consider the p-adic aspects of TGD - the first thread of the number theoretic vision - as I see them at this moment.

1. I will describe p-adic mass calculations based on p-adic generalization of thermodynamics and super-conformal invariance [K41, K14] with number theoretical existence constrains leading to highly non-trivial and successful physical predictions. Here the notion of canonical identification mapping p-adic mass squared to real mass squared emerges and is expected to be key player of adelic physics and allow to map various invariants from p-adics to reals and vice versa.

2. I will propose the formulation of p-adicization of real physics and adelization meaning the fusion of real physics and various p-adic physics to single coherent whole by a generalization of number concept fusing reals and p-adics to larger structure having algebraic extension of rationals as a kind of intersection.

   The existence of p-adic variants of definite integral, Fourier analysis, Hilbert space, and Riemann geometry is far form obvious, and various constraints lead to the idea of NTU and finite measurement resolution realized in terms of number theory. Maybe the only way to overcome the problems relies on the idea that various angles and their hyperbolic analogs are replaced with their exponentials and identified as roots of unity and roots of e existing in finite-dimensional algebraic extension of p-adic numbers. Only group invariants - typically squares of distances and norms - are mapped by canonical identification from p-adic to real realm and various phases are mapped to themselves as number theoretically universal entities.

   Another challenge is the correspondence between real and p-adic physics at various levels: space-time level, embedding space level, and WCW level. Here the enormous symmetries of WCW and those of embedding space are in crucial role. Strong form of holography (SH) allows a correspondence between real and p-adic space-time surfaces induced by algebraic continuation from string world sheets and partonic 2-surface, which can be said to be common to real and p-adic space-time surfaces.

3. In the last section I will describe the role of p-adic physics in TGD inspired theory of consciousness. The key notion is Negentropic entanglement (NE) characterized in terms of number theoretic entanglement negentropy (NEN). Negentropy Maximization Principle (NMP) would force the growth of NE. The interpretation would be in terms of evolution as increase

of negentropy resources - Akashic records as one might poetically say. The newest finding is that NMP in statistical sense follows from the mere fact that the dimension of extension of rationals defining adeles increases unavoidably in statistical sense - separate NMP would not be necessary.

In the sequel I will use some shorthand notations for key principles and key notions. Quantum Field Theory (QFT); Relativity Principle (RP); Equivalence Principle (EP); 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); Quantum Criticality (QC); Hyper-finite Factor of Type II_1 (HFF); Number Theoretical Universality (NTU); Canonical Identification (CI); Negentropy Maximization Principle (NMP); Negentropic entanglement (NE); Number Theoretical Entanglement Negentropy (NEN); are the most often occurring acronyms.

Part II

COMPARISON WITH OTHER THEORIES OF CONSCIOUSNESS

Chapter 5

Comparison of TGD Inspired Theory of Consciousness with Some Other Theories of Consciousness

5.1 Introduction

This work has been inspired by two books. The first book "On intelligence" is by Jeff Hawkins. The second book "Consciousness: the science of subjectivity" is by Antti Revonsuo.

5.1.1 On Intelligence

Jeff Hawkins [J46] has developed a highly interesting and inspiring vision about neo-cortex, one of the few serious attempts to build a unified view about what brain does and how it does it. Since the key ideas of Hawkins have quantum analogs in TGD framework, there is high motivation for developing a quantum variant of this vision. The vision of Hawkins is very general in the sense that all parts of neo-cortex would run the same fundamental algorithm, which is essentially checking whether the sensory input can be interpreted in terms of standard mental images stored as memories. This process occurs at several abstraction levels and involve massive feedback. If it succeeds at all these levels the sensory input is fully understood.

TGD suggests a generalization of this process.

1. Quantum jump as a moment of consciousness and a sequence of quantum jumps inducing repeated state function reduction at the same boundary of causal diamond (CD) as self would be the basic identifications. These would define the fundamental algorithm realized in all scales defining an abstraction hierarchy. Negentropy Maximization Principle (NMP, [K45]) would be the variational principle driving this process and in optimal case lead to an experience of understanding at all levels of the scale hierarchy realized in terms of generation of negentropic entanglement. The analogy of NMP with second law suggests strongly thermodynamical analogy and p-adic thermodynamics used in particle mass calculations might be also seen as effective thermodynamics assignable to NMP.

   One can imagine the analogs of temperature and various other parameters as characteristics of "thermal equilibrium" under some constraints with respect to NMP instead of second law. These would be macroscopic parameters characterising the state of consciousness, and one can easily imagine psychological counterparts of thermodynamical notions. Psychological pressure would not be a mere metaphor!

2. The anatomy of quantum jump implies alternating arrow of geometric time at the level of embedding space [K4]. This looks strange at first glance but allows to interpret the growth of syntropy introduced by Fantappie [J54] as a growth of entropy in reversed direction of

embedding space time. As a matter fact, one has actually wave function in the moduli space of CDs and in state function reductions localisation of either boundary takes place and gradually leads to the increase of the embedding space geometric time and implies the alternating arrow for this time. The state function reduction at positive energy boundary of CD has interpretation as a process leading to sensory representation accompanied by p-adic cognitive representation.

The time reversal of this process has interpretation as motor action in accordance with Libet's classical findings [J18]. This symmetry holds true in various length scales for CDs. In the same ways p-adic space-time sheets define cognitive representations and their time reversals as intentions. It seems that self model could be assigned to negentropically entangled collections of sub-CDs and negentropic entanglement would stabilize them.

A rather obvious inaccuracy in the earlier interpretation of negentropic entanglement has been corrected. The statement that negentropic entanglement corresponds to the experience of understanding (or any conscious experience) is in conflict with the basic postulate of TGD inspired theory of consciousness. The correct wording is that the *generation of negentropic entanglement* gives rise the experience of understanding and possibly some other emotionally positively colored experiences. Generation and loss of negentropic entanglement would be the key to the understanding of emotions.

3. One could understand the fundamental abstraction process as generation of negentropic entanglement serving as a correlate for the experience of understanding. This process creates new mental images (sub-CDs) and to longer sequences of mental images (accumulation of experience by formation of longer quantum association sequences). Abstraction process involves also reduction of measurement resolution characterizing cognitive representations defined in terms of of discrete chart maps mapping discrete set of rational points of real preferred extremals to their p-adic counterparts allowing completion to p-adic preferred extremal. The reversal of this abstraction process gives rise to improved resolution and adds details to the representation. The basic cognitive process has as its building bricks this abstraction process and its reversal.

4. The notion of self, which should be distinguished from a model for self, has been a continual source of worries in TGD inspired theory of consciousness [K74, K4]. Hierarchy of quantum jumps suggests that self can be identified as quantum jump and that the conscious information corresponds to the change of negentropy in quantum jump. The notion of negentropic entanglement however raises the temptation to identify self model (distinguished from self) as a property of quantum state, which consciousness certainly cannot be in TGD framework. Self representations would naturally correspond to negentropically entangled tensor products approximately invariant under quantum jump sequence. One can of course ask whether the notion of self reduced to quantum jump is needed at all.

5.1.2 Consciousness: The Science Of Subjectivity

Antti Revonsuo has written a wonderful book about consciousness with title "Consciousness: the science of subjectivity" (see `http://tinyurl.com/y868klny`) [J17].

1. Revonsuo discusses philosophical, historical, and conceptual foundations of consciousness science.

2. Various disorders of consciousness provide test benches for the theories of consciousness and Revonsuo discusses neuropsychological deficits of visual consciousness, neuropsychological dissociations of visual consciousness from behavior, and neuropsychological disorders of self-awareness.

3. If one believes (and even if one does not!) that the state of brain dictates completely the contents of consciousness, it is natural to search for the neural correlates of consciousness since brain state could indeed correlate in one-one way with certain (say cognitive and representational) aspects of consciousness. Revonsuo analysizes methods and design of a typical NCC experiment, discusses neural basis of consciousness as a state and studies on the neural basis of visual consciousness.

4. A lot of theories of consciousness have been proposed and Revonsuo discusses both philosophical and empirical theories of consciousness critically pointing out the basic difficulties of various approaches. Revonsuo does not discuss quantum theories of consciousness.

5. The last chapters are devoted to altered states of consciousness (ASC) with a discussion of dreaming and sleep, hypnosis, and higher states of consciousness. The understanding of ASCs obviously define also tests for any theory of consciouesness.

In the following I will first discuss the ideas of Hawkins and then summarize some relevant aspects of quantum TGD and TGD inspired theory of consciousness briefly in the hope that this could make representation comprehensible for the reader having no background in TGD (I hope I have achieved this). The representation involves some new elements: reduction of the old idea about motor action as time reversal of sensory perception to the anatomy of quantum jump in zero energy ontology (ZEO); interaction free measurement for photons and photons as a non-destructive reading mechanism of memories and future plans (time reversed memories) represented 4-dimensionally as negentropically entangled states approximately invariant under quantum jumps (this resolves a basic objection against identifying quantum jump as moment of consciousness) leading to the identification of analogs of imagination and internal speech as fundamental elements of cognition; and a more detailed quantum model for association and abstraction processes.

After that I compare various theories and philosophies of consciousness with TGD approach following the beautifully organized representation of Revonsuo. Also anomalies of consciousness are briefly discussed. My hope is that this comparison would make explicit that TGD based ontology of consciousness indeed circumvents the difficulties against monistic and dualistic approaches and also survives the basic objections that I have been able to invent hitherto.

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` [L4].

5.2 The Vision Of Hawkins

Jeff Hawkins has written together with Sanda Blaskeslee a very inspiring book about conscious intelligence with title "On intelligence" [J46]. What makes the book so inspiring to me is that it tries to build a holistic strongly structured vision about the functioning of neo-cortex easily generalizable outside to its original context - in my case TGD inspired theory of consciousness based on rather different basic philosophy.

5.2.1 The Philosophical Attitudes Of Hawkins

Before continuing I want to locate the vision of Hawkins to the map of theories.

1. Hawkins accepts functionalism stating that intelligence and maybe even consciousness are properties of organization and have nothing to with the stuff that the system is made of. This was the justification for AI people to regard brain as a primitive realization of something which can be realized much more elegantly using digital computers. Hawkins assumes that the functional structure at neuronal level determines the contents of consciousness and could therefore be seen as a materialist allowing emergence.

2. Hawkins does not discuss the possibility of quantum consciousness but his vision might allow also quantum formulation and in the following I will represent such a generalization.

Although Hawkins accepts functionalism, he represents excellent arguments against AI and connectionism, and computationalism in general stating brain is a computer.

1. The argument against computationalism according to AI goes as follows. The time scale of neural processing is 1 ms: this is million times longer than 1 ns: the time scale of processing in modern computers. Despite its slowness brain is able to recognize a face represented in various ways in a fraction of second. For recent day computers this is a mission impossible. Computationalistic brain should make this feat by using basic programs consisting of roughly

100 steps. Parallelism does not help as often claimed. As an analogy Hawkins mentions a task of carrying some amount of material to another side of a desert. Irrespective of how many camels are hired the task takes some minimum time determined by the maximal load carried by single camel over the desert and the distance to the other side.

2. Gradually the failure of AI was accepted, and the follower of AI was connectionism. Connectionism takes the notions of association and and standardized mental image (memory) seriously and is therefore nearer to what brain is thought to do. The possibility to complete full patterns from pieces by a non-linear algorithm seemed to give excellent hopes about progress. The dream was not fulfilled.

   Pattern recognition by computers differs from what brain does in one but overall important aspect: the ability to form invariant representations is lacking. When sensory input representing the same object but from a different perspective is used, computer based pattern recognition fails. A mere shift of the spatial pattern is enough to make recognition impossible. Brain can however easily recognize the pattern seen from different perspectives, the pattern can be even deformed in wide limits. Even patterns represented using pictures, sound, and touch are recognized as same object.

3. Hawkins criticizes also the behavioristic approach assuming that contents of consciousness can be deduced by looking only the behavior. Turing's test relies formulates mathematically this behavioristic dogma. It is probably relatively easy to cheat human subject to believe that machine is conscious by using Turing test. This however does not demonstrate anything. The basic problem is that the more abstract the level of cognitive process is is, the less it shows itself in the behavior. The situation in which a person is fully conscious but completely paralyzed so that he is not able to express any thoughts via motor actions illustrates a failure of the naïve behavioristic approach.

In TGD framework it is easy to agree with Hawkins. Turing machine is a model of computer in which one implicitly takes granted the identification of experienced and geometric time, which differ in many crucial aspects as even child knows. The starting point of TGD inspired consciousness theory as a generalization of quantum measurement theory is the paradox of quantum measurement theory caused by this identification. The discretization of geometric time is also an extremely heavy idealization and I find it surprising that it has raised so little criticism. In TGD framework the behavioristic approach and the materialistic identification of contents of consciousness with the state of brain must be given up since consciousness cannot be identified as a property of quantum state since it is assigned with the quantum jump between two quantum states.

5.2.2 Basic Observations Of Hawkins

Several observations and ideas of Hawking relate to the notion of time.

1. Instead of computation Hawkins sees memory, recognition of familiar objects in the sensory input, and their naming as fundamental processes in neo-cortex. Nerve pulse patterns are identified as names for objects. A cognitive representation is what sensory input gives rise to, and means a decomposition of the sensory input to objects with names, analogous to a linguistic essentially linear description of the percept.

2. It is not only spatial patterns but temporal sequences of them which matter. At higher level of abstraction one has a sequence of patterns instead of single patttern and the representation is less detailed. Sensory inputs are this kind of temporal sequences as are also plans for motor actions resulting as a reaction to the sensory input. Here "sensory input" and "motor action" could be understood very generally: even the nerve pulse patterns arriving neuron and leaving it can be seen as "sensory inputs" and "motor actions".

3. Hawkins emphasizes the similarities between sensory input and motor action and one can indeed claim that they one and same thing except that they seem to proceed in opposite directions of time: bottom-up and top-down. Libet's well-known findings that the neuronal

activity begins a fraction of second earlier than conscious decision for motor action and later experiments suggesting even longer time scales might be understood in this framework. If one takes this idea seriously, one must however modify the existing beliefs about the relation between subjective time and the geometric time of physicists identified as fourth space-time dimension. Subjective time has constant arrow but this arrow might correspond to different arrow of geometric time for sensory input and motor action. This brings in mind TGD based view about time [K4] and suggests more detailed interpretation of the arrow of time as it emerges in TGD framework.

4. Hawkins sees as the basic function of neo-cortex construction of predictions based on the "understanding" of the sensory input and coded by cognitive representation. Prediction might seen also as an intention how to behave realized as a motor program defining the reaction to the sensory percept.

This general vision is very elegant. The challenge is to understand what various concepts such as memory, recognition of familiar objects, naming, and understanding do mean physically. This is far from trivial in the materialistic framework of standard physics, and one can hope that quantum TGD generalizing considerably also the quantum theory itself, could help in this challenge. In particular, p-adic physics and p-adic space-time sheets could serve as correlates for the "mind stuff", and one could see the formation of cognitive representations as a formation of p-adic charts about real physical systems. Sensory perception would be real, cognitive representation p-adic. In p-adic topology the decomposition to objects and discretization in a given resolution are natural so that it would be ideal to the description of cognition. Negentropic entanglement would be an excellent candidate for a correlate of understanding.

5.2.3 Invariant Representations

Hawkins emphasizes the ability of brain to recognize objects represented in very different ways as a basic distinction between brain and computers.

1. Invariant representations distinguish brain from computer. Invariant representations are abstractions. Abstraction summarizes something common to a large class of objects and gives a name for this class of objects. For instance, "living room" as a name of this kind of class is extremely economical manner to represent information in terms of a concept instead of remembering every detail of every living room one has spent some time.

   So called idiot savants can have this kind of sensory memory, and are able to perform incredible memory feats, but this kind of memory is not useful unless one is an artist. An interesting question is whether animals could still possess sensory memories: this would be certainly useful gift in jungle. Another interesting question is whether cerebellum could have sensory memories not conscious-to-us and whether these could become conscious-to-us in some altered states of consciousness.

   Abstraction appears also in the music experience. Ordinary listener is not able to identify the key of the music piece but this does not affect the music experience much since only the ratios of the pitches of notes of the melody matter. People with "absolute ear" can however recognize the absolute key of the music piece and regard pieces in different keys as different ones. In the standard scale used for the piano, the ratios are not quite the same in different keys but this causes troubles for people with "absolute ear".

2. Hawkins sees the formation of associations as an important aspect of invariant representations allowing to recognize the same object using different sensory channels. Second aspect of abstraction is the elimination of un-necessary details: kind of reduction of sensory/cognitive resolution. Some kind of averaging could be involved.

3. Hawkins concludes that neo-cortex is specialized to the construction invariant representations and that there is a hierarchy of increasingly abstract invariant representations assignable to sensory percepts and motor actions. All these representations are needed to achieve ideal perception but only the highest level abstractions are usually conscious-to-us. Note that in standard neuro-science framework "conscious-to-us" is synonymous to "conscious" but in

quantum TGD approach entire hierarchy of conscious entities can be imaged so that "subconscious" translates to "conscious-but-not-to-us". This distinction allows to understand many brain disorders [J17] such as being not conscious of being able to see (and other agnosias) or believing that one sees although one is cortically blind or being cortically blind but believing that one is able to see. Note that if primary visual experience is at the level of retina, cortical blindness need not mean subjectively experienced blindness.

One of the hard challenges is to identify the mechanism giving rise to invariant representations. Neural firing patterns are though to transform synaptic connections and in this manner give rise to associations. Hebb's rules define an attempt to model what happens in the process. One can also understand what abstraction could mean.

In TGD framework one can consider the generation of negentropic entanglement as a mechanism of association: negentropically entangled state defines a rule represented as a superposition of state pairs (or n-plets) such that each pair (n-tuple) represents one particular instance of the rule. Abstraction means also getting rid of insignificant details. Here one can consider some kind of averaging (kind of ensemble of mental images at quantum level) or quantum superposition of states representing same object but with different details below cognitive resolution. I have also proposed that quantum states in general are superpositions of preferred extremals which have equivalent statistical geometries meaning that various geometric correlation functions are identical for them.

5.2.4 Observations About The Structure And Functioning Of The Neocortex

The proposal of Hawkins relies heavily on the observations about the structure and functioning of the neo-cortex.

1. Neocortex (see `http://tinyurl.com/ksoqn4`) [J9] is a very thin grey layer at the top of cortex having thickness of about 3 mm and consisting of 6 layers, which according to Hawkins are functionally hierarchically ordered with layer 1 at the top representing the highest level of abstraction. Layer 4 is the layer to which inputs from distant regions of neocortex arrive and are transferred to the levels above and below it. There is a strong feedback and feedforwad between the layers.

2. Neo-cortex decomposes to various sensory and motor areas. In associative areas the inputs from sensory areas are combined and sent to motor areas. Sensory and motor areas in turn have hierarchical structure: for instance, visual areas consisting of sub-areas V1, ..., V5. Sensory input arrives to V1 and V1 is believed to identify from the sensory input various simple features. Higher areas identify more abstract features and sequences of them.

3. Hawkins emphasizes the fact that sensory perception and motor action are not simple bottom-up and top-down processes. Feedback is present and can be even 10 times more massive than input. The proposed interpretation is that input to from a given layer of neo-cortex to a higher layer (from say from 3 to 2) means formation of a more abstract and less detailed representation and vice versa. This representation consists also longer sequences of basic patterns and allows easier recognition. A good example is a situation in which music piece on CD changes: at the lower level this means unexpected input. At higher level music pieces on CD form a sequences and recognition as new piece is possible. The higher level can send this prediction back to the lower level.

4. Neo-cortex and also cortex look the same everywhere. This suggests that all basic units of the cortex perform essentially same basic function or algorithm. This idea is elegant and far reaching and would apply to the formation of cognitive representations which would be just the identification and naming of objects of sensory percept.

5. This picture applies also to motor action. If one accepts that motor action is time reversal of sensory perception and leads from abstract to less abstract and more detailed, one can ask whether the feedback to less abstract levels could be interpreted as motor action at neuronal

level. A fractal structure in which sensory perception and motor action takes place in various time and length scales would suggeset this kind of view.

There are many notions which require more detailed definition. The proposed detailed model for feedback need not of course be correct as such. What matters is the existence of hierarchical structure and communications between the levels of the hierarchy. In TGD framework this hierarchy would naturally correspond to self hierarchy and hierarchy of quantum jumps within quantum jups. In zero energy ontology it has as correlates the hierarchy of space-time sheets at space-time level and that of causal diamonds within causal diamonds at the level of embedding space. Also the p-adic length scale hierarchy and hierarchy of effective Planck constants assigned with dark matter in TGD Universe relate to these hierarchies.

5.2.5 Universal Algorithm

These observations inspire Hawkins to propose for the universal algorithm run by the units of neo-cortex.

1. The homogenuity of neocortex motivates the proposal that all units of the neo-cortex forming a hierarchy are performing the same universal algorithm, which is recognition of the virtual sensory input represented as nerve pulse pattern with some standard input stored in memory. If the recognition attempt fails, the input is sent to a higher more abstract level with less details and this level makes a similar trial. If the recognition attempt is successful, the input is sent to a lower level (this corresponds to a feedback) and same attempt is made.

2. This process continues until recognition is made at all levels or if this is not possible, the pattern is sent to hippocampus as a genuinely new pattern to be stored to memory. Some maximum time of unsuccessful processing is a natural criterion for the novelty. Percept is thus stored as a memory in hippocampal level only when it represents something new. The percepts which do not enter hippocampus are stored at lower cortical layers but do not represent memories conscious-to-us. This could explain why people at older age are not able to remember details of say movie unless they represent something genuinely new.

To me this picture looks rather attractive and inspires the question whether a generalization to quantum context - say in TGD framework - is possible.

5.2.6 The Basic Objection Against The Vision Of Hawkins

The basic objection against Hawkins's vision applies to neuroscience view in general.

1. As Hawkins notices, the homogenuity of the neocortex and brain in general is in conflict with the idea that cortex is the seat of the sensory qualia. It is difficult to understand why the auditory and visual pathways could give rise to so different sensory qualia if only the organization of the sensory pathways matters.

2. A possibility not discussed by Hawkins nor by neuroscientists is that sensory qualia could be formed at the level of sensory organs.

   (a) TGD approach would suggest that qualia are realized at the level of sensory organs [K30] and quale mental images (sub-selves) entangle with the cortical mental images representing names of objects of the perceptive field represented at cortex and thus give rise to a coloring of the cognitive map. This would explain why the qualia associated with different sensory pathways are so different. Pure thought would correspond to cognition without this coloring and dreams would involve a feedback to the level of sensory organs (REM sleep) transforming thinking to vivid imagination. Note that also the feedback to the level of sensory organs and comparison of this virtual sensory input with the actual one is quite possible in TGD framework since there is no reason to restrict the feedback hierarchy to the 6 neo-cortical layers. Dark photons with large value of $\hbar_{eff}$ could make possible this feedback by generating sensory input by transforming to ordinary visible photons interpreted as bio-photons.

(b) The basic objection against this view is the phenomenon of phanton limb (see `http://tinyurl.com/5gvftz`) [J33], which in standard physics framework forces to locate the pain to the map of sensory field at cortex. One manner to solve the problem would be that that the pain is somewhere else than in phantom limb but mislocated in the construction of cognitive representation: this would be just wrong kind of association. The alternative approach would give up the standard view about the relationship between subjective and geometric time: the phantom pain is sensory memory of an actual pain in the limb which exists in the geometric past at a distance of maybe decades. The third option is that qualia are formed at the level of neurons and under some conditions correspond to those experienced by us. This requires new physics at the level of neurons and clear identification what the physical correlates of qualia are in this new physics.

5.3 Quantum TGD Very Briefly

Before discussing the TGD inspired identification of the universal algorithm as quantum jump in turn identified as a moment of consciousness, it is good to briefly summarize some basic aspects of quantum TGD.

5.3.1 Many-Sheeted Space-Time, Embedding Space, WCW

The basic geometric notions of TGD are many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book), embedding space $M^4 \times CP_2$ (see **Fig. ??** in the appendix of this book) and "world of classical worlds" (WCW) identified as the infinite-dimensional space of space-time surfaces, which can be seen as analogs of Bohr orbits representing kind of archetypal field patterns in their geometry. The choice of the embedding space is fixed by particle physics considerations uniquely and can be justified also by very general mathematical arguments. For instance, M^4 is the only space with Minkowskian signature allowing twistor structure, and CP_2 is one of the very few Euclidian compact manifolds allowing twistor structure and the only one for which twistor space is Kähler manifold. TGD leads to geometrization of the classical fields appearing in standard model and particle quantum numbers can be understood in terms of the symmetries of the embedding space.

I will not go the detailed definitions of these notions here but refer to the articles and books at my homepage. What is essential is that TGD space-time is topologically non-trivial in all length scales and objects of various size scales that we see around us can be interpreted in terms of space-time sheets defining their own sub-Universes.

Second essential generalization and deviation from Maxwell's electrodynamics (and other field theories) is topological field quantization. For instance, magnetic field decomposes to flux quanta (flux tubes and sheets) represented as space-time time quanta. This quantization is in key role in the model of living matter and the dynamics of the "magnetic bodies" is crucial for understanding various aspects of bio-catalysis and also EEG. Magnetic body (hierarchy of them) brings to the usual picture of living system as biological body interacting with environment a completely new level.

5.3.2 Zero Energy Ontology (ZEO)

The failure of the strict determinism for the preferred extremals of Kähler action means that data in time=constant snapshot do not determine the future and past behavior. Several time=constant snapshots must be assumed and this led originally to the notion of association sequence. Later the notion of zero energy ontology (ZEO) emerged and was forced by number theoretical universality: the vanishing total quantum numbers indeed make sense in number theoretically universal manner. ZEO allows also to avoid the paradox suggested by the fact that Poincare invariance is exact in laboratory scales but not in cosmological scales: the solution relies on the observation that the notions of energy and momentum for the positive energy parts of zero energy states are scaled dependent in ZEO.

1. Zero energy states are superpositions over pairs of positive energy states and negative energy states and correspond to initial and final states of a physical event in positive energy ontology. Positive and negative energy states are localized at the opposite light-like boundaries of a causal diamond (CD) defined as intersection of future and past directed light-cones (CP_2 appears as a Cartesian factor but will not be mentioned separetely in the sequel). Space-time surfaces in the quantum superposition are identified as preferred extremals of Kähler action and are restricted inside CD for the simplest option.

2. CDs form a fractal hierarchy with size scales coming as integer multiples of fundamental size scale. Translates and Lorentz boosts of CDs are also possible. It is not quite clear whether one should allow CDs to intersect or should one require strict nesting. System has in general wave function in the moduli space of CDs and in quantum jump a localization to CDs for which either upper or lower boundary is fixed takes place.

3. CDs are the geometric correlates of selves at the level of embedding space $M^4 \times CP_2$. The 4-D space-time surfaces define the correlate of selves at space-time level. One can consider two time coordinates: embedding space time coordinate and that of 4-D surface.

5.3.3 P-Adic Physics And Cognition

I ended up with p-adic physics from accidental observations related to the mass scale ratios of elementary particle spectrum. The construction of p-adic thermodynamics predicting particle masses with excellent accuracy inspired questions which led to the proposal that p-adic physics describes cognition present already at elementary particle level.

1. Embedding space has also p-adic sectors corresponds to various p-adic number fields. These sectors are glued together along rational points common to real and p-adic number fields and also via common algebraic points in the case of algebraic extensions of p-adic number fields. The common rational points of real and p-adic space-time surface (or at least partonic 2-surface) define cognitive representation so that cognitive representations are always discrete.

   At the level of WCW the points of real and p-adic sectors identifiable with each other correspond to surfaces, whose algebraic representations make sense both in real and p-adic sense. The general vision is that life resides in this this intersection of real and p-adic worlds. For instance, this motivates the notion of number theoretic entanglement entropy which can be negative and is interpreted as a measure of information assignable to entanglement.

2. Mappings of real space-time surfaces to p-adic ones are fundamental and define cognitive representations [K98]. The mappings of p-adic space-time surfaces to real ones are interpreted as realizations of intentional actions. When motor action is identified as the time reversal for the formation of sensory representation, intentional action becomes time reversal for the formation of cognitive representation so that a very powerful and elegant symmetry emerges.

3. Finite measurement resolution is fundamental notion and actually forced by the notion of p-adic manifold. An attractive additional constraint is that the space-time surfaces in the superposition are perceptively equivalent in given measurement resolution characterized by p-adic prime assignable to the space-time surface and corresponding pinary cutoffs and also by the algebraic extension of p-adic numbers characterizing the angle resolution.

5.3.4 Length Scale Hierarchies And Cognitive Hierarchies

TGD involves several hierarchies.

1. One hierarchy is formed by the p-adic length scales assignable to p-adic primes coming as primes near powers of two.

2. Second hierarchy corresponds to size scales of CDs coming as integer multiples of CP_2 scale with secondary p-adic length scales being favored. One can assign to these length scales length scale resolution as p-adic length scale multiplied by a half-integer power of p, and angle resolution defined in terms of algebraic extenion of p-adic numbers used. These length

scales are now an essential part of the definition of the notion of p-adic manifold necessary for the construction of number theoretically universal calculus.

The resolution scales have also natural counterpart at quantum level and can be realized in terms of inclusions of hyper-finite factors of type II_1 [K96]. The included factor defines the degrees of freedom which cannot be seen in given resolution and the factor space obtained by dividing with the included factor defines quantum space with finite but fractional dimension.

3. The increase of resolution means getting rid of un-necessary details in the case of cognitive representations it would be un-necessary information allowing a formation of abstraction. The reduction of the resolution means addition of details and formation of lower level representation. In the realization of motor action this process indeed occurs. This process can be however as a formation of sensory representation in non-standard time direction. The findings of Libet conform with this view about motor action.

4. The hierarchy of (effective) Planck constants $\hbar_{eff}$ was conjectured for about 8 years ago [K26].

   (a) The values of $\hbar_{eff}$ would come as multiples of ordinary Planck constant: $\hbar_{eff} = n\hbar$. TGD provides two possible explanations for how $\hbar_{eff}$ emerges. The first one relies on multi-furcations of space-time surface implied by the failure of strict determinism of the basic variational principle: $\hbar_{eff} = n\hbar$ would correspond to n-furcation taking place at the boundary of causal diamond. Second explanation relies on the general structure of p-adic Lie-algebras predicting effective values of Planck constant coming in the proposed manner [K98]. These explanations should and could be equivalent.

   (b) For large values of $\hbar_{eff}$ the quantal scales (say Compton length of electron) become large and this makes possible macroscopic quantum coherence. The hypothesis is that dark matter corresponds to ordinary matter but with non-trivial value of $\hbar_{eff}$. What would make it dark is that particles with different values of $\hbar_{eff}$ cannot occur in the same vertex of a generalized Feynman diagram although particles with different value of $\hbar_{eff}$ can transform to each other.

   (c) The proposal is that magnetic flux quanta (sheets and tubes) can be carriers of dark matter. The phase transitions reducing $\hbar_{eff}$ reduce the length of the magnetic flux tube and if biomolecules form an "Indra's net" connected by flux tubes, these phase transitions could force two biomolecules connected by flux tube near to each other so that they could find each other in the dense molecular soup. The reconnection of closed magnetic flux tubes associated with two molecules in turn generates two flux tube pairs connecting the molecules and allowing the two systems to become effectively single quantum system in dark degrees of freedom with large value of Planck constant. Persinger's recent experiments give support for this vision [L3].

5.4 Quantum Jump As The Counterpart Of Fundamental Algorithm In TGD?

In order to formulate the interpretation of quantum jump sequence as a fundamental algoritm of sensory perception, cognition, intentional action, and motor action, one must describe the basic ideas of TGD inspired theory of consciousness.

5.4.1 Basic Ideas Of TGD Inspired Theory Of Consciousness

Before discussing the TGD based analog for universal algorithm, it is good to begin by giving a list about basic ideas of TGD inspired theory of consciousness.

1. Identification of quantum jump between zero energy states as moment of consciousness. It is essential that the quantum states counterparts for entire time evolutions of Schrödinger equation rather than time=constant snapshots of single evolution. In this manner one can avoid the conflict between non-determinism of state function reduction and determinism of

Schrödinger equation. This however implies that subjective time, whose chronon quantum jump is, cannot be identified with the geometric time of physicists. The correlation between these two times is of course possible in the sense that quantum jump sequences corresponds to an increase of geometric time defined in some natural manner. This correlation must be strong since these two times are usually identified.

2. Originally I distinguished between the notions of quantum jump and self proposed to emerge from some kind of gluing together of quantum jumps to larger structures in a manner analogous to the fusion of particles to bound states. The fractality of quantum jump in the sense that there are quantum jumps within quantum jumps led to the identification of quantum jump and self. This identification has however remained somewhat fuzzy.

   The recent considerations however suggests that negentropic entanglement in time direction is necessary for mental images (having sub-CDs as correlates) to mental images representing spatial patterns and for these patterns in turn to bind to a sequence 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.

   Should these sequences define selves so that self would be something characterizing quantum state rather than something identified as quantum jump? Or could these sequences define a model of self to be distinguished from self identified as quantum jump? By definition negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) tends to be preserved in quantum jumps 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. This information would not be however conscious if the original view about conscious information as change of information is accepted. Could one imagine a reading mechanism in which this information is read without changing the negentropically entangled state at all? This reading process would be analogous to deducing the state of a two-state system in interaction free measurement to be discussed below.

3. Selves form a hierarchy, which predicts higher level selves identifiable in terms of collective and transpersonal consciousness. Also lower levels of hierarchy should be present so that even neuron and even electron should possess primitive self-awareness.

4. The sub-selves of self are identified as mental images of self and sub-sub-selves are assumed to be experienced as ensemble averages- at least when the entanglement is not negentropic. This averaging could be seen as an alternative mechanism for the formation of abstractions. Another mechanism would be based on quantum superposition of perceptively equivalent space-time surfaces. Sharing of mental images by entanglement of sub-selves is proposed and the motivation comes from the space-time correlates of entanglement identified as magnetic flux tubes connecting the space-time sheets of sub-selves although space-time sheets of selves are disjoint. This picture requires a generalization of the usual tensor product description for the formation of many-particle states.

Negentropy Maximization Principle (NMP) defines the basic variational principle of TGD inspired theory of consciousness.

1. NMP states that the negentropy gain in the quantum jump is maximal. For the ordinary entanglement entropy NMP implies that state function reduction leads to a pure state, which is an eigenstate of the density matrix characterizing the interaction of subsystem with its environment. An interesting purely mathematical result is that the assumption that density matrix always reduces to a partial trace of pure state density matrix leads to the basic rules of quantum theory probabilities. TGD inspired theory of consciousness, which can be seen as a generalization of quantum measurement theory, allows only this kind of density matrices.

2. If one accepts the notion of negentropic entanglement, number theoretic entropy can become negative in state function reduction. This makes possible formation of negentropically entangled states whereas in the usual state function reduction entanglement is always reduced.

Negentropy is however associated with the entanglement rather that single particle states of either particle so that no problmes with second law emerge.

Consistency with quantum measurement theory forces to assume that the density matrix of the final state is projector, which can be higher than 1-dimensional. This allows to identify negentropic entanglement uniquely: in the general case it would be impossible to tell in practice whether entanglement is negentropic.

A further refinement to NMP is what I call weak NMP. It does not force the best possible outcome. Self has freedom to project also to the lower-dimensional sub-space. This has several interesting consequences, mention only the possibility to say something interesting about the physical correlates of ethics and moral and origin of emotional intelligence [K93], and also about the origin of p-adic length scale hypothesis [K95].

3. NMP and second law are structurally very similar and one can consider the notion of the counterpart of thermodynamical equilibrium in which the average values of some conserved quantities are fixed so that one can assign to them temperature like parameters. At least in the ideal situation quantum jump could lead to the analog of thermal equilibrium prevailing in all scales with maximum amount of negentropic entanglement. This is probably too strong an idealization. The assignment of the experience of understanding with the generation of negentropic entanglement is a highly attractive idea. To assign it with negentropic entanglement itself does not conform with the basic postulate.

Both p-adic length scales and CDs form a hierarchy and this raises the question whether or not the quantum jumps inside CDs within CDs are related or not. One can consider three options.

1. For the first option the cascade of state function reductions can begin from any *unentangled* CD and after that proceeds to shorter length scales (smaller sub-CDs) until it stops when maximally negentropic entanglement is reached. This cascade would be analogous to motor action proceeding from long to short scales as detailes of the motor action are fixed. For sensory perception the cascade would be same but in opposite direction of embedding space geometric time (state function reduction for the opposite boundary of CD). This would imply an effect analogous to quantum Zeno effect. If for given CD quantum jump cascade can begin only if CD is unentangled, negentropic entanglement stabilizes the CD, and it can spend long times in this negentropically entangled state but would not be conscious.

2. One can consider also the possibility that the CD from which the cascade begins is entangled with other CDs so that in quantum superposition of states the state function reduction cascades could occur separately for all summands. This would mean quantum parallelism for state function reductions. What is essential that state function reductions for components of the linear superposition in a given scale can occur only in shorter scales. For instance, in this picture hadrons could be seen as quantum coherent structures in hadronic length scales but dissipative quantum structures in quark length scales. It is is not clear to me whether the possible non-uniqueness of the state basis could exclude quantum parallellism for state function reductions.

3. For the third option quantum jumps inside various CDs would occur independently and top-down and bottom-up cascades are not predicted.

5.4.2 The Anatomy Of Quantum Jump In Zero Energy Ontology (ZEO)

Zero energy ontology (ZEO) emerged around 2005 and has had profound consequences for the understanding of quantum TGD. The basic implication is that state function reductions occur at the opposite light-like boundaries of causal diamonds (CDs) forming a hierarchy, and produce zero energy states with opposite arrows of time. Also concerning the identification of quantum jump as moment of consciousness ZEO encourages rather far reaching conclusions. In ZEO the only difference between motor action and sensory representations is that the arrows of embedding space time (CDs) are opposite for them. Furthermore, sensory perception followed by motor action corresponds to a basic structure in the sequence of state function reductions and it seems that these processes occur fractally for CDs of various size scales.

1. State function reduction can be performed to either boundary of CD but not both simultaneously. State function reduction at either boundary is equivalent to state preparation giving rise to a state with well defined quantum numbers (particle numbers, charges, four-momentum, etc...) at this boundary of CD. At the other boundary single particle quantum numbers are not well defined although total conserved quantum numbers at boundaries are opposite by the zero energy property for every pair of positive and negative energy states in the superposition. State pairs with different total energy, fermion number, etc.. for other boundary are possible: for instance, the coherent states of super-conductor for which fermion number is ill defined are possible in zero energy ontology and do not break the super-selection rules.

2. The basic objects coding for physics are U-matrix, M-matrices and S-matrix. M-matrices correspond to hermitian square roots of density matrices multiplied by a universal S-matrix which depends on the scale n of CD in very simple manner: $S(n) = S^n$ giving thus a unitary representation for scalings. The explicit construction of a unitary U-matrix in terms of M-matrices is carried out in [K49]: U-matrix elements are essentially inner products of M-matrices associated with CDs with various size scales. One can say that quantum theory is formally a square root of thermodynamics. The thermodynamics in question would however relate more naturally to NMP rather than second law, which at ensemble level and for ordinary entanglement can be seen as a consequence of NMP.

   The non-triviality of M-matrix requires that for given state reduced at say the "lower" boundary of CD there is entire distribution of states at "upper boundary" (given initial state can lead to a continuum of final states). Even more, all size scales of CDs are possible since the position of only the "lower" boundary of CD is localized in quantum jump whereas the location of upper boundary of CD can vary so that one has distribution over CDs with different size scales and over their Lorentz boots and translates.

3. The quantum arrow of time follows from the asymmetry between positive and negative energy parts of the state: the other is prepared and the other corresponds to the superposition of the final states resulting when interactions are turned on: also quantum superposition over CDs of different sizes with second boundary belonging to the same fixed $\delta M^4_\pm$ is possible. What is remarkable that the arrow of time at embedding space level (at least) changes direction as quantum jump occurs to opposite boundary.

   It is however possible to have sequences of quantum jumps occurring at the same boundary: these periods are counterparts for repeated state function reductions, which do not change the state at all in standard quantum measurement theory. During these periods the superposition of opposite boundaries of CDs and states at them change, and the average distance between the tips of CDs tends to increase, hence the flow of subjective time and its arrow.

   NMP dictates when the first quantum jumps to the opposite boundary of CD takes place. The sequence of state function reduction at the same boundary defines self as a conscious entity and the increase of the average distance between the tips of CD defines the life-time of self.

   This brings strongly in mind the old proposal of Fantappie [J54] that in living matter the arrow of time is not fixed and that entropy and its diametric opposite syntropy apply to the two arrows of the embedding space time. The arrow of subjective time assignable to second law would hold true but the increase of syntropy would be basically a reflection of second law since only the arrow of the geometric time at embedding space level has changed direction. The arrow of geometric at space-time level which conscious observer experiences directly could be always the same if quantum classical correspondence holds true in the sense that the arrow of time for zero energy states corresponds to arrow of time for preferred extremals. The failure of strict non-determinism making possible phenomena analogous to multi-furcations makes this possible.

4. This picture differs radically from the standard view and if quantum jump represents a fundamental algorithm, this variation of the arrow of geometric time should manifest itself in the functioning of brain and living organisms. The basic building brick in the functioning

of brain is the formation of sensory representation followed by motor action/volition realized as the first reduction at the opposite boundary.

These processes look very much like temporal mirror images of each other such as the state function reductions to opposite boundaries of CD look like. The fundamental process could correspond to a sequences of these two kinds of state function reductions at opposite boundaries of CDs and maybe independently for CDs of different size scales in a "many-particle" state defined by a union of CDs.

How the formation of cognitive and sensory representations could relate to quantum jump?

1. The earlier view was based on the idea that p-adic space-time sheets can transform to real ones and vice versa in quantum jump and these process correspond to a realization of intention as action and formation of though. This view is mathematically awkward and has been replaced with the adelic vision in which all systems have both sensory (real space-time sheets) and cognitive (p-adic space-time sheets) space-time correlates. The real and p-adic number fields form a book like structure - adele- with an algebraic extension of rationals as its back. Same applieds at the level of embedding space, space-time surfaces, and WCW. In this framedwork holography makes it possible to understand real and p-adic space-time surfaces as continuations of string world sheets and partonic 2-surfaces to space-time surfaces, either real or p-adic. The string world sheets themselves are in the intersection of reality and various p-adicities in the sense that the parameters characterizing them belong to an extension of rational numbers.

2. Self having the mental image about intention can be be seen as the agent transforming intention to action. By NMP negentropy is typically generated in this transition tending to increase the value of Planck constant $h_{eff} = n \times h$ and thus reducing quantum criticality and occurring therefore spontaneously. Negentropy Maximization Principle eventually forces the occurrence of volitional action - self experiences the urge to perform the action so strong that cannot resist. Subself representing the mental image about intention tries to prevent it as long as possible because it means death: all living systems try to stay at the existing level of criticality and avoid the fatal final state function reduction by practicing homeostasis and using metabolic energy. Weak form of NMP states that self has freedom to decide whether it performs the reduction producing maximal entanglement negentropy. It can also perform ordinary quantum jump reducing entanglement entropy to zero and destroying entanglement. The outcome is isolation from the external world. The motivation for the weak form of NMP is that we do not live in the best possible world and have free will to choose between Good and Evil. Strong form of NMP would produce always mazimal negentropy gain and would mean best possible world.ur in various length scales in fractal manner.

5.4.3 How Memories Are Represented And Recalled?

Formation of memories and memory recall are key elements in the vision proposed by Hawkins. 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 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.

5.4.4 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 zero energy state resulting in the reduction for given CD would generalize this hypothesis. If this assumption hold true, the subsequent reductions at the same boundary of CD would effectively correspond to single reduction 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. 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 cyclity 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.

5.4.5 Self Or Only A Model Of Self?

Negentropic entanglement 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 negentropic entanglement 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 negentropic entanglement is necessary for mental images (having sub-CDs as correlates) to mental images representing spatial patterns. Negentropic entanglement 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.

This picture however challenges the identification of self as quantum jump. Should the negentropically entangled sequences of mental images define selves so that self would be something characterizing zero energy state rather than something identified as quantum jump? Could they define a model of self to be distinguished from self identified as quantum jump? Or could one give up the notion of self altogether and be satisfied with model of self? At this moment it seems that nothing is lost by assuming only the model of self.

By definition negentropic entanglement tends to be preserved in quantum jumps 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. There is however a problem involved. This information would not be conscious if the original view about conscious information as a change of information is accepted.

Could one imagine a reading mechanism in which this information is read without changing the negentropically entangled state at all? This reading process would be analogous to deducing the state of a two-state system in interaction free measurement to be discussed below in more detail. If has turned out that the original proposal that interaction free measurement could allow to achieve this does not work. Indeed, the recent formulation of TGD inspired theory as quantum measurement theory in Zero Energy Ontology and assuming NMP requires that negentropic entanglement assignable to the passive boundary of causal diamond (CD) is directly experienced and defines what might be called unchanging self.

The interaction free measurement could however allow to read memory representations constructed in terms of bits without changing them at all at idealized limit and for this reason is discussed below.

5.4.6 Could Interaction Free Measurement Be Used To Read Memory Representations?

If memory representations are realized in terms of bits, there should exists a way to read them without changing them. No-cloning theorem prevents this but one can imagine a reading mechanism inducing no changes at idealized limit. The following proposal for non-destructive reading of memories and future plans allows to resolve this problem.

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 realized in terms of bits at active boundary of CD. 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, see `http://tinyurl.com/kx2jsyu` [B1] for an illustration of the system considered.

   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 bit 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 only the time direction of the signal differs for them.

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.

5. Active/passive dichotomy can be 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.

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 bits. 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 [J34] 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.

Some critical questions

There are two basic objections against quantum theories of consciousness. How it is possible to have conscious information about invariant under quantum jumps if only change is experienced continuously? The outcome of state function reduction in standard quantum theory is random: how can one understand freedom of choice and intentional behaviour in terms of state function reduction? NMP and the possibility of negentropic entanglement imply that TGD based quantum theory is not equivalent with the standard one, and this allows to circumvent the objections.

The experiments carried out to test whether 40 Hz thalamocortical resonance is correlate for conscious experience suggests that the resonance is present only when a new pattern is discovered, not when it has become a memory. The TGD inspired interpretation would be that the resonances accompanies negentropy gain and quantum jump is necessary for conscious experience. However, the reports about higher states of consciousness (and also my own experiences) suggest that the invariants can be experienced directly when all thoughts (interaction free measurements) are eliminated. This experience cannot be however communicated: one understands does not know what one understands. Therefore also the original vision that negentropic entanglement corresponds to conscious experience - experience of pure understanding, which is not communicable - and in apparent contradiction with the basic hypothesis about quantum jump, would be correct after all!

Why vision and hearing are so fundamental for cognition?

The interaction free measurement is formulated in terms of photons. It can be however formulated also for sound waves using phonon detectors and acoustic waves traversing through two different paths. Quantum coherence is required but the hierarchy of Planck constants makes sense also for phonons by the basic equation $E = hf$.

In TGD framework there are good reasons to believe that sound waves are not only something emerging at the level of condensed matter but correspond to oscillations of string like objects at 4-D space-time surface. These strings connect the wormhole contacts assignable to the light-like orbits of partonic 2-surfaces. Partonic 2-surfaces can be assigned with elementary particles but also to 2-surfaces with arbitrarily large size scale. The outer boundary of any physical object would correspond to a partonic 2-surface. String world sheets carry fermion fields localized at them (right-handed neutrino is an exception in that it is de-localized at entire space-time surface). The fact that strings always connect two partonic 2-surfaces corresponds to the fundamental two-particle character of sound waves. Sound would be as fundamental phenomenon as photons and other massless bosons.

This encourages to ask whether photon (more generally gauge boson: TGD suggests that scaled up copies of gluons and weak bosons behaving like massless particles even in cell length scale are possible) and photon absorption could define fundamental memory representations of information realized in terms of interaction free measurements.

Photons would correspond to "seeing" but at neuronal level rather than at the level of retina - and imagination. Phonons would correspond to hearing at neuronal level and internal speech which is also essential for cognition. Both internal speech and imagination could be understood at fundamental aspects of cognition. Dark photons with energies of visible photons (decaying to what is interpreted as bio-photons) and dark phonons would be behind imagination and internal speech. I have already earlier proposed that the lipid layers of neuronal membranes (and maybe also ordinary cell membranes) can be regarded as pixels of a sensory map representing neuronal qualia [K30]. These pixels could serve as the counterparts of the detectors C and D appearing in interaction free measurement. The evidence for the importance of bio-photons (in TGD framework dark photons decay to bio-photons in energy conserving manner) in biology and neuroscience is emerging, see for instance the experiments of Persinger's group [J36, J37, J38]. I have discussed these findings from TGD point of view in [L3].

One can speculate about direct translation between the words of language and visual pre-images. In general I try to avoid reference to anything personal since but at this time I cannot resists the temptation to mention that during my first "great experience", which served as a powerful inspiration for TGD inspired theory of consciousness, I was able to see my thoughts and discovered that this kind of correspondence seems to exists: I did experimentation with internal speech by uttering words and immediately getting visual image to my visual field as a response!

Biophotons seem to be associated only with the right hemisphere [J36]. This suggests that right hemisphere or some parts of it prefer dark photons being thus specialized to visual imagination in accordance with the fact that spatial relationships are the speciality of the right hemisphere. Could this mean that left hemisphere or some parts of it prefer dark phonons (or dark photons in IR range transforming [L3] to ordinary photons at ear and generating virtual auditory input? Left hemisphere indeed is the verbal hemisphere specialized to linear linguistic cognition and produces also internal speech.

Realization of memory representations in terms of braided flux tubes

While reading a marvellous book "The Field" by Lynn McTaggart [I11] about evolution of ideas about the role of electromagnetic fields in biology and neuroscience, I became aware of two questions which I had not yet answered. The first question is following: How various representations (sensory -, memory -, ...) - "Akashic records" - are realized as negentropically entangled states?

Magnetic body should be the seat of memories in some sense.

1. I have already earlier proposed this kind of realization based on the observation that braiding in time direction generates space-like braiding [K2]. Dancers on the parquette with their feet connected to the wall by threads illustrates the idea. When dancers move at the parquette their world lines define a time-like braiding in 3-dimensional space-time assignable to the floor. Also the threads connecting the dancers to the wall get braided - or entangled - as one might also say. There is clearly a duality between time-like and space-like braidings: the running topological quantum computer program coded by braiding in time direction is stored as space-like braiding defining memory representation of what happened. Note that same mechanism realizes also predictions and future plans as time reversed topological quantum computer programs in ZEO. CDs in various scales contain this kind of programs and their memory representations.

2. I have also proposed that the geometric entanglement - braiding - of flux tubes defines a space-time correlate for quantum entanglement. In the case of topological quantum computation it would be naturally described by probabilities, which are rational numbers (or perhaps even algebraic numbers in some algebraic extension of p-adic numbers characterizing together value of the p-adic prime the evolutionary level of the system). Hence the notion of number theoretic negentropy makes sense and one obtains a connection with topological quantum computation.

3. The representation of memories in terms of space-like braiding of magnetic flux tubes connecting various systems would be universal, and not restricted to DNA-cell membrane system

in which the flux tubes would connect DNA nucleotides [K2, K92] or codons (this seems to be the more plausible option [L3]) with the lipids. One could indeed speak about Akashic records (see `http://tinyurl.com/5hxjpr`).

4. The time reversals or these representations defined by the zero energy states of opposite arrow of the embedding space time would define a representation for future predictions/ plans in ZEO. For instance, the development of a seed to a full-grown organism could be coded in this manner in time scale where CD has time scale of order of the lifetime of the organism. Already Burr found evidence that the radiation field assignable to the seed has the same shape as the plant [I7, I11] or animal (salamander in his experiments). This energy field would naturally correspond to the magnetic body containing dark photon Bose-Einstein condensates. The Akashic records and their time reversal would naturally correspond to the morphic fields of Sheldrake [I15, I16]: memories and future plans in time scales longer than than duration of life cycle for an individual member of species would be possibles. Every scientist of course agrees that the societies are busily predicting and planning their futures but find very difficult to accept the idea that this could have some concrete quantum physical correlate.

How to construct and read conscious hologram?

The above discussion raises the question about how the vision about brain as a conscious hologram is realized in the proposed conceptual framework.

The idea about living system as a hologram has strong empirical basis. One of the most dramatic demonstrations of the hologram like character of brain was the discovery of Pietch [J63] that salamander's brain can be sliced to pieces and shuffled like a deck of cards and put together. When the resulting stuff is returned to the head of the salamander, it recovers! This extreme robustness is very strong support for the non-local hologram like storage of biological information. Ironically, Pietch tried to demonstrate that the theory of Karl Pribram [J51, J52] about brain as a hologram is wrong! In TGD framework one can go even further and ask whether this robustness actually demonstrates that various representations (sensory - , cognitive -, memory -...) are realized at the long magnetic flux loops and sheets of the magnetic body rather than brain.

The notion of conscious hologram [K8] is one of the key ideas of TGD inspired theory of consciousness. Hitherto I have not been however able to find a really convincing concrete proposal for how brain could be a hologram in TGD Universe. The reading of memory - and other representations by interaction free measurement however leads to a natural proposal for what the hologram might be.

1. Certainly the formation of the hologram must closely relate to the vision about universal Akashic records realized in terms of braided flux tubes and their non-destructive reading by interaction free measurement. Oversimplifying, for a given bit of the representation the photons scattered without interaction would kick either of the two detectors C and D associated with it to an excited state (see `http://tinyurl.com/y86ysuyd`). This process is very much like absorption of photons by a photosensitive plate defining an ordinary hologram.

2. The lipids of the cell membrane are good candidates as something in 1-1 correspondence with the basic units of this hologram (note the analogy with computer screen - also a liquid crystal!). If one irradiates the laser like system formed by the detectors not only by the radiation scattered from the quantum Akashic records but by its superposition with the reference wave of same frequency, one obtains a good candidate for a hologram. It would be defined by the excited quantum state consisting of laser systems analogous to the detectors C and D. Any piece of the system should give and approximate representation of the memory and robustness of the representation is achieved.

3. In semiclassical treatment the probability that a given laser like detector is excited must be proportional to the modulus squared of the net field amplitude, which is a superposition of reference wave and scattered wave Also just. as in the case of ordinary holograms, the irradiation of the laser like system by the negative energy counterpart of the reference wave (its phase conjugate emitted in a state resulting in state function reduction to the opposite

boundary of CD) effectively generates the conjugate of the scattered wave since only those parts of the system can return to the ground state with considerable probability for which the probability to go to excited state is high enough. Note that this implies that magnetic body contains geometric representations of the perceptive field as indeed assumed [K38, K39]. This is however not quite the classical hologram. Rather, the total number of absorbed negative energy phase conjugate photons for given pixel defines the "real" picture. A given point of the hologram corresponds to an ensemble of laser like detectors so that a statistically deterministic response is obtained as an ensemble average.

How to realize this concretely?

1. I have proposed that the lipids of cell membrane could serve as pixels of sensory representations [K30]. They could indeed serve as the pixels of conscious hologram. Each pixel should contain large number of laser like "detectors" so that statistical determinism would be achieved.

2. There should be pair C and D of detectors such that either of them absorbs photon in an interaction free measurement so that a value of bit is defined. Universality serves as a strong constraint as one tries to guess what C and D could be.

   (a) The lipids at the two lipid layers of cell membrane could be in 1-1 correspondence with C and D. This option is not however universal.

   (b) It is however quite possible that the magnetic fields involved are what I have called wormhole magnetic fields [K99], which carry monopole flux and and involve two space-time sheets carrying opposite net fluxes. As a matter of fact, all elementary particles correspond to flux quanta of wormhole magnetic fields. In this case the two sheets would naturally correspond to detectors C and D and in the simplest situation they would have same Minkowski space projection. Universality of both detectors and holograms is achieved.

3. The cyclotron Bose-Einstein condensates for charged particles at magnetic flux tubes assignable to lipids are good candidates for the laser like systems if they contain cyclotron Bose-Einstein condensates. There are however several options since the magnetic flux tubes are closed and there are several ways to realize this.

   (a) DNA as topological quantum computer vision and the view about cell membrane as a sensory receptor communicating data to the magnetic body in turn sending control signals via DNA suggest the following. Magnetic flux loops have a part connecting DNA with nuclear or cell membrane (this would be the analog for the dipole of the dipole magnetic field) and part which is long - even with size scale of Earth and corresponds to the magnetic field created by the DNA-cell membrane system. This picture applies both to the flux tubes of ordinary magnetic field and to the flux tubes of the wormhole magnetic field.

   (b) An assumption in accordance with the general role of magnetic body is that Akashic records reside at the short portions of flux tubes connecting lipids with DNA codons: their braiding would define basic example about universal representations in living matter. The laser like detectors would reside at the long portions of the flux tubes connecting cell membrane and DNA. If wormhole magnetic fields are in question, the detectors C and D could correspond to the two parallel flux tubes carrying opposite monopole fluxes.

   (c) Universality suggest that this picture allows many alternative realizations. In principle, the relative motion of any system (partonic 2-surfaces with light-like orbits) connected by flux tubes could give rise to Akashic records. The lipids of axonal membrane are excellent candidates for the pixels and the flux tubes connecting the lipids to microtubuli [J8] would also define Akashic records with long parts of the flux tubes serving as the laser like system. The maximization of the memory capacity would also explain why the neural pathways to brain tend to maximize their lengths by connecting right side of the body to left hemisphere and vice versa.

4. What remains still open is how to integrate the Josephson junctions defined by the lipid layers of the cell membrane to this picture.

5.4.7 Could Quantum Jump Represent The Basic Aspects Of Abstraction Process Automatically?

Could quantum jump automatically represent the basic aspects of abstraction process and its reversal as it manifests itself at the level of brain?

1. The sizes of CDs in the quantum superposition defining zero energy state tend to increase. This means that the time scale of sensory and cognitive representations increases. Also new sub-CDs are generated as the size scales of CDs increase and this means generation of new mental images identifiable as memories.

2. NMP favors the formation of negentropic entanglement between sub-CDs so that sequences of mental images with both space-like entanglement (spatial patterns) and time-like entanglement (sequences of spatial patterns) are formed. NMP guarantees their stability. Zeno effect could make possible the analog of thermodynamical equilibrium to prevail for several quantum jumps on same boundary of CD having no effect in a given length scale. If quantum jumps occur independently for several scales, they can occur simultaneously in other scales.

3. Map from real to p-adic sector occurs defines a cognitive representation, a prediction for the future (or past when intention is realize as action). In the ideal situation "thermal equilibrium" with respect to NMP is achieved for a given CD. Next state function reduction having observable effects occurs at the opposite boundary of CD and gives rise to motor action or intention about motor action defined by this sensory representation. The transformation to real sector realizes intention.

5.4.8 Quantum Jump As The Counterpart Of Fundamental Algorithm?

In TGD framework the materialistic identification of consciousness as a property of the physical state of brain is not made. Consciousness is assigned with quantum jump and is therefore something between two quantum worlds.

In quantum TGD context functionalism does not look like an attractive idea. However, the idea that cognitive processing as identification and naming of objects of the perceptive field could be totally universal and taking place already at the elementary particle level, does so. The additional feature would be coloring of this cognitive map. Sensory qualia would do this and could be assigned to the quantum jump and identifiable basically in terms of increments of various quantum numbers in quantum jump.

The TGD counterpart of the functionalistic dream could be dream about the reduction of basic aspects of brain function - formation of sensory and motor representations and their realization, to the basic the basic anatomy of quantum jump and properties of negentropically entangled states approximately invariant under quantum jumps. All systems, even electron would do this, but brain would be highly specialized to this fundamental process.

5.4.9 Could Quantum Computationalism Make Sense?

There are strong objections against classical computationalism but what about its quantum variant? The first question is about what one means with quantum computationalism. The usual quantum computation algorithm is modelled by classical computation and might not catch all aspects of activity that one might want to call quantum computation or more generally, conscious cognitive processing.

The vision about DNA as topological quantum computer is one of the key ideas of TGD inspired quantum biology and might actually apply to much wider class of biomolecules biological structures. The notion of magnetic body which distinguishes TGD from ordinary biology and neuroscience is central here. The braiding of magnetic flux represents topological quantum computation programs. One can actually see the braid strands connecting DNA nucleotides or triplets with lipids of nuclear or cell membrane as a representation for quantum software whereas DNA represents the hardware. The reconnections of flux tubes would generate quantum coherence between distant objects and the phase transitions changing their lengths could make possible the miracles of bio-catalysis. The so called cultural evolution could correspond to the evolution of the magnetic bodies.

Could brain - or perhaps even entire Universe - perform quantum computation in some generalized sense and whether sensory processing could be seen as quantum computation in this more general sense? In TGD framework one can consider a generalization of the notion of quantum computation so that quantum jump identified as moment of consciousness defines quantum computation in generalized sense and can be seen also as the counterpart of fundamental algorithm giving rise to sensory and cognitive representations and realizations of motor actions as their time reversals.

1. Generalized Feynman diagrams [L11] involve propagator lines for fermions to which one can assign topological quantum computation with basic gate identified as the basic braiding operation. These braid strands can be assigned with fermions at the ends of the light-like orbits of partonic 2-surfaces. Also the magnetic flux tubes can take the role of braid strands.

2. The vertices, which come in two varieties, do not have counterpart in ordinary quantum computation and seem to represent something totally new. The first vertex is the analog of string vertex and represents fusion or decay of 3-surface (or associated partonic 2-surface).

   (a) To this vertex one can naturally assign direct sum of state spaces associated with the braid strands carrying fermions. This $\oplus$ vertex has also time reversal and identifiable as co-vertex so that algebra and co-algebra structures are present simultaneously.

   (b) Second vertex is not encountered in string model and generalizes the ordinary 3-vertex of ordinary Feynman diagrams. At this vertex the orbits of 3 partonic 2-surfaces meet at their common end (partonic 2-surface). Now tensor product $\otimes$ is the natural operations and again one has algebra and co-algebra structure. These vertices are algebraically completely analogous with the ordinary sum and product.

   This led to the crazy proposal that arithmetics, the notions of real and p-adics numbers, and even more general mathematical notions generalize by replacing numbers with Hilbert spaces and that calculus for Hilbert spaces could make sense [K54]. This brings in infinite abstraction hierarchy and means a huge generalization of the structure of mathematics but might be needed if one wants to understand reflective consciousness.

3. The replacement of points of Hilbert space with Hilbert space to get a new structure means an abstraction. Single state is replaced with a set of states defined by state basis. Could this process correspond to the formation of abstractions is at the fundamental level? If so $\oplus$ could mean formation of quantum superposition of perceptively equivalent zero energy states representing the percept. $\otimes$ would represent association of different percepts (say through different sensory channels) which represent same object. The superposition of tensor product states would define rule and abstraction and could be the basic cognitive process assignable to generalized Feynman diagrams.

4. This process would be far reaching generalization of the ordinary arithmetics with $+$ and $\times$ to that for $\oplus$ and $\otimes$ and their co-operations. The basic fact about practical arithmetics is that the same computation as a sequence of operations can be performed with very many ways but there is the shortest manner to do it. At the level of generalized Feynman diagrams this would mean huge symmetries. The physical equivalence classes of generalized Feynman diagrams would be huge and in twistor approach to generalized Feyman diagrams these symmetries have an identification as counterparts for the symmetries of twistor diagrams.

Whether the representatives inside these equivalence classes are also cognitively equivalent is not clear. These observations suggest that generalized Feynman diagrams might be much nearer to what happens when human brain computes and that quantum computation in the ordinary sense corresponds only to a single line of generalized Feynman diagram, and has same relation to what really happens in brain as single particle quantum mechanics to full quantum field theory.

5.5 Philosophical And Conceptual Foundations Of Consciousness Science

Revonsuo [J17] discusses both philosophical, historical, and conceptual foundations of consciousness science. In the following I will restrict the attention to philosophical and conceptual foundations. In the following discussion the book of Revonsuo serves as excellent reference providing also references to various articles relating to the topics discussed so that I have not included them.

5.5.1 Philosophical Foundations

Revonsuo distinguishes between dualism and monism as basic approaches and discusses in detail both kind of approaches and in section "Why the mind-body problem will not go away?" considers the basic problems (explanatory gap/hard problem) shared by both approaches. In materialism the understanding of qualia, phenomenal experience, is the problem. In dualism the assumption of material and mental as separate "substances" leads to problems with the laws of physics. If one assumes that the mental causation to reduces to that of laws of classical physics, consciousness loses its causal role and becomes a mere epiphenomenon.

Quantum consciousness allows a third philosophical approach giving hopes of avoiding the problems of monism and dualism. This view is not discussed by Revonsuo. If quantum jump is identified as a moment of consciousness, the attempts to reduce the phenomenal aspects of consciousness to the properties of quantum states do not make sense. Consciousness would be in the change, in the re-creation of quantum world.

The challenge is to understand that the contents of consciousness represents also properties of the internal and external world at least approximately invariant under quantum jumps (mental images must represent useful information: rules, memory mental images, self model, model for the external world, etc...). Here quantum theory provides a solution: interaction free measurement [B1] allows to obtain conscious knowledge about subsystem (defining memory representation now) such that the probability for the change of the state can be made arbitrary small.

5.5.2 Conceptual Foundations

Revonsuo also discusses conceptual foundations of consciousness.

Phenomenal consciousness and qualia

1. Phenomenal consciousness and qualia should certainly be the central concepts of consciousness science. Ironically, in many theories of consciousness (eliminative materialism and some forms of functionalism and representationalism) qualia and phenomenal consciousness are not accepted at all so that not much remains to be explained as Dennett's "Consciousness Explained" (title of this book) expresses it.

   In TGD framework quantum jumps is naturally the source of phenomenal consciousness and qualia cannot be properties of the state since they are assigned with the re-creation of the Universe in quantum jump. This means that the "-ness" in "consciousness" is not appropriate. In finnish language the word "tajunta" would be much more appropriate word.

   One must of course considerably generalize the notion of quantum jump from the state function reduction of wave mechanics in order to understand basic aspects of conscious experience. In ZEO the positive energy parts of zero energy states are characterized by quantum numbers. In complete analogy, fundamental qualia can be labeled by the increments of various quantum numbers in quantum jump for positive/negative energy part of zero energy state.

2. Phenomenal consciousness seems to consists of centre and periphery. Attention seems to distinguish between centre and periphery. Whether a genuine background is present in phenomenal conscious experience is however difficult to test, say by introspection.

   Change blindess and inattentional blindness are general phenomena involving no brain disorder and in strong conflict with the intuitive belief that sensory experience represents all that is present in the perceptive field. In experiments demonstrating change blindness subject person sees a complex visual scenery. A little bit later the subject person is shown second picture and told that some big change distinguishes it from the first picture. As a rule subject persons are unable to identify this change unless they have directed their attention to just the particular feature that changes. Change blindedness obviously relates to the memory representations about the earlier sensory percepts. It seems that without attention they do not become parts of the memory representation.

   Inattentional blindness means that subject person concentrated on some cognitive task, does not notice unexpected stimuli in the perceptive field. A classic example is a situation in which person focuses attention to basket ball and fails to notice a person walking over the playground in gorilla mask. These findings have inspired the hypothesis that attention can be equated with consciousness and that only the target of attention is in the spotlight of consciousness. The mental image representing person in gorilla mask would not be negentropically entangled with the memory representation.

Attention

What attention could then mean in TGD framework?

1. Both change blindness and inattentional blindness that the mental images representing object of perceptive field becomes part of memory representation when it is attended. This suggests that attention corresponds to the generation of negentropic entanglement binding the new mental images to the negentropically entanglement sequence of earlier mental images. Generation of negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) would characterize attention. Clearly, attention cannot be equated with consciousness.

   We do not usually remember our dreams unless we wake-up immediately: could this be due to the fact that the dream mental images are not attended unless person wakes up during the dream? Could the objects of dream percept attended during lucid dreaming?

2. The target of attention should become a part of self + world model of the perceiver at the level of cognitive and memory representations at least. To direct attention is to store as a memory. If this does not happen, there is no potentially conscious memory about the object (memory recall would correspond to interaction free measurement) although it t could contribute to phenomenal consciousness even when it is not attended. Illusions in which subject person is deluded to identify some inanimate system as his body part are consistent with the proposed definition of attention.

3. I have proposed the formation of magnetic flux tubes connecting target of attention and perceiver as a space-time correlate of attention. "Perceiver" would correspond to a space-time sheet to which one can assign a negentropically entangled collection of sub-CDs representing a model for self + external world. Obviously the systems connection by a bridge of attention would form a single macroscopic quantum system. The negentropic entanglement of zero energy states associated with corresponding sub-CDs would be the quantum correlate of attention. At embedding space level the correlate could be overlap of the M^4 projections of the CDs involved.

   Various meditation practices suggests that the attention can be generated also when the target is inanimate object and means the experiencer becomes one with the target of attention. The recent experiments of Persinger [J36, J37, J38] provide support for the role of magnetic flux tubes as correlates for the formation of macroscopic quantum coherence binding the two systems to single quantum system.

4. Selective attention would also mean a state function reduction for a particular sub-CD representing sensory mental image negentropically entangling it with the collection of sub-CD: s representing self model of perceiver but eliminating its entanglement with sub-CDs representing other objects of the perceptive field.

5. Attention would have metabolism as a physiological correlate. I have proposed that ATP either carries negentropic entanglement and transfers it to the target or that the energy liberated in the process ATP$\rightarrow$ ADP generates negentropic entanglement. I have also proposed that ATP $\rightarrow$ ADP process means standardized manner to build reconnection in the network of magnetic flux tubes changing the connectedness of the magnetic Indra's net between biomolecules. In the case of two objects with disjoint magnetic bodies, reconnection of the flux tubes means that they become connected by a pair of magnetic flux tubes making possible negentropic entanglement. This is just what should happen when the new mental images is connected to the negentropically entangled connection of old mental images. Therefore a rather direct connection with metabolism, attention, and building of sensory representations seems to emerge.

Reflective consciousness

Reflective consciousness is second key aspect of consciousness besides phenomenal consciousness. Some consciousness theorists accept only reflective consciousness since it makes consciousness theorizing easy by allowing the reduction of brain to classical computer.

1. Reflective level of consciousness is typically about conscious experience itself and is often equated with the formation of representations. Becoming conscious about what one was conscious suggests however strongly that the representations are extended in this step. The binding of new mental images by negentropic entangled to a negentropically entangled collection of older mental images is what would happen in this process and the dynamics of quantum jump in ZEO would automatically induce this process.

2. The mathematical description of abstraction involves two elements: tensor product and direct sum. Tensor product identified as a correlate for association is the first element. The higher the abstraction level, the larger the number of factors in the tensor product. For instance, various sensory qualia are tensor producted in associative areas so that large number of different views about object a generated simultaneously.

   Direct sum by superposing perceptively equivalent zero energy states represents the averaging aspect of abstraction allowing to get rid of un-necessary details and to see the wood from trees. The measure for the abstraction level for direct sum can be identified as perceptive/cognitive resolution. The notion of resolution emerges unavoidably from the notion of p-adic manifold based on cognitive maps mapping real preferred extremals of Kähler action to their p-adic counterparts and their inverses (see the appendix of the book). This map is defined only for a discrete set of rational points (also algebraic for algebraic extensions of p-adic numbers). A reasonable working hypothesis is that the preferred extremals in the quantum superpositions have same discretizations characterized by the resolution. An alternative working hypothesis is that they have same geometric correlation functions in the resolution used.

3. In particular, quantum jump typically implies the increase of the size scale of CD involved and the addition of tensor factors to the negentropically entangled structure representing self model and model for self + external world.

About the definition of consciousness

The notion of consciousness is rather fuzzy and there is large number of definitions of consciousness which emphasize some aspect of consciousness and neglect others. Revonsuo lists some definitions and discusses their failures.

1. Consciousness as the ability to respond to stimulation emphasizes the visible behavioral aspects of consciousness state (ability to respond to them). The problem is that pure reflex

responses are not conscious-to-us and person can be fully paralyzed and still be fully conscious. Responsiveness would be better term than consciousness in this case.

2. Consciousness as the ability to represent information from the external world. This definition applies only to the representative part of conscious experience and one can imagine a person having phenomenal conscious but without ability to build cognitive representations. Living matter and also computers and even camera form representations about external world so that this ability obviously not complete characterization of consciousness.

3. Consciousness defined as wakefulness requires both awareness about self and environment and ability to respond to changes in the environment. Dream experiences represent the obvious objection now.

4. Consciousness as access to output systems, control of behavior or behavioral interactions with the world. Functionalists want to reduce consciousness to the existence of some input-output function and define consciousness as "access consciousness". Conscious information is information which can be represented verbally or realized as a motor response. This definition neglects completely the phenomenal aspects of consciousess and according to it computers are conscious.

All the definitions discussed by Revonsuo regard consciousness as a property of system. If this property is physical then consciousness becomes epiphenomenon without causal role. In TGD framework the identification of quantum jump as consciousness means that consciousness is not a property of physical world but something between two physical worlds.

5.6 Philosophical And Empirical Theories Of Consciousness

Revonsuo [J17] analyzes in detail selected philosophical and empirical theories of theories of consciousness demonstrating their problems.

5.6.1 Some Philosophical Theories Of Consciousness

Revonsuo discusses as examples of philosophical theories of consciousness.

- Multiple drafts theory of Dennet (see `http://tinyurl.com/y6uoyclp`) [J27],
- Sensorimotor theory of O'Regan and Noe (see `http://tinyurl.com/oodtodv`) [J61].
- Biological naturalism of Searle (see `http://tinyurl.com/yhga9ep`) [J49].
- Naturalistic dualism of Chalmers (see `http://tinyurl.com/yd2dcxrk`) [J25].
- Higher order theories of consciousness (HOTs) [J62] (entire industry).
- External representationalism of Tye and Dretshke (see `http://tinyurl.com/ybfxkhxo`) [J57, J40].
- Neurophenomenology Varela, Lutz, Thompson, and Noe (see `http://tinyurl.com/6l8jqfy`) [J10, J41].
- Reflexive monism of Velmans [J58] (see `http://tinyurl.com/y84znmdv`).
- Virtual reality theory of Metsinger and Lehar [J70, J74]. The book of Revonsuo gives a lot of references to these theories.

In the following some comments about these theories from TGD vantage point.

1. Dennett can be seen as eliminative materialist and functionalist. Dennett's theory denies qualia, phenomenal consciousness, and subjectivity - all that is usually counted as core elements of consciousness - and accepts only representational, narrative consciousness. Consciousness accompanies complex, parallel information processing system in this framework

and complex enough computer is conscious in Dennett's Universe. "Multiple drafts" means that different streams of information are competing with each other to get access to output systems - or to gain fame in brain - as Dennett puts it. The competiion for metabolic resources between sub-selves could correspond to this competition in TGD framework.

2. Sensorimotor theory of O'Regan and Noe defines consciousness as ways of acting or as something we do, rather as phenomenal experiences or internal representations. The relation to the external world becomes decisive. The conclusion is that consciousness does not involve brain activity at all so that the search for neural correlates of consciousness would be waste of time. Also the notion of phenomenal consciousness is rejected. There are obvious killer objections against sensorymotor theory. People who are totally paralyzed can still be conscious. Dreams - whose reality even very few philosophers are ready to deny - serve as a second killer objection against the theory.

3. Biological naturalism of Searle identifies consciousness as a biological phenomenon, a higher level emergent feature of brain activity. In accordance with the materialistic dogma conscious phenomena would be caused by the neurobiological properties of neuronal systems and consciousness has no causal powers. Subjectivity - first person ontology as philosopher would put it - is however accepted and not assumed to reduce to any objective neurophysiological phenomenon so that consciousness becomes more or less a miracle. The theory therefore assumes strong emergence as opposed to weak emergence meaning that consciousness can be explained using physics. The problem is that there is no ideas about the systems for which phenomenal consciousness should emerge.

   In TGD framework quantum jump would bring in subjectivity. Miracle like emergence is not needed and subjectivity is assigned with a basic process of quantum physics.

4. Chalmers is known for introducing the hard problem (see `http://tinyurl.com/2ws2zq`): How any physical system can product any experiential, qualitative states at all? Chalmers's naturalistic dualism is a dualistic theory which does not regard phenomenal experience as a part of the physical world but accepts it as an internal representation of information. Chalmers does not however postulate "eternal soul" as Descartes did. The consistency with the laws of physics forces to conclude that consciousness has no causal powers. Chalmers approach implies panpsychism: all physical systems have some kind of phenomenal consciousness.

   The solution of hard problem in TGD approch relies of the identification of quantum jump as moment of consciousness. Consciousness is not assigned with the state but with its change. Panpsychism is unavoidable and self hierarchy expresses this concretely. In TGD consistency with the laws of quantum physics is achieved and the more refined view about quantum jump allows to understand the basic sensory input-motor action sequence at various levels of self hierarchy.

5. In higher order theories (HOTs) consciousness is always reflective consciousness. Phenomenal consciousness is denied and all conscious experiences are representational (intentionality, aboutness, directedness). HOTs deny consciousness from all creatures no able to formulate higher order thoughts. Therefore infants and animals are doomed to be unconscious zombies in HOT universe.

   In TGD framework the negentropically entangled states defining abstractions and rules at various levels of hierarchy would define almost invariants. In the recent formulation one must assume that negentropic entanglement gives rise to conscious information. This conscious information would be the only kind of conscious information accepted in HOTs as conscious information.

6. Externalistic representationalism (Tye, Dretske) assumes that brain constructs only representations of inputs coming from the external world. Therefore also phenomenal aspects, qualia, are something in the external world and only represented in brain. Redness of rose is thus a property of rose, not something generated by the absorption of photons of certain wavelength in retina. The idea that the visual perception of distant galaxy would mean direct experiencing of its visual qualia seems rather strange - at least in the universe of standard

physics. The question how the qualia of external world are represented in brain represents a difficult problem for externalistic representationalism.

The idea that sensory qualia are in the external world looks rather weird in standard physics framework. In TGD framework qualia are assigned with sensory organs defining the boundary between internal and external world for a given CD. In TGD Universe consciousness is however not restricted to brain. The hierarchy of dark matter realized as phases with effective value of Planck constant coming as integer multiple of the ordinary Planck constant and residing at magnetic flux quanta makes macroscopic quantum coherence possible in arbitrarily long length and time scales so that it is quite possible to imagine that the contents of our conscious experience can contain contributions from quite long length and time scales.

p-Adic space-time sheets have literally infinite size in real sense (this statement makes sense for common rationals and some common algebraic points) so that cognition is in TGD framework a cosmic phenomenon and only cognitive representations defined by the discrete intersections of real and p-adic space-time sheets are located inside CDs.

5.6.2 Some Empirical Theories Of Consciousness

Revonsuo discusses also current empirical theories of consciousness taking as examples the following theories.

- Global workspace theory [J19] (Baars, see `http://tinyurl.com/ycvmgn96`).
- Neurobiological theory [J24] (Crick and Koch, see `http://tinyurl.com/y8wkg32`).
- The dynamic core theory [J30] (Tononi and Edelman, see `http://tinyurl.com/ycngrbvv`).
- The integrated information theory [J42] (Tononi, see `http://tinyurl.com/y995nmqp`).
- Thalamocortical binding theory [J65] (Llinas, see `http://tinyurl.com/yadnttno`).
- Recurrent processing theory [J76] (Lamme, see `http://tinyurl.com/ycmmeh8o`).
- Microconsciousness theory [J72] (Zeki, see `http://tinyurl.com/yc4yfdse`).
- Consciousness as the feeling of what happens [J15] (Damasio, see `http://tinyurl.com/f75kp`).

In the following some TGD inspired comments about these theories.

1. The neurobiological theory introduced the hypothesis that 40 Hz frequency assignable to thalamocortical resonance (see `http://tinyurl.com/8vt8pzu`) is fundamental for binding the conscious experiences. The motivation is that thalamus has dense net of bi-directional loops to cortex. It turned out later that this resonance is strong only when the objects of perceptive field are recognized.

   (a) A possible TGD inspired interpretation is based on the observation that negentropic entanglement is generated during the sensory perception as the sensory mental image or its representation at cortex negentropically entangles with the earlier sensory mental image or its cortical representation to form an updated memory representation. This stage could involve 40 Hz resonant interaction with the earlier stored sequence of sensory memories giving rise to the negentropic entanglement (the process is driven by NMP).

   (b) The experience of understanding that I earlier erratically assigned with negentropic entanglement (in conflict with NMP!) would be assigned with the *generation* of negentropic entanglement (in accordance with NMP!) and with the defining postulate of TGD inspired theory of consciousness. Revonsuo has performed an experiment which demonstrates that 40 Hz resonance appears when a random looking visual pattern consting of dots and short line segments is recognized to represent 3-D object but fades out after the recognition [J16]. The finding conforms with TGD based interpretation.

(c) In TGD framework thalamus would suggest itself as a central self representing "me" having as sub-selves the negentropically entangled mental images assignable to cortex (reflective consciousness) and the sensory mental images assignable to various sensory organs (phenomenal consciousness).

2. Damasio's theory emphasizes the importance of emotions as a basic building brick of conscious experience. In TGD framework emotions are associated with negentropy: positive emotions correspond to negentropy gain and negative emotions to negentropy loss. NMP states that the information gain in state function reduction is maximal and is therefore analogous to second law and indeed implies for ordinary entanglement second law at the ensemble level [K45]. NMP suggests the analog of thermodynamics and even non-equilibrium thermodynamics for negentropic entanglement. In the presence of constraints on zero energy states (fixed average energy, particle number, etc..) this would imply existence of parameters analogous to temperature, pressure, etc..) so that the use of thermodynamical quantities as metaphors for the macro aspects of consciousness would have justification. In this picture emotions define a central element of experience.

5.6.3 Major Issues Of Disagreement Between Theories

Revonsuo summarizes the two chapters by discussing the major issues of disagreement between theories of consciousness. These issues concern the location of consciousness (externalism vs. internalism), the fundamental nature of consciousness (phenomenology vs. cognition), and fundamental form of phenomenal consciousness (atomism vs. holism).

Internalism vs. externalism

Internalism and externalism are basic views about the location of phenomenal conscious experience.

1. Internalism assumes that the neurophysiological and functional state of the brain determines the contents of consciousness. It seems possible to understand the representational aspects of consciousness: brain decomposes sensory field to objects and gives them names represented as patterns of neuronal activity. The understanding of how phenomenal consciousness, qualia, is not so easy. The neurons look the same everywhere and it has not been possible to point out or even imagine how the organizational structure of the neurons could give distinguish between say hearing, vision, and touch although they all carry geometric and dynamical information.

2. Externalism locates qualia in the external world and that brain only represents them. This option has been already discussed.

What happens in TGD Universe?

1. The first thing to observe is that in TGD framework it is not possible to locate consciousness anywhere: consciousness is in the quantum jump, between two zero energy states of the Universe. The contents of consciousness can be however localized and one could ask whether the seat for the contents of conscious experience is located inside or outside brain. Actually this is too limited formulation if one takes seriously the self hierarchy and the notion of magnetic body implying that brain alone is not the seat for the contents of consciousness in TGD Universe.

2. In TGD framework both internalism and externalism are both right and wrong: qualia are in the intersection of external and internal worlds defined appropriately. Sensory organs define examples about this kind of intersection but there is fractality involved. Also cell membranes can be seen as sensory organs. This picture follows from the basic assumptions of quantum TGD.

    (a) Strong form of general coordinate invariance implies strong form of holography. Already holography implies that space-time surfaces as carriers of geometric information provide classical space-time correlates associated with the light-like 3-surfaces representing the orbits of partonic 2-surfaces representing boundaries between space-time regions with Euclidian and Minkowskians signatures of the induced metric. By strong form of holography these partonic 2-surfaces and the 4-D tangent space data of space-time surface at them are enough to fix zero energy states: I call this effective 2-dimensionality.

The partonic 2-surfaces have interpretation as boundaries of physical objects in all scales and they carry the quantum numbers and therefore also the quantum number increments are associated with them and therefore also phenomenal consciousness and qualia. The space-time regions of Minkowskian and Euclidian signature of induced metric define the space-time correlates of "internal" and "external". The partonic 2-surfaces are therefore identifiable as seats of conscious experience. It is important to notice that there is entire fractal hierarchy of partonic 2-surfaces. Partonic 2-surfaces can be also connected by strings carrying fermion number and these string world sheets connect different partonic 2-surfaces: string oscillations define sound as a fundamental phenomenon and are behind hearing and internal speech as already proposed.

(b) Strong form of holography implies that partonic 2-surfaces and their 3-D orbits are very much like sensory organs which indeed define boundary between internal and external worlds. This motivates the assignment of qualia to sensory organs. The fractal generalization suggests that even elementary particles enjoy primitive phenomenal consciousness. p-Adic physics as physics of cognition suggests that even primitive cognition is associated with elementary particles.

This would elegantly solve the basic objection against internalism since qualia would indeed strongly correlate with their physical cause (oscillations of string like objects in 4-D space-time possibly underlying sound waves, photons and possibly also other masless bosonic quanta at various wave lengths underlying vision, physical touch having topological correlate in TGD Universe).

Phantom limb and dreams define the basic objections against this picture but it is possible to circumvent these objections if one accepts feedback from brain to sensory organs as virtual sensory input realized as dark photons travelling along magnetic flux tubes, and TGD based view about time allowing to interpret pain in non-existing limb as a sensory memory. Also erratic assignment of position to the actual pain somewhere else than non-existing limb can explain phantom pain. This kind of mis-assignments can be produced as illusions at the level of sensory representations.

(c) There is however a question to be answered. Space-time regions can have Euclidian or Minkowskian signature of the induced metric. Does holography hold for both and do the light-like 3-surfaces between them represent holographically both. For instance, can one assign the two representations two the two sides of this 3-surface and for strong form of holography to partonic 2-surfaces and the tangent space data at the two sides of space-like 3-surface at the boundary of CD?

Do these two representations define representations of internal qualia (virtual input from sensory representations) and external qualia (real input from external world)? Is the comparison of the virtual input generated by sensory representation with external input crucial in the construction of sensory representations: sensory representation is faithful only when these qualia are opposites of each other (when defined in terms of quantum number increments). One can get convinced about the reality of virtual qualia by swimming for some time in windy sea. At the beach the wave motion continues in the body and can make walking difficult.

Representational aspects of consciousness are usually identified as internal aspect localizable inside brain. In TGD framework the notion of magnetic body forces to challenge this assumption.

1. Negentropically entangled subsystems tend to remain unchanged under the dynamics dictated by NMP even at the active boundary of CD and therefore represent information as quantum rules as superpositions of their instances. At passive boundary negentropic entanglement

is absolutely stable during the lifetime of self. Thus the negentropic entanglement at the passive boundary of CD corresponds to what one might call unchanging self.

The representations for declarative memories, a model for external world, self model, predictions of future, plans for motor action and future, ...: all this night allow representations would be associated with the active boundary of CD and could be represented in terms of bits.

2. One can thus imagine memory representations based on bits and reading of them using interaction free measurement, which in ideal situation leaves the bit representations unaffected. Elizur-Weizman bomb tester is an excellent representation (see `http://tinyurl.com/y9zenssv`) for this. It 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. The value of bit would correspond to the two states of the bomb and memory bit 1 would make the system able to perform quantum measurement. One can ask whether the ability to make quantum measurement is something fundamental and determined by whether the entanglement between system and measured system is negentropic or ordinary.

3. There is no reason to localize the representational states to sub-CDs inside brain although cognitive representations and naming of objects of perceptive field might be carried out by brain. The memories and plans of future (related by time reflection) could correspond to something in their real time scale and at the level of magnetic bodies this would mean size scale of Earth (EEG as communication tool to magnetic body) and even light years! Also scaled variants of these representation are expected by fractality and these zoom-ups and zoom-downs defining “stories” might be one of the key features of intelligence.

4. In the case of cognition having p-adic space-time sheets as space-time correlates, it is impossible to locate even contents of consciousness to a finite space-time region in real sense. Cognitive representations consisting of common rational and possibly also some algebraic points of real and p-adic preferred extremals of Kähler action, can be however said to be located to a finite volume of space-time defined by causal diamond.

Phenomenology vs. cognition

As already noticed, in TGD Universe even representational consciousness reduces always to phenomenal consciousness. Imagination and internal speech represent our experiences about phenomenal consciousness at neuronal level and the representation - as we experience it - does not carry sensory qualia. Contrary to the original wrong intuition, interaction free measurements do not allow to deduce what negentropic entanglement is - this must be directly experienced. They could however allow measurements of say memory bits leaving them unaffected in arbitrary good approximation.

The interaction free measurement could be realized in terms of photons and also as sound waves with absorption of phonon replacing the absorption of photon. This could give rise to internal speech and eventually to written language. This suggests that neuronal vision *resp.* hearing is fundamental for imagination *resp.* internal speech. One can also wonder whether there exists a translation of the worlds of language to visual images.

Atomism vs. holism

Atomism postulates that conscious experience can be decomposed to fundamental building bricks defining “micro-consciousness” in the same sense as matter consists of elementary particles. Holism in turn assumes that the experience is holistic and does not have this kind of decomposition.

In TGD framework the presence of self hierarchy changes the situation. One has fractal hierarchy of levels of consciousness having length scale hierarchy of CDs as embedding space correlate and p-adic length scale hierarchy as space-time sheets as space-time correlate. One can identify fundamental qualia as increments of quantum numbers dictated by the symmetries of TGD Universe. On the other hand, the geometric aspects of experience related to the patterns defined by subsystems of negentropically entanglement subsystems defining representative aspects of consciousness do not reduce to fundamental qualia.

5.6.4 Common Beliefs Consciousness Theories From TGD Point Of View

It seems that most theories of consciousness agree in some key aspects.

1. Brain serves as a seat of consciousness including phenomenal experience in the case that qualia and phenomenal experience are accepted at all as something real. The causal powers of consciousness are denied since in the ontology inspired by classical physics this would lead to difficulties.

   In TGD framework the situation is different. Brain is the seat of sensory and cognitive representations whereas phenomenal consciousness can be assigned with sensory organs. Qualia can be assigned to quantum number increments associated with quantum jump and sensory representations become conscious via secondary qualia realized as internal speech and imagination.

2. The privacy of consciousness seems to be accepted as something totally obvious. This has been formulated as question "What it feels to be a bat" claimed to have no answer.

   In TGD framework self hierarchy and the notion of magnetic body (field body) encourages to give up the belief on privacy of consciousness. Magnetic flux tubes are identified as space-time correlates for attention binding some parts of the systems connected in this manner to single quantum system so that sharing of mental images becomes possible: therefore the claim that it is not possible to feel what it is to be a bat might be wrong in TGD Universe. For a scientists it is of course very difficult to take seriously the claim that shaman could directly experience what it is to be a bear: maybe scientist should be ready to reconsider their belief system in this respect.

5.7 Disorders Of Consciousness

Revonsuo [J17] discusses also various disorders of consciousness typically associated with representative and reflective aspects of consciousness. These disorders pose strong constraints on the theories of consciousness.

In TGD framework the generation of negentropic engtanglement (directed attention) is the basic mechanism making possible the updating of memory representations. If this mechanism fails, the outcome is a disorder explaining various neuropsychological deficits of consciousness and neurophysiological dissociation of consciousness from behavior. Failure to generate negentropic entanglement at all or generation of the negentropic entanglement with wrong memory representation would be the basic reasons for disorders. At physiological level ATP$\rightarrow$ ADP transition generates flux tube connections giving rise to negentropic entanglement so that the problem could reduce to dysfunction at this level.

5.7.1 Neuropsychological Deficits Of Visual Consciousness

The first kind of anomalies discussed by Revonsuo are neuropsychological deficits of visual consciousness. Examples of this kind of deficits are visual agnosia: loss of coherent visual objets, semantic dementia: loss of the meaning of objects, asimultangnosia: loss of the phenomenal background, neglect: loss of phenomenal space, and akinetopsia: loss of visual animation.

These anomalies clearly demonstrate the modular character of the information processing in brain. In TGD framework this corresponds to negentropic entanglement for systems representing various components of experience and represenging abstract rules. Neurophysiological deficit could imply that some component is missing (say emotional component giving meaning to the objects in semantic dementia or component represring phenomenal background). Second possibility is that the components are not at all organized to form a negentropically entangled tensor product (visual agnosia).

Loss of visual animation could mean that the sequence of negentropically entangled sub-CDs (time-like entanglement) representing the positition of object in space has too low temporal resolution. In other words visual mental images are updated with too low frequency. The resolution needed to experience discrete sequence of imagines as a continuous motion corresponds to at least 50 Hz frequency for visual mental images.

5.7.2 Neuropsychological Dissociations Of Visual Consciousness From Behavior

Second kind of anomalies correspond to neuropsychological dissociations of visual consciousness from behavior. Examples are blind sight, implicitly visually guided action, implicit face recognition in prosopagnosia, implicit recognition of words and objects in neglect. In most theories of consciousness self hierarchy has only one-level so that the only interpretation is that there is an appropriate zombie represent making possible these dissociations but carrying the information needed for the action in question. In TGD framework also this information would be conscious albeit not conscious-to-us.

1. Consider first the dissociation from of sensory consciousness from motor action. As described above, ZEO more or less forces to conclude that for given CD there are two "mes" corresponding to lower and upper boundary of CD and they correspond to sensory me and motor me for which motor action is time reversed sensory perception. Thus the motor me, I_m, could enjoy time reversed sensory consciousness.

2. The minimal option is that the dissociated sub-self is present but does not entangle negentropically to the sub-self system of "me" representing memory mental images. Sensory "me" I_s would have sensory qualia but since it does not attend to the target of perceptive field would not remember anything about it. I_m would have not only the time reversed sensory qualia and they would also negentropically entangle with time reversed memory representations defining plans and volitions. This would mean that motor actions using sensory information would be possible.

A person suffering from blind vision (cortical blindness is not in question) reports that she is unable to see consciously but her visual areas are intact and she demonstrates the access to visual information via successful motor activities. It could be that person has still retinal vision but this phenomenal visual images do not negentropically entangle with cortical representations so that there are no conscious visual qualia or remembered visual qualia.

The proposed picture suggests that both the sensory I_s and motor "me" I_m assignable to sub-CDs in a time scale of say.1 seconds could have phenomenal vision. Only I_m could however build sensory representations consistent with incoming information (containing also the retina level representation in the tensor product). As mental images of CD these representations would correspond to volitions, decisions, and plans: this information would be enough for coherent motor activities.

The unability to recognize faces could be due to the fact that the name of person represented as sub-CD is not negentropically entangled with the collection of visual mental images representing the face. Same applies to inability to recognize words and objects. Implicit recognition however occurs and manifests itself in measured changes of skin conductance. This would suggest that emotional response is still present and realized as negentropic entanglement of the visual sub-CD with emotional sub-CD and expressing itself motorially as change a in skin conductance. The change of skin conductance would therefore be neurophysical correlate for time reversed sensory input.

5.7.3 Neuropsychological Disorders Of Self-Awareness

Neuropsychological disorders of self-awareness represent third kind of anomalies of consciousness discussed by Revonsuo and include amnesia, split-brain state, anosognosia, asomatognosia, and deficits of belief systems (delusions). An interesting observation is that left-hemisphere acts as a rationalizing interpreter capable of amazing self deceptions and right hemisphere takes the role devil's advocate.

1. In the case of amnesia the patient lives in eternal now but can remember the events before he became amnesic. Hippocampus seems to be at least partially responsible for constructing memories so that either memory construction or memory recall fails for these memories. One possibility is that for some reason the sensory mental images representing personal history are not anymore negentropically entangled in time direction so that self model is not up-dated.

2. Split-brain state is artificially induced by splitting the corpus callosum. In this state patient behaves as had possessed two separate selves, which can have conflicting future plans, desires, and actions. This seems to be in strong conflict with standard views about consciousness but if one accepts self-hierarchy this is just what is expected. Corpus callosum would entangle the different brain hemispheres to single unit.

   The non-trivial topology of TGD space-time makes also sharing of mental images possible since two unentangled selves can have entangled sub-selves. This corresponds to a situation in which one has two space-time sheets which are disjoint but there are smaller space-time sheets (sub-selves) topologically condensed on them and connected by flux tubes. In the appropriate resolution the larger space-time sheets are un-entangled whereas smaller space-time sheets in their own and better resolution are entangled.

3. In the case of asognonosia thr patient has some deficit but is not conscious about it, and fabulates all kinds of explanations for why the deficit manifests itself in this behavior. The deficit could be paralysis, cortical blindness, neglect of second half of perceptive field, or something else. The simplest explanation is that the self-model is not updated so that basically a failure of negentropic tensor producting would be in question.

   A cortically blind person suffering Anton's syndrome claims that he sees. If qualia are seated at sensory organs, person could have genuine visual qualia if the retina is intact. Flawless sensory representations are necessary for a successful motor action since the zero energy state resulting in motor action is obtained by state function reduction from the zero energy state defining sensory and memory representations. Therefore the loss of appropriate cortical visual representations would make person effectively blind even if phenomenal vision is intact.

   Patient can also suffer from paralysis and refuse to admit that something is wrong. Besides the general explanation one could also consider the possibility that motor representations still contain the lowest level as time reversed sensory representation. This explanation would be analogous to that for Anton's syndrome.

4. In asomatognosis person denies the possession of part of his own body. Also this disorder could be understood if the representation of that part of body is not negentropically entangled with representations of other parts of the body.

5.8 Altered States Of Consciousness

Revonsuo [J17] devotes three chapters to altered states of consciousness (ASC) discussing dreaming and sleep as ASCs, hypnosis as a candidate for ASC and higher states of consciousness as ASCs.

5.8.1 Dreaming And Sleep As ASC

The first chapter about ASCs is devoted to dreaming and sleep as altered states of consciousness. Hypnagogic and hypnopompic hallucinations, sleep paralysis, sleep mentation vs. dreaming, the contents of dreaming, lucid dreaming, bad dreams and nightmares, night terrors, sleepwalking and nocturnal wander, and sleep behavior disorder and dreamwalking are the titles of the sections and give a good overall view about topics discussed.

In preceding sections I have already discussed TGD view about dreams as virtual sensory experiences generated by the input from brain or even magnetic body to the sensory organs, which in TGD Universe serve naturally as seats for the contents of phenomenal experiences. This interpretation distinguishes TGD from the competing theories of consciousness.

5.8.2 Hypnosis

Second chapter about ASCs is devoted to hypnosis (see `http://tinyurl.com/mgy2e`) as a possible candidate for ASC and discussed hypnotic induction and hypnotic suggestivity.

Hypnosis can be seen as a challenge to the cherished belief about the privacy of consciousness. Hypnotist and subject person indeed seem to form a larger coherent unit in which the motor system of the subject person becomes effectively part of the motor system of hypnotist. Hypnotist can also induce suggestions giving rise to sensory experiences what could be regarded as hallucinations, perhaps by inducing virtual sensory inputs, which also can be seen as motor actions in very general sense. The formation of negentropic entanglement by the generation of magnetic flux tubes connecting the subject person and hypnotist would be part of the TGD based model. This would allow the hypnotist to negentropically entangle with the self model of the subject at highest level and realize his volitions using the motor system of the subject person [K35].

5.8.3 Higher States Of Consciousness

The third chapter devoted to ASCs is about higher states of consciousness: meditation, optimal experience and flow, runner's high, OBEs, NDEs, and mystical experiences. In several experiences of this kind sensory input and motor activity contribute minimally to the conscious experience. Typical for OBEs is that person sees his own body from third person perspective.

Remark: Besides genuine OBE like experiences I have personally had also OBE like experiences in which I see my body in somewhat surreal perspective and find myself floating in the roof and thinking hardly for possible tests whether I am really levitating.

OBEs and in particular NDEs obviously challenge the belief that brain alone is the seat of consciousness. Therefore it is not surprising that both OBEs and NDEs are labelled as pathological in materialistic approach to consciousness (or what is left from it after application of the basic dogmas). It is of course possible that this kind of conscious experiences become possible under some brain disorders such as epilepsy.

The explanation of NDE as a kind of final activity of a dying brain looks rather artificial: especially so because these experiences are highly structured and coherent and rather universal rather than being chaotic as one might expect if the state of consciousness corresponds directly to the state of brain as materialistic dogma states.

OBEs and NDEs

TGD suggests the following approach to OBEs [K86] and NDEs.

1. The notion of magnetic body (bringing in mind the "aether body" of the esoteric teachings) could have central role in TGD inspired quantum biology and neuroscience, and especially so in the explanation of OBEs and NDEs. EEG and its scaled variants would provide control and communication tool for the magnetic body and also lower frequencies than those appearing in EEG could be involved so that the flat EEG during NDEs would reflect only the absence of sensorimotor activities.

2. The highest level sensory representations would be naturally realized at magnetic body and give rise to sensory representations about biological body and even its environment and in this manner give rise to the third person aspect of consciousness. If this is the case, one could understand how it is possible to see own biological body as an outsider during OBEs and NDEs.

   The representations at the magnetic body could in turn generate virtual sensory input as a feedback down to the level of sensory organs also in the ordinary wake-up consciousness as a check that these representations are consistent with the sensory input. The mechanism for generating the sensory input as dark photons and perhaps also dark phonons has been already suggested.

3. This model is consistent with the correlation of these experiences with the epileptic seizures. Epileptic seizure could lead to a failure to communicate sensory data to the magnetic body by EEG and also to a failure to receive signals from the magnetic body reflecting itself as chaotic motor activities. Therefore the contribution of magnetic body and third person perspective would dominates the experience.

4. One can argue that in absence of sensory input and motor activity, and perhaps even neural activity (EEG in many NDEs is flat) the contribution of the magnetic body to the conscious experience dominates. Magnetic body could provide the virtual sensory input even during ordinary dreams and dreams might be seen as a kind of simulation of the external world by virtual input from the magnetic body and as brain level interpretation for what possibly happens at the level of the magnetic body. Also motor actions could be simulated as motor actions of the magnetic body. Maybe purely mental image exercises known to have genuine effect on motor skills could be interpreted as motor exercises performed by magnetic body!

5. Also some illusions such as moving train illusion (the sensation that the stationary train in which person is sitting moves induced by a train passign by) could be understood as resulting from the motion of personal magnetic body relative to the biological body. The moving train catching the attention of the subject person (recall the proposal that attention has magnetic flux tubes as a correlate) would anchor the magnetic body of the subject person to its rest system.

6. The unpleasant sensation of falling down near a precipice could be due to the imagined falling down. It would be magnetic body which represents the falling down and its acceleration with respect to the biological body generates the sensation. Magnetic body quite generally simulate the motion of biological body and the discrepancy between the simulation and real motion of biological body would generate a conscious experience. If the simulation is ideal, no conscious experience would be generated. This would allow to understand why the learned skill becomes unconscious routine. Similar simulations would take place already in the case of sensory input as already proposed. If time reversal relates motor activity and sensory perception, this kind of symmetry is very natural.

Mystical states

The third chapter about ASCs is about mystical states. Mystical experiences have often long-lasting effects on the life of the experiencer as increased spontaneity and courage to choose one's own way to live. Typically it is difficult to express verbally the contents of experience: for instance, the writings of Krishnamurti emphasize this. I have had some spontaneous mystical experiences of my own, and in the following I will take the liberty to insert remarks about them to the nice summary of Revonsuo about emotional, cognitive and perceptive aspects of mystical stats.

- Emotionally mystical states are highly positive: peace, calmness, harmony, love, joy, awe, bliss are the words used to characterize the emotional state. The realization that everything in the Universe has a deep hidden meaning makes these experiences so special. Universe is experienced a a holy place, not at all that dirty world of everyday experience.

- Mystical states involve the experience of deep understanding of underlying principles of existence and direct answers to deep questions about life and existence. Dramatic expansion of consciousness to even cosmic consciousness is also reported. There is also a direct experience about hierarchical structure of conscious existence and about communication with higher levels of the hierarchy. In religious experiences God represents one (in monoteistic religions often the only accepted) higher level in the hierarchy.

  Remark: In my own mystical experiences I had deep experience of understanding but without knowing what it was that I understood. In the light of afterwisdom the ideas that I became conscious of during these experiences for almost three decades ago could be interpreted as precognitions about some basic ideas of TGD and TGD inspired theory of consciousness.

- Mystical states are also accompanied by a heightened sensory consciousness. The world looks extremely bright, clear, brilliant, colorful, and pure.

  Remark: My own experiences began with the increase of the experienced intensity of the sounds from environment.

- *Remark*: The experience about own body can change dramatically. The usual unpleasant sensory noise suddenly disappears and the entire body ends up to what might be called fluid like state: experience is akin to the sensation localizable to spine that music sometimes creates. In my own case this was actually the beginning of the experience.

- enlightenment experiences are regarded as the highest form of mystic experience and involves the experience timelessness, emptiness, liberation from all attachments, and the realization that even self is an illusion.

Could one say something interesting about these experiences in TGD framework?

1. The experience about hierarchical structure of consciousness is certainly consistent with TGD view which however derives from the mathematical structure of the theory (fractal hierarchy of quantum jumps) rather than being assumed on basis of my personal mystical experiences.

2. The generation of negentropic entanglement should be accompanied by the experience of understanding and the large increase in the size of personal CD could generate large amount of negentropic entanglement. This could also explain the strongly positive emotional coloring of the experiences in general. The experience of understanding would mean genuine understanding but perhaps at levels remaining unconscious or indescribable using the existing tools of language.

3. The generation of negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) at the scales of biological body leading to enhanced quantum coherence could create the dramatic change in the experience about own body.

4. The personal magnetic body could be significant in mystic experiences. A phase transition increasing $\hbar_{eff}$ could scale up the size of some parts of the magnetic body. Reconnection mechanism could make possible fusion of the magnetic body with other magnetic bodies: this could relate to the sensation of becoming one with the external world and disappearance of separations. Krishnamurti has beautifully described the experience of becoming the people around him. Also t this experience challenges the belief on absolute privacy of consciousness.

5. The hierarchy of quantum jumps assignable to the hierarchy of CDs with various scales is basic prediction of TGD inspired theory of consciousness. The characteristic time scale of long term memories and planned action and size scale of the perceptive field are natural characteristics for the level of self in self hierarchy. Mystic experiences could correspond to a state function reduction leading to an especially large average size scale of CDs involved in quantum superposition of zero energy state representing "me". This would mean higher abstraction level and large. A phase transition leading to an exceptionally large increase of the effective Planck constant $\hbar_{eff}$ scaling up the size of CD is a good guess for what might happen.

6. Could one find quantum correlate for the experience of understanding without any mental images and without knowing what it is that one understands? This seems to be the case on both reported and my personal experiences. Hence I am forced to ask whether the invariants defined by various representations could be experienced directly in absence of the memories generated by interaction free measurements and giving rise to cognition. The "Akashic records" defined by the negentropically entangled representations would be the counterpart for this wisdom, which can be only felt but not expressed using language or pictures. Accepting this would force to give up the hypothesis that the change in quantum jump alone contributes to conscious experience: also what remains invariant in quantum jump would do so.

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Chapter 6

TGD Inspired Comments about Integrated Information Theory of Consciousness

6.1 Introduction

I received a link to a very interesting article by John Horgan in Scientific American with title "Can Integrated Information Theory Explain Consciousness?" [J47] (see http://tinyurl.com/h7btppb). Originally IIT is a theoretical construct of neuroscientst Giulio Tononi (just Tononi in the sequel). Christof Koch is one of the coworkers of Tononi. IIT can be regarded as heavily neuroscience based non-quantum approach to consciousness and the goal is to identify the axioms about consciousness, which should hold true also in physics based theories. The article of Horgan was excellent and touched the essentials and it was relatively easy to grasp what is common with my own approach to consciousness and comment also what I see as weaknesses of IIT approach.

To my opinion, the basic weakness is the lack of formulation in terms of fundamental physics. As such quantum physics based formulation is certainly not enough since the recent quantum physics is plagued by paradoxes, which are due the lack of theory of consciousness needed to understand what the notion of observer means. The question is not only about what fundamental physics can give to consciousness but also about what consciousness can give to fundamental physics.

The article "Consciousness: here, there and everywhere" of Tononi and Koch [J75] (see http://tinyurl.com/zgm985f) gives a more detailed summary about IIT. The article "From the Phenomenology to the Mechanisms of Consciousness: Integrated Information Theory" [J60](see http://tinyurl.com/z9s4k7n) gives a more techanical description of IIT. Also the article of Scott Aaronson [J68](see http://tinyurl.com/zarjfzz) was very helpful in providing computer scientific view about IIT and representing also mathematical objections.

In the article [J60] it is emphasized that IIT is a work in progress. This applies also to TGD and TGD inspired theory of consciousness. Personally I take writing of TGD inspired commentary about IIT as a highly interesting interaction, which might help to learn new ideas and spot the weaknesses and imperfections in the basic definitions of TGD inspired theory of consciousness. If TGD survives from this interaction as such, the writing of these commentaries have been waste of time.

The key questions relate to the notion of information more or less identified as consciousness.

1. In IIT the information is identified essentially as a reduction of entropy as hypothetical conscious entity learns what the state of the system is. This definition of information used in the definition of conscious entity is circular. It involves also probabilistic element bringing thus either the notion of ensemble or frequency interpretation.

2. In TGD the notion of information relies on number theoretical entanglement entropy (EE) measuring the amount of information associated with entanglement [K45]. It makes sense for

algebraic entanglement probabilities. In fact all probabilities must be assumed to belong to algebraic extension of rationals if one adopts p-adic view about cognition and extends physics to adelic physics involving real and various p-adic number fields. Circularity is avoided but the basic problem has been whether one can apply the number theoretic definition of entanglement entropy only in p-adic sectors of the adelic Universe or whether it applies under some conditions also in the real sector. Writing this commentary led to a solution of this problem: the state function reduction in the intersection of realities and p-adicities which corresponds to algebraic extension of rationals induces the reductions at real and p-adic sectors. Negentropy Maximization Principle (NMP) maximizes the sum of real and various p-adic negentropy gains. The outcome is highly non-trivial prediction that cognition can stabilize also the real entanglement and has therefore causal power. One can say that cognition tames the randomness of the ordinary state function reduction so that Einstein was to some degree right when he said that God does not play dice.

3. IIT identifies qualia with way, which I find difficult to take seriously. The criticism however led also to criticism of TGD identification of qualia [K30] and much simpler identification involving only the basic assumptions of ZEO based quantum measurement theory emerged. Occam's razor does not leave many options in this kind of situation.

IIT predicts panpsychism in a restricted sense as does also TGD. The identification of maximally integrated partition of elementary system endowed with mechanism, which could correspond to computer program, to two parts as conscious experience is rather near to epiphenomenalism since it means that consciousness is property of physical system. In TGD framework consciousness has independent causal and ontological status. Conscious existence corresponds to quantum jumps between physical states re-creating physical realities being therefore outside the existences defined by classical and quantum physics (in TGD classical physics is exact part of quantum physics).

6.2 Critical Summary of IIT

Tononi starts from neuroscience and information theory. Information theoretic approach has the virtue that can avoid sticking into the dogmas of existing philosophy. Tononi and Koch emphasize that IIT tries to axiomatisize the essential aspects of consciousness so that physical theories of consciousness could start from this picture. Concerning the definition of information the starting point is classical probability theory.

One can criticize this view. Quantum physics provides extremely non-trivial new view about physical existence that it seems almost impossible to comprehend by organisms at our evolutionary level. Quantum measurement theory - the poorly understood part of quantum theory - forces to ask fundamental questions about the nature of consciousness, which suggests that neglecting it can mean a fatal loss of information. Quantum information theory is rapidly developing and should be highly relevant for any theory of consciousness starting from the notion of information. IIT's integrated information Φ is also a measure for complexity. Quantum theory provides a vision about complexity based on quantum entanglement. Also quantum biology has emerged as a new branch of science.

Information, integration and conceptual structure are basic notions introduced by Tononi. All these notions are poorly understood in standard physics framework. Also the notion of elementary mechanism is introduced. Mechanism could correspond to computer program or asequence of neural associations or formation of self-organization pattern. Elementary mechanisms can be combined to more complex mechanisms and these into systems of mechanisms. Mechanism can be identified as time evolution of some kind and has has inherent time arrow associated with it.

As the title "Consciousness, here, there, and everywhere" of [J60] expresses, panpsychism is adopted in IIT in the form that consciousness can be a property of any material system. For this reason the approach of Tononi is regarded by Horgan as an extremely ambitious approach - certainly it is so from the perspective of neuroscience. For a physicist taking consciousness seriously panpsychism in some sense is the only possible option and predicts hierachy of conscious entities.

This panpsychism does not mean that everything is conscious but that everything can be conscious. The criterion for this is that integrated information is large enough. This roughly means that system is coherent structure such that information cannot be localized to its part.

6.2.1 Information

The key vision is that conscious experience carries information and that this information is integrated in the sense that parts of experience give information of each other: one might say that conscious information defines a rule $A \to B$. In neuroscience association would be the counterpart for this. This relationship need not be strictly causal but is as near to causal as possible.

In quantum theory entanglement could realize the strong correlation: now one however knows the state of the entire system but has very little information about the states or parts.

A mechanism can contribute to consciousness only if it specifies "differences that make differences" within a system. This sounds rather fuzzy statement. A slightly clearer manner to say this is that a mechanism generates information only if it constrains the states of a system than can be its possible causes and effects. One speaks of cause-effect repertoire. An even clearer identification of mechanism is as a dynamics of some kind.

In biology one could interpret cause-effect repertoire as a counterpart of a biological function assigning to sensory input a a motor output. In neuroscience mechanism could correspond to a sequence of associations defined by nerve pulse patterns or a behavior assigning a motor response to a given sensory input. Mathematician could speak of function. Physicist could speak of time evolution - say classical or self-organization. In computational science one could interpret Boolean functions or computer programs as mechanisms. The obvious criticism is that one can imagine endless variety of mechanisms and the theory loses its predictive power.

For a mechanism leading from a state of A to that of B information could be defined mathematically as $I(A \to B) = H(B|A) - H(A)$ by subtracting from conditional entropy for output associated with probabilistic input the entropy of the input. The information serves a measure for the reduction of ignorance and one cannot speak of ignorance without assuming a conscious entity able to interpret the output. This kind of notion in the definition of conscious information implies circularity.

One of the predictions is that feedback in the dynamics of mechanism is necessary for consciousness. Intuitively feedback means self-control characteritizing living systems (homeostasis). It is known that system theoretically a system with feedback can be approximated with a more complex system with only forward feedback. A system with/without feedback could/would be conscious/zombie. The theory would not therefore be behavioristic. Also rather simple non-living systems with feedback could be conscious.

I must admit that I did not quite understand why feedback is necessary for consciousness. If one defines information assignable to mechanism as sum $I(A \to B) + I(B \to A)$ then it is is easy to understand the importance of feedback. For instance, if the output depend only weakly of the input as in self-organizing systems without feedback (all irrelevant details are polished away in thermal non-equilibrium state), $I(B|A)$ would be very small and the criterion for cause-effect relationship would not be satisfied. Feedback changes the situation.

6.2.2 Integration

Intuitively it seems that intelligent systems consist of highly correlated parts but that the correlation cannot be too high (completely random system carries no information and spontaneously magnetized systems carries just one bit of information). Tononi introduces a measure -Φ - that he calls integrated information that would serve as a measure for this property measuring the level of consciousness.

This suggests that a mechanism can contribute to consciousness only if it specifies a cause-effect repertoire that is irreducible to independent components. The irreducibility of experience means that the experience cannot be reduced to parts. A more comprehensible statement is that information contained by system cannot be localized to any art of it. Here one can criticize: mental images could be seen as rather independent parts of experience.

Tononi speaks of integrated information defined in terms of maximum of relative entropy (see `http://tinyurl.com/hazmflc`). Scott Aaronson represents a rather comprehensible definition.

1. One wants a concrete measure for the interdependence of the subsystems A and B defining partition of the system. The integrated informations should correspond to maximally interdependent partition. The measure for integrated information - call it Φ - must have a maximum Φ_{max} if A and B are in causal relation. Φ is obtained by maximizing over all

divisions of system to two parts A and B some measure of the sum of mutual informations definable in terms of conditional entropies assuming that the states in either A or B are random. Conditional entropy is entropy $H(A|B) - H(B)$ and if A and B are strongly correlated is negative and has interpretation as information. FIn the case of brain, left and right hemispheres are natural candidates for maximally integrated pair (A,B) and one could understand left-/right- hemisphere dominance as a failure of integration.

These entropies are associated with mechanism, which translates to a function mapping the states of the entire systems to its states. The maximizing pair (A,B) would define the maximally causal relationship and give rise to a building brick of experience deserving to be called quale. This definition of quale is to my opinion rather ad hoc. The introduction of the mechanism brings in so many subjective assumptions that the definition might not have practical value. There are also difficulties related to the estimation of maximally integrated subsystem and thus of Φ_{max}: this might represent problem in NP class.

2. A measure for complexity is in question and numerous measures for complexity has been introduced by mathematicians. Φ would be a measure for feedback between and interdependence of different parts of the system. When Φ is above critical value, system is conscious. Intuitively, if the parts of the system are not correlated and communicating, system is not conscious. Even proton could be conscious since quarks are strongly correlated although it is questionable whether it makes to sense to talk about feedback in this context. In any case, this looks rather reasonable. $\Phi_{max} = 0$ means that system is completely reducible into its parts. The problem is that the connection with fundamental physics is lacking. Φ_{max} would measure the level of consciousness. I do not know how Φ_{max} would be measured and probably no one knows.

3. Aaronson gives a concrete example giving a gist about what integrated information could means. He also demonstrates that the definition of Tononi leads to technical problems using his identification of mechanism as a map of states of system to states of system. This could be of course quite too limited definition.

   The idea is to consider all partitions of the system to two parts A and B. One can consider a system consisting of a ordered set of points to which one can assign finite number of states. Also binary digits could be considered. The states in set A are assumed to be random.

   To identify the partition giving rise to maximal integrated information, one calculates the relative entropies for the images of the points and identifies integrated information as their sum. One can do the same by regarding the states assignable to points of B as random. One sums the relative entropies. If there is strong correlation between A and B then the randomness in A implies that this sum is large. If there is no dependence between A and B the sum vanishes. The partition (A,B) for which the sum of entropies is minimal corresponds to the partition defining the decomposition, which can define cause-effect pair. Integrated information is assigned with this pair.

4. Aaronson's first objection relates to the difficulty of identifying of the connection network of brain. One does not even idea about how to identify the nodes of this network. Neurons in state 1 or 0 is hardly suggested by anyone nowadays. Should one try to reduce to microtubular level. Or perhaps to the level of DNA and proteins? The identification of mechanisms as analogs of functions is a further heavy difficulty. Do their correspond to analogs of classical computer programs or to sequences of associations? Aaronson also thinks that panpsychism is unacceptable. To my view this particular criticism cannot be taken too seriously.

Consciousness can be present even when neural activity is low as in meditative states and IIT can explain also these states. What matters is the degree of integration - not so much the input. This leads to ask whether a closed system without sensory input and metabolic feed can be conscious. IIT says makes no obvious statements about the role of metabolism. IIT is also silent about the social aspects of consciousness and reduces consciousness to the properties of a network.

The assumption that the decomposition (A,B) corresponding to maximally integrated information as characterizing the contents of consciousness is to my opinion very problematic. Information is a relative notion: only a conscious system can have information about something.

One therefore defines consciousness as an aspect of conscious experience so that the definition is circular. Second problem is that information as also consciousness is always about something unlike matter which such exists. Information as independent "substance" makes no sense.

Standard physics allows only to speak about entropy characterizing the lack of information about the state of system. When intelligent entity learns what the state of system is it receives information equal to this entropy. Here however the notion of conscious experiencer leaks in! The assignment of information to a bit sequence assumes that there is system for which the bit sequence has meaning by generating a process leading to a conscious experience interpreted as understanding. I dare guess that for my cat (or even for standard man in the street) these lines carry absolutely no information. Thus the dream about measuring information as a physical observable and concluding from this whether system is conscious and what the level of consciousness is, fails. The identification of Tononi leads to the notion of consciousmeter. To me this notion crystallizes what goes wrong with the physicalistic and purely information theoretic approaches.

To make the criticism more precise, one can look at the expression for $I(A,B) = S(A|B) - S(B)$ with conditional probabilities defined by $p(A|B) = p(A,B)/p(B)$. If A and B are independent events that is if the output has no correlation with input as in the case of thermodynamical system, one has $p(A,B) = p(A) \times p(B)$ and one has $I(A,B) = S(A) - S(B)$. Second law tells that the information is negative. In thermal equilibrium $I(A,B) = 0$. Quite a reasonable result.

Intuitively optimal situation is achieved when $S(A|B)$ having interpretation as the entropy associated with the causal evolution is zero: evolution would be completely deterministic as in classical computer programs or quantum computer programs during computation. Therefore classical computer programs, which do not map two inputs to same output would be ideal (the error correction program mentioned by Scott Aaronson) as far as consciousness is involved: this is not surprising taking into account the idea about neuron as bit.

The situation would be optimal for the maximally entropic initial state: this looks admittedly strange. Printing of a page of text about whose content I know nothing would be a highly conscious process! If I knew the content of the page, it would not be a conscious process! Obviously this is true but for me, not the system claimed to be conscious! The circulatory definition of conscious information leads to this non-sensical result. All definitions of conscious information based on Shannon entropy lead to the same result. One must have genuine definition of information.

These are classical considerations. Could this paradoxical situation make sense quantally or in TGD framework? Conscious entity - self - would live in adelic world and would be negentropically entangled subsystem - superposition of several state pairs. By NMP in Zero Energy Ontology implying self as generalized Zeno effect it would not allow state function reduction during its lifetime so that outsider could not learn what it's state is!

Real entanglement entropy would describe this missing information and the sum of p-adic negentropies the conscious information posssessed by the self (for rational entanglement probabilities these two measures would have the same value). In TGD inspired theory of consciousness the paradoxical statement would thus make sense! Schrodinger cat remains conscious as long as no-one is able to measure the state of cat (note that here dead-alive dichotomy as a metaphor is not good). Conscious systems are secretive!

6.2.3 Architecture of consciousnes

Exclusion

Exclusion means that a mechanism can contribute to consciousness at most one cause-effect repertoire. This repertoire has maximum value of integration/irreducibility Φ_{max}. Exclusion is taken to mean that although subsystems of brain can have large Φ the entire brain masks their contribution to conscious experience. The masking postulate looks rather strange but is necessary unless one assumes hierarchy of consciousness so that subconscious would correspond to conscious but not at our level of hierarchy. Not all brain activity would be conscious to us. The activities of brain regions such as cerebellum are regarded as unconscious although there are more neurons there than in cortex. It could be that cerebellum is only unconscious to us?

Composition of mechanisms and conceptual structure

It is also possible to compose mechanisms. This is analogous to the composition of functions or formation of network from modules defining elementary functions. Composition can be also in time domain - say as a sequence of program modules as in computer program - so that the spatial realization is not changed. Composition is also analogous to what engineer is doing when he constructs more complex structures from primitive ones or programmer builds more complex programs from simple basic modules. This principle is very clearly present in biology and neuroscience based notion of conceptual structure.

The above postulates apply also to systems of mechanisms obtained by composition. This defines a conceptual structure identified as a constellation of points in concept space, where each axis consists of past/future state of the set of elements, and each point is a concept specifying differences that make a difference within a set. The higher the number of different concepts and Φ_{max} value, the higher the conceptual information.

Conceptual structure is kind of network build from mechanisms and analogous to a composition of functions or of computer programs. From the definitions it seems clear that conceptual structure does not correspond to independent ontological level in any sense. Conceptual structure should determine qualia and intensity of conscious experience. Here physicist starts to shake his head. I find it very difficult to imagine that qualia could be reduced to a structure of a network diagram. The unsuccessful attempts to identify qualia in terms of neural networks have demonstrated this (it is not possible to demonstrate any difference between the structure of neural networks in various sensory areas nor in the structure of sensory pathways).

The partial reduction of consciousness to mechanisms is in accordance with the idea about brain as computer. In this framework imagination might perhaps be understood as motor actions stopped before becoming real. Virtual sensory inputs which do not begin from sensory receptors is interpretation in the case of sensory experiences. They might have also this aspect but there might be something deeper distinguishing between imagination and reality.

Identity postulate

One of the axioms states that consciousness exists. Something rather trivial. But does this mean that consciousness exists as something reducing to matter/physics as we know it. This is the crucial question distinguishing between monistic and dualistic and possible other theories.

One of these dogmas manifests in the question “dualistic or monistic” inspired by the belief that no other options are possible (TGD represents such an option). Tononi answered the question whether IIT is materialistic or dualistic theory of mind cryptically by saying “IIT is what IIT is”. On the other hand, the proposal of consciousmeter could come only from a physicalist and physicalism reduces consciousness to an epiphenomenon.

IIT resembles physicalistic/materialist approach in that it identifies consciousness with the decomposition of elementary system to a pair (A,B) of subsystems information measure Φ and selects a unique pair as that for which this information is maximal. I_{max} measures the intensity of conscious experience. To this pair one assigns experience. Thus experience corresponds to unique decomposition of system to two parts. The technical problem is that this decomposition need not be unique! In any case, the structure and dynamics of system defined by mechanism would dictate completely the contents of consciousness.

Qualia

Qualia are assigned with the links of a net like structure. If I understand correctly, this structure corresponds to a collection of mechanisms with link identified as a mechanism connecting members of a causal pair. One assigns to link an information as relative entropy defines as the difference of entropies of the network and network without the link.

Why the link should carry say sensory quale remains a mystery to me. I would be ready to accept that the structure of experience corresponds to a network but assigning qualia with the links does not look like a feasible idea. It remained unclear to me whether qualia space corresponds to the links of the network or whether it corresponds to a collection of the networks. For instance, it is not easy to understand how basic colors could be understood in his framework. What properties of the link identified as mechanism or its relationship to the rest of the network could make the color quale "red" instead of "green".

6.3 TGD inspired theory of consciousness as quantum measurement theory in ZEO

To make the comparison easier for the reader I first summarize very briefly the basic ideas of TGD inspired theory of consciousness identified as quantum measurement theory in zero energy ontology (ZEO).

6.3.1 Zero Energy Ontology (ZEO)

ZEO [K49] was motivated by TGD inspired cosmology. Physical states have vanishing conserved net quantum numbers and are decomposable to positive and negative energy parts. The particle physics interpretation is as initial and final states of a particle reaction. A profound modification of existing views about realization of symmetries is in question.

The notion of causal diamond (CD) is closely related to ZEO. CD corresponds to an intersection of past and future directed light-cones of Minkowski space (with points replaced by CP_2). Positive and negative energy parts of physical states are at future and past boundaries of CD which form part of light-one. Poincare transforms of CDs are allowed and CDs for a fractal hierarchy. A number-theoretically attractive hypothesis is that the distance between the tips of CD is quantized essentially as multiple of the size scale CP_2. CD can be interpreted as the 4-D perceptive field of conscious entity: zero energy state corresponds to a superposition of space-time surfaces having their ends about light-like boundaries of CD.

S-matrix and density matrix are unified to the notion of M-matrix defining time-like entanglement and expressible as a product of square root of density matrix and of unitary S-matrix. At least formally, thermodynamics becomes therefore a part of quantum theory, which can be regarded as "complex square root" of thermodynamics. One has kind of thermodynamical holography in the sense that square roots of thermal ensembles are realized at single particle level. One must distinguish M-matrices identifiable as products of orthonormal hermitian square roots of density matrices and universal S-matrix from U-matrix defined between zero energy states and analogous to S-matrix and characterizing the unitary process associated with quantum jump. The detailed description of U- and M-matrices is considered in [K49].

The most dramatic ontological implication is that quantum jump sequence can in principle lead to any zero energy state: this allows to avoid many unpleasant paradoxes forcing theorist to wonder whether theories are needed at all (in deterministic context only single solution of field equations is realized!). ZEO is consistent with the basic laws of quantum physics, allows maximal free will, and allows to solve the basic paradoxes of quantum measurement theory (determinism viz. non-determinism paradox and problems with the notion of time).

6.3.2 Hierarchy of Planck constants and dark matter hierarchy

One motivation for the hierarchy of Planck constants came from neuroscience from the observations made by Blackman and other pioneers of bio-electromagnetism [J23] [K81]. The observations could be summarized by saying that electromagnetic radiation of vertebrate brain at ELF frequencies (say multiples of 15 Hz) has both physiological and behavioral effects, which also look quantal. Quantal character is in conflict with the fact that ELF frequencies correspond to photon energies $E = hf$, which are extremely low, something like 10 orders of magnitude below thermal at physiological temperature. This inspired the proposal that photons are dark in the sense that for them one has $h_{eff} = n \times h$.

The identification of dark matter as phases having large value of Planck constant [K79, K26, K22] led to a vigorous evolution of ideas. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant coming as integer multiples $h_{eff} = n \times h$ of ordinary Planck constant is predicted. A further assumption was that the dark matter in question is at magnetic flux tubes of the magnetic body of living system or of its part. This leads to the identification of EEG as a communication tool from biological body to magnetic body (MB). MB would receive sensory data from cellular and nuclear membranes and send control commands - most naturally via genome - to the biological body. MB would act as intentional agent using biological body as sensory receptor and motor instrument. This assumption allows to identify a long list of mechanisms used by magnetic body. Bio-photons can be understood as ordinary photons resulting when dark photons transform to ordinary ones [L3, K6].

The mathematical understanding of the hierarchy of Planck constants took a longer time [K26, K18, K19, K20, K21]. 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 - 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 somes 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 at least. These ramified primes would characterize physical system and the weak form of NMP would allow to understand how p-adic length scale hypothesis follows [K95]. The continuation could be possible for all p-adic primes due to the possibility of p-adic pseudo-constants having vanishing derivative. It could quite well happen that the continuation fails 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 [K52]. 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 [K18, K19, K20, K21]. 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 in negentropic entanglement (NE) allows to satisfy the needs of NMP so that the system survives and provides a garden in which sub-selves can are born and die and gradually generate NE. Living systems are thus negentropy gatherers and each death and re-incarnation generates new negentropy.

All particles in the vertices of scattering 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 [K18, K19, K20, K21, K58].

The construction gives also the 4-D space-time sheets associated with the light-like orbits of the partonic 2-surfaces: it remains to be shown whether they correspond to preferred extremals of

Kähler action. The hierarchy of Planck constants has become an essential part of the construction of quantum TGD and of mathematical realization of the notion of quantum criticality rather than a possible generalization of TGD.

6.3.3 p-Adic physics as physics of cognition and imagination

During years it have become more and more clear that consciousness involves cognition in an essential manner.

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 [K95]. 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 dropped intentionality away since I am not quite certain.

The difficult question has been how real and p-adic physics relate to each other. 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.

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 general coordinate invariance 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?

The 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. 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 general coordinate invariance 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.

Negentropic entanglement

In given p-adic sector the 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 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 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 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.

Strong form of holography and p-adic view about imagination

A further step in the progress came from the discovery of strong form of holography (SH) [K16]. 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!

6.3.4 Quantum measurement theory in ZEO

NE is key notion and entanglement negentropy identified as number theoretic entanglement entropy (EE), which can be negative, takes in some sense takes the role of Φ serving as a measure for integrated information of TGD to be discussed below. NE can only increase in state function reductions and this brings in evolution forced by NMP. This leads to a precise identification for the notion of self, allows to understand the relationship beween subjective time and geometric time, and even what life and death of a conscious entity mean. Here only the key aspects are listed.

1. Causal diamond (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.

2. One possibility is that sensory input and mental images ("Maya") generated by it can be assigned with the active boundary of CD. A more elegant assumption suggested by quantum measurement theory is that the passive boundaries for sub-CDs give rise to mental images as outcomes of repeated quantum measurements. The unchanging part of self ("Self") is associated with the passive boundary. It corresponds to negentropically entangled subsystem having no entanglement with environment. In ordinary ontology it would not be possible keep self un-entangled from the environment.

3. NMP forces eventually the first state function reduction to the opposite boundary of CD: the pot starts to boil. Self dies and re-incarnates as time reversed self at the opposite boundary. The life-time of self is measured as the increase of the temporal distance between the tips of CD. Time reversed self evolves as reductions shifting the opposite boundary of CD to opposite time direction so that the size of CD continues to increase and defines a measure for the duration of the entire sequence of re-incarnations. This implies quantum physical realization for the idea about transmigration of souls! Excellent manner to get rid of street-credibility is to tell to academic audience about this implication.

4. One big news is that selves form a hierarchy (CDs within CDs) and sub-selves are identified as mental images. In TGD framework it is also possible for sub-selves of two unentangled selves to entangle negentropically. This corresponds to sharing of mental images and means that our conscious experience is not completely private. The pool of shared mental images might in fact make possible communication and social structures. Sharing of mental images is possible only in many-sheeted space-time forcing to generalize the standard view about subsystem.

The divisions of system to two parts are involved with the definition of integrated information. Also in the formulation of NMP in terms of maximal negentropy gain one considers divisions of the system into subsystem and complement and finds the pair for which the reduction of entanglement would give maximum reduction of entropy. If the system is irreducible this kind of pair characterized by entropic entanglement cannot be found. The eigenstates of density matrix for negentropically entangled subsystems are in 1-1 correspondence. An interesting question is whether associations in the sense of neuro science corresponds to NE between the states of associated systems.

State function reduction scade is also key notion. State function reduction sequences is a top down cascade propagating downwards to smaller system sized. First the reduction in CD scale occurs. The resulting two subsystems decompose to two parts and so on untile decomposition is not possible anymore because it would not generate negentropy.

6.3.5 TGD view about qualia

The TGD inspired theory of qualia [K30] 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 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 di-electric breakdown [K45] 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 di-electric breakdown generates Bose-Einstein condensate and the quantum numbers for the BE condensate give rise to qualia assignable to sub-self.

6.4 Comparison of IIT with TGD

6.4.1 Basic concepts of IIT from TGD point of view

Pan-psychism, identity postulate, and physicalism from TGD viewpoint

In TGD framework panpsychism is assumed but in different form. Consciousness is not a property of matter unlike in IIT but an independent form of existence not reducible to say geometric existence so that notions like qualia space introduced in IIT do not make sense. Consciousness is the state function reduction occurring between different material worlds. This resolves the fundamental problems related to quantum measurement theory and the notion of time. In ZEO one can talk about conscious entities (this is almost unavoidable since our language reflects the belief that consciousness is a property of physical system) as internally negentropically entangled systems de-entangled from the rest of the world at the possive boundary of CD. In standard quantum theory this would make no sense. All qualia would correspond to outcomes of repeated quantum measurements at passive boundaries of sub-CDs of CD and defining mental images. The flow of time would correspond to contribution from the active boundaries of CDs involved.

Causal networks and the assignment of qualia to the links of the causal network

Causal network is assumed with motivations coming from neuroscience and qualia are assigned with the links of this network. They would correspond to axons or neural pathways in neuroscience.

Criticism:

1. The idea that various sensory qualia could be understood in terms of topological structure of a network formed by neuronsandaxons is old but has not led to the understanding of qualia. The neural network looks exactly the same in various sensory areas. Also the sensory pathways looks the same.

2. Causal interactions between parts of brain are assumed to give rise to consciousness. People having no corpus callosum have synchronous left and right hemispheres [J39] (see `http://tinyurl.com/3gjhtgb`)! One might expect that causal interactions between hemispheres must be responsible for the synchrony but it is difficult to imagine anything like this now. There seems to be something like "boss" forcing both hemispheres to synchrony.

In TGD the qualia correspond to the eigenvalues assignable to the observable measured during repeated state function reductions leaving the states at passive boundary of sub-CDs representing mental images of self invariant. Non-locality and new view about time allows to consider also the possibility that qualia can be assigned with the sensory organs. One cannot of course exclude the possibility that also neurons can have primary sensory experiences rather than just sharing the primary sensory mental images assignable to the sensory organs.

In TGD framework the networks emerge naturally as networks of magnetic flux tubes [L15].

1. The "boss" forcing the synchrony of disconnected left and right hemispheres would be magnetic body (MB) of brain [L18]. Magnetic bodies appear in all scales. NE between nodes of this network is what is more significant.

2. The so called tensor networks [B11] [L12] (see `http://tinyurl.com/y9kwnqfa`), which have emerged as realizations of error correction codes in quantum computation and realize holography can be seen as a realization of NE. The realization in terms of magnetic flux tubes could define kind of template for the dynamics of bio-systems. Magnetic body (MB) would define both geometric and dynamical template for bio-chemistry and even genetic code could be reduced to this level. MB would complete the organism-environment duality to trinity.

3. The dynamics of MB (motor actions of MB as reconnections, contractions of flux tube, changes of the topology of the network inducing NE transfer) and also the dynamics at MB (supra currents, dark photons propagating along flux tubes in targeted manner) would define the analog for the causal dynamics appearing in IIT. ADP-ATP transition attaching phosphate to ADP has interpretation as transfer of NE. Phosphate-X (X some large system) flux tube is attached to ADP to give ATP-X NE and when ATP gives phosphate to biomolecule Y one obtains Y-X NE (for what Y could be, see below). Metabolic energy could go basically to transfer NE between systems. This would mean that the local dynamics of the network would be central for what it is to be living.

4. This picture would suggest that the changes of topology making possible transfer of negentropy are crucial for consciousness in living systems. Dynamics of bits in static networks represents only the classical communications associated with genuinly quantal system.

Bio-photons identified as decay products of dark photons with large value of Planck constant h_{eff} is an essential element of resonant like precisely targeted communications along flux tubes of MB. It must be made clear that TGD has had an interpretational problem related to the identification of bio-photons as decay products of dark protons [K18, K19, K20, K21, K58]. The resolution of this problem leads to conclusion that MBs with field strengths assignable to Earth's *resp.* galactic magnetic fields control living matter and have EEGs related by scaling: for details see [L15].

What the mysterious looking entity X could then be? The MB of Earth assignable with Earth's mass via $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ is the first candidate for X but for it EEG would be scaled down since the flux tubes would correspond to those of galactic magnetic body with $B_{gal} \sim 10^{-9}$ Tesla: 10 Hz alpha band would correspond to 72 minute time scale and natural periodicity would be given by sidereal day. Spottiswoode observed that sidereal day defines periodicity for precognition [J48]. A mass $M_D \simeq 5.\times^{-5} M_E$ forming a spherical layer at the distance of Moon from Earth associated with the magnetic Mother Gaia controlling bio-dynamics would correspond to the ordinary EEG. This would also predict that 1 s cyclotron time for DNA sequences in $B_{end} = .2$ Gauss corresponds to 12 h cyclotron time for $B_{gal} = .63$ nT.

The presence of these two MBs be a dramatic manifestation of non-locality. These MBs would make life possible at Earth. 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 their 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.

The notion of integrated information (Φ) from TGD viewpoint

In TGD the analog of Φ as measure of complexity would be number theoretic entanglement negentropy involving p-adic norm in its definition. If defined as average for the entanglement negentropies for various partitions of the system to two parts it would define a measure for the complexity and correlations.

Formally a modification of Shannon entropy is in question but the surprise is that it can be negative in which case one has NE It makes sense for entanglement coefficients in algebraic extension of rationals: this predicts number theoretic evolutionary hierarchy of conscious entities. The definition relates closely to p-adic physics as physics of cognition. Number theoretic EE measures the information associated with NE (ordinary EE measures the lack of information about state of entangled system due to entanglement). The basic variational principles is NMP stating that the negentropy gain is maximal in each state function reduction. NMP forces the amount of NE measured by number theoretic entanglement negentropy to increase. One interpretation for the NE resources of the Universe is as "Akashic records". Universe would be a huge growing library of books formed by negentropic mental images.

In TGD framework the reduction of the system to its parts leading to a loss of consciousness would occur by state function reduction. NMP can prevent this in presence of cognition. That state function reductions occur rather often at elementary particle level tells that their cognitive level is rather low. Breaking of time reversal symmetry analogous to that in thermodynamics is also a signature of cognition.

The proposal about critical value of Φ makes the situation analogous to that in critical thermodynamical systems. This also brings in mind quantum criticality of TGD fundamental for the understanding of the evolution of conscious entities in TGD framework. It brings in the hierarchy of dark matter represented as phases of ordinary matter with non-standard value $h_{eff} = n \times h$, $n = 1, 2, ...$ of Planck constant emerging at quantum criticality and making macroscopic quantum coherence possible.

In TGD NE is a correlate for conscious information. NE also provides a correlate for integration. Conceptual structure could be assigned with the topological structure of NE, which would also be a correlate for complexity in quantum sense. Quantum computer people have indeed realized that the physics of complexity is essentially physics of entanglement. Conscious entity corresponds to the sequence of quantum jumps/reductions at fixed boundary of CD. Conscious entities have inherent NE and they are not entangled with environment. There is however no attempt to identify NE as consciousness.

The correlation produced by causal evolution in IIT is replaced with NE in TGD. Hence the two views look rather different as far as conscious information is considered. On the other hand, classical physics is exact part of TGD and quantum classical correspondence realized by strong form of holography (SH). Quantum computation accompanies self and quantum computation is accompanied by a quantum superposition of classical computations. Therefore one can ask whether the generalization of the formula for $I(A, B)$ could be meaningful in TGD and even relate to consciousness.

1. In TGD framework the superpositions of classical space-time surfaces identified as preferred extremals connecting the positive and negative parts of zero energy states at opposite boundaries of CD define the counterparts of causal evolutions. Quite generally, classical deterministic evolution is highly analogous to a classical computer program.

2. The analog of $I(A, B)$ in TGD could be assigned with the evolution zero energy state based on time evolution of the space-time surfaces: A and B would correspond to the positive

and negative energy parts of states at opposite boundaries of CD (initial and final states of classical time evolution) defining self. B would correspond the passive boundary of CD and A to the active boundary, which moves farther from B during the reduction sequence and states at it experience a discretized variant of unitary time evolution. The evolution for the active boundary of CD is the analog of unitary Schrödinger evolution and analogous to quantum computer program.

Note that in TGD framework quantum theory is purely classical theory formally! WCW spinor fields representing zero energy states are indeed purely classical spinor fields formally. Only state function reduction is something genuinely quantal.

3. $S(A|B)$ could be interpreted as entropy generated by evolution analogous to classical computation. The time evolution however fails to be strictly deterministic and particle reactions represented topologically in terms of generalized Feynman diagrams would naturally relate to this non-determinism. Hence $S(A|B) > 0$ is expected to hold true and could be very much like entropy generated by particle decays and creation and the interpretation in terms of thermodynamics would be natural.

4. The very existence of self thus breaks second law (note however that state function reductions occur for sub-CDs assignable to mental images which die and are reborn). As self dies, thermodynamical entropy increases since this reduction is non-deterministic. On the other hand, new time-reversed self is born and carries NE and there is negentropy gain by NMP [K45]. Second law holds true in time scales longer than the life time of the long-livest self. $I(A,B) > 0$ could be thus assigned with selves during their life-time. Since the state function reduction to the opposite boundary of CD is non-deterministic, the conjecture that $I(A,B)$ equals to negentropy gain in this reduction, does not make sense.

5. The definition of $I(A,B)$ is non-trivial problem and discretization implied by finite measurement resolution at fundamental level is necessary in order to avoid mathematical difficulties in the case of deterministic evolution.

Counterparts of mechanisms and irreduciblity in TGD

Mechanism is central notion in IIT. In ZEO self organization patterns in 4-D sense serve as counterparts of behavioral patterns realizing causal relationship. Space-time surfaces identified as preferred extremals of Kähler action satisfying extremely powerful constraints coming from strong form of holography are space-time correlates for these self-organization patterns. System approaches reduction by reduction to these 4-D patterns: in positive energy ontology these patterns would be 3-D. This difference has profound implications.

The analog for the notion of irreducibility in TGD framework is that any subsystem at the passive boundary of CD is inherently negentropically entangled and remains so as long as the conscious entity lives and is in this sense irreducible at the passive boundary of CD. The information carried by NE cannot be localized.

Maximal NE defines isometric map between subsystem and its complement. In fact, the isometric map is possible for all subsystem complement pairs for so called perfect entanglement discussed by Preskill [B11] in his proposal for error correcting codes based on holography. This model has application in TGD inspired model of living systems based on the notion of magnetic body [L12].

NE is stable against NMP allowing state function reductions in which system splits into subsystem and complement is similar notion. Hilbert spaces with prime dimension are also irreducible in the sense the decomposition into tensor product of two subystems is not even possible and this might deeply relate to the fact that Mersenne primes seem to be very important in TGD [L22]. (see `http://tinyurl.com/gp9mspa`).

In TGD framework metabolism is not just feed of ordered energy but feed of NE carried by nutrients [K58, K37]. This NE means feeding in of connections to other system realized in terms of magnetic flux tubes and couple the system to environment and other conscious entities.

Self hierarchy makes exclusion postulate un-necessary

Exclusion postulate looks to me like the most problematic axiom of IIT. Hierarchy of selves with sub-system of system corresponding to sub-self makes exclusion postulate un-necessary in TGD framework. System can have sub-systems conscious sub-systems and these in turn can have conscious sub-systems so that one has a hierarchy. The hierarchy of space-time sheets corresponds to this hierarchy at space-time level and the hierarchy of CDs at embedding space level. Subsystems correspond to mental images, which are kind statistical averages over mental images of sub-selves so that the information about lower levels is only statistical. This saves the system from drowning to irrelevant conscious informations.

Tononi does not consider the possibility of self hierarchy. Maybe the reason is that the idea about hierarchy of selves is central in spiritual practices involving angels and gods but is very difficult to accept in the western science accepting only what is directly perceived. In TGD framework the new space-time concept - in particular the notions of field body and magnetic body - support the notion of self-hierarchy. For instance, EEG could be seen as communications to the magnetic body of organism having onion-like structure with layers with sizes even larger than the size of Earth [K62, K61].

For instance, the damaging of cerebellum does not affect much consciousness. This is true but it is "our" consciousness, which is not affected - only one level in the self hierarchy. Cerebellum could quite well represent a level few levels below cortex in the hierarchy of selves. It can of course decompose to sub-structure, which are negentropically entangled but unentangled with each other.

This failure is reflected in the rather weird looking exclusion postulate. Parts of brain can have Φ allowing them to be conscious. Tononi cannot however make sense of this. The explanation would be that brain as a whole has so large a Φ that it overrides that for parts so that they are not conscious. By the same argument the Φ of Universe would be so large that there would be not a single conscious entity besides the entire Universe! One ends up with solipsism.

No variational principle of consciousness is introduced in IIT

In IIT no variational principle defining the dynamics of consciousness is introduced - say a postulate that the property measured by Φ would increase being therefore mathematically analogous to NMP in TGD framework. This kind of variational principle should imply evolution.

The definition of NMP involves quite refined number theoretic details but is consistent with standard quantum measurement theory and with standard measurement theory for ordinary entropic entanglement - that it is for ordinary matter. For dark matter one has NE and the situation changes. One can however say that second law for a given self holds true in time scales longer than the life-time of self.

NMP implies a kind of competition between subsystems, which can reduce their entanglement with environment in state function reduction. One can say that for a given system the state function reduction occurs for the subsystem-complement pair for which the reduction of EE is maximal. This if the entanglement is ordinary entropic entanglement, which is always reduces in accordance with the standard quantum measurement theory. For maximally negentropically entangled systems NMP need not lead to any effect. NE can be stable since as a whole it tends to increase. This does not prevent transfer of NE between systems.

The builder of consciousness theory is eventually led to ask about the origins of ethics and moral. NMP does not completely deterministically select the final state in the case of NE. For instance, if NE corresponds to $N \times N$ identity matrix it can happen that reduction occurs to a lower-dimensional space and one can speak of free will. The outcome can make the negentropy gain smaller but also larger. One can say that system has free will and even speak about ethics based on maximization of negentropy and moral choices. Complete reduction of entanglement would mean the worst possible deed and implies the system is de-entangled and thus isolated from the rest of the Universe.

6.4.2 Engineering aspect of consciousness

The idea that consciousness is engineered from simple building bricks is rather attractive and realized also in TGD framework.

The problematic notion of conceptual structure

The notion of conceptual structure is problematic in the sense that the assignment of qualia to the links of this structure does not look feasible. In TGD the combinatorial structure of NE the most natural TGD analog of conceptual structure. It would correspond in the most general case to a quantum superposition of networks - the so called spin liquid could actually realize this notion in condensed matter physics. Conscious entity would correspond to a sub-system having no entanglement with environment but its internal entanglement would be negentropic and maximal in well-defined sense. The notion of tensor network, which appears in quantum computations could be equivalent with the notion of negentropically entangled system. A quite recent proposal of Preskill [B11] is that error correcting quantum codes could be realized using tensor networks. This fits very nicely with TGD view [L12].

The structure of NE provides abstract backbone for the structure of conscious experience. The structure of NE does not however give any clue about qualia. In ZEO they can be assigned with either the passive of active boundary of CD. At active boundary they could be assigned with the quantum number transfer rates between the active part of self and environment. At passive boundary they would naturally correspond to the quantum numbers of the passive part of some sub-self at passive boundary of its CD: repeated measurement would give experience about what the quantum numbers are. This option would fit nicely with quantum measurement theory. If one interprets mental images as sub-selves, one can indeed understand why the sensory experiences vary from moment to moment although the passive part of self - “Self” - does not change.

The notion of conceptual structure unavoidably brings in mind p-adic physics as physics of cognition and imagination but these two notions should be distinguished. Adelic physics fuses real and various p-adic physics to single coherent role. To me this option looks much more plausible.

The problems of free will, intentionality, and time

IIT says nothing about volition, intentionality, and (not completely) free will. Mechanisms could be non-deterministic but this does not help much. To my opinion, trying to say something about free will leaves no other options than quantum theory or its generalization.

IIT says nothing about experienced time. Standard quantum measurement theory involves the notion of observer and is plagued by a deep paradox related to the determinism of Hamiltonian time evolution and non-determinism of quantum measurement theory. This has led to the Copenhagen interpretation depriving ontological status from the basic mathematical notions of quantum theory. The problem relates directly to the notion of observer, the question about reality of free will, and to the question about the relationship between the geometric time of physicist and the experienced time.

Obviously, non-conservative theorist cannot imagine more promising starting point for a theory of consciousness. One should generalize quantum theory so that one gets rid of paradoxes and provides a description of observer as conscious entity. In TGD framework the qualia can be reduced to fundamental physics, which to my opinion is much more convincing identification than the identification in terms of a particular partition associated with some mechanism assumed to be associated with the system considered.

The randomness of state function reduction does not resonate with the idea of intentional free will but it could be tamed by cognition making possible intentional free will made possible by the extension of real physics to adelic physics.

In principle ZEO allows also creation of any zero energy from vacuum state without any problems with the laws of physics. That this is impossible in positive energy ontology and is one of the main reasons for adopting the materialistic/physicalistic view about consciousness reducing it to epiphenomenon. It seems that the same reduction occurs in IIT.

TGD provides an elegant interpretation for the act of free will. Since nothing drastic happens during repeated state function reductions to the same boundary of CD, the act of free will can only corresponds to the first reduction to the opposite boundary of causal diamond (CD). The act of volition means the death of sub-self and reincarnation as time reversed sub-self. This explains the finding due to Libet that conscious decision to perform motor action (to raise finger) initiate neural activity before the decision. Negative energy signal to the geometric past of brain would initiate the neural activity.

A further outcome is that p-adic entanglement can be negentropic and by NMP and SH it stabilizes the entanglement also in real sector. Cognition would not be a passive formation of cognitive representations but would have causal power taming the randomness of quantum jumps making possible directed intentional will. Religions express this intuition in various ways: for instance, the Finnish version of Genesis contains the sentence “First was the word”. Also Finnish national epic gives magic power to the words: first comes the world and only after it what the word refers to.

6.4.3 Why deep learning neutral networks are so effective?

Deep learning means AI systems with large number of hierarchy levels: programs calling programs calling... is the first intuitive idea of AI outsider like me. These algorithms are learn from examples mimicking the formation of associations in brain. These programs can also rewrite themselves but all is based on given algorithm.

The surprising finding is that deep learning neural model work much better than one might expect on basis of mathematical arguments alone (see `http://tinyurl.com/zvrmao7`. This looks like a real mystery. The solution of the puzzle proposed by physicists is elegant. The physical world is much much simpler than mathematicians - wanting to be as general as possible - assume! Simplicity means among other things holography and hierarchical structures and deep learning relies on hierarchical structures. It would be amazing if AI and physics finally could meet each other (see the article of Lin and Tegmark at `http://tinyurl.com/hz2jp8z` and the remarks of Ben Goertzel at `http://tinyurl.com/z8tcqht`).

Holography and its strong form

The Universe is indeed very simple according to hololographic theories. For instance, in TGD not only holography but strong form of holography holds true. The quantum and classical data assignable to string world sheets and partonic 2-surfaces dictates the dynamics of 4-D space-time surface. This effective 2-dimensionality of dynamics means enormous simplification of the quantum physical world from what it could be. For instance, preferred extremals defining space-time surfaces satisfy infinite number of conditions stating vanishing of certain Noether charges.

This extreme simplicity is lost when the sheets of the many-sheeted are lumped together to obtain the space-time of general relativity and standard model and effective classical fields are sums over geometrizes classical fields associated with the sheets. In biological systems however the dynamics of many-sheetedness comes manifest and the actions of single sheet need not be masked: things get simple in this kind of situation.

Various fractal hierarchies

Holography need not the only reason for the simplicity. The possibly physical world of TGD has hierarchical fractal structure: length scale reductionism is replaced with fractality. Dynamics looks more or less similar in all zooms and this simplifies the situation of mimicker enormously. There are hierarchies of space-time sheets topologically condensed on larger space-time sheets, hierarchy of p-adic length scales defined by primes near powers of two (or more general small prime), hierarchy of Planck constants, self hierarchy. p-Adic length scale hierarchy allows extremely simple model for elementary particle masses: one might perhaps say that one does not model the mass of ”real” particle but its cognitive representation about itself in terms of p-adic thermodynamics relying on conformal invariance. The hierarchy of Planck constants means fractal hierarchy of zoom-ups of system: dark matter phases assignable to quantum criticality would be crucial for the understanding of living systems.

These hierarchies also define hierarchies of measurement resolutions making possible abstraction, getting rid of details at the level of conscious experience and behavior. The hierarchical structure would be especially important for conscious mind. Self has subselves which it experiences as mental images and is mental image of higher level self. Goal hierarchies mean a lot of structural restrictions making it easier for artificial intelligence to mimick conscious systems.

p-Adic variant for the theory of computation?

In TGD Universe p-adic physics is physics of cognition and imagination and real physics also carries signatures about the presence of p-adic physics as p-adic fractality: this would explain the unexpected success of p-adic mass calculations [K41]. The outcome would be a fusion of real and various p-adic number fields to form adeles. Each extension of rationals giving rise to a finite-dimensional extension of p-adic numbers defines an adele, and there is hierarchy of adeles defining an evolutionary hierarchy. The better the simulation p-adic space-time sheet is for real space-time sheet, the larger the number of common algebraic points is. This intuitive idea leads to the notion of monadic geometry in which the discretization of the embedding space causal diamond is central for the definition of monadic space-time surfaces [L17]. They are smooth both in real and p-adic sense but involve discretization by algebraic points common to real and p-adic space-time surfaces for some algebraic extension of rationals inducing corresponding extension of p-adics.

How this could relate to computation? In the classical theory of computation recursive functions play a key role. Recursive functions are defined for integers. Can one define them for p-adic integers? At the first glance the only generalization of reals seems to be the allowance of p-adic integers containing infinite number of powers of p so that they are infinite as real integers. All functions defined for real integers having finite number of pinary digits make sense p-adically.

What is something compeletely new that p-adic integers form a continuum in a well-defined sense and one can speak of differential calculus. Exact numerics is lost but p-adic continuity (the values $f(x)$ and $f(x+kp^n)$) would be near to each other p-adically) and smoothness could make possible approximations and would allow to pose additional conditions on recursive functions for given prime p.

How could one map p-adic recursive function to its real counterpart? Does one just identify p-adic arguments and values as real integers or should one perform something more complex? The problem is that this correspondence is not continuous. Canonical identification for which the simplest form is $I: x_p = \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n} = x_R$ would however relate p-adic to real arguments continuously [K51]. Note that the real counterpart is rational for finite p-adic integers and real number in the general case. Canonical identification has several variants typically mapping small enough real integers to p-adic integers as such and large enough integers in the same manner as I. In the following let us restrict the consideration to I.

Basically, one would have p-adic valued recursive function $f_p(x_p)$ with a p-adic valued argument x_p. One can assign to f_p a real valued function of real argument - call it f_R - by mapping the p-adic argument x_p to its real counterpart x_R and its value $y_p = f_p(x)$ to its real counterpart y_R: $f_R(x_R) = I(f(x_p) = y_R$. I have called the functions in this manner p-adic fractals: fractality reflects directly to p-adic continuity. It should be made clear that canonical identification maps finite p-adic integers to real rationas and p-adic integers infinite as real integers to reals.

f_R could be 2-valued. The reason is that p-adic numbers $x_p = 1$ and $x_p = (p-1)(p+p^2+..)$ are both mapped to real unit and one can have $f_p(1) \neq f_p((p-1)(p+p^2+..))$. This is a direct analog for $1 = .999...$ for decimal expansion. This generalizes to all p-adic integers finite as real integers: p-adic arguments $(x_0, x_1, ...x_n, 0, 0, ...)$ and $(x_0, x_1, ...x_n - 1, (p-1), (p-1), ...)$ are mapped to the same real argument x_R. Using finite pinary cutoff for x_p this ceases to be a problem.

Recursion plays a key role in the theory of computation and it would be nice if it would generalize in a non -trivial manner to the realm of p-adic integers (or general p-adic numbers).

1. From Wikipedia (see `http://tinyurl.com/m9by2zn`) one finds a nice article about primitive recursive functions. Primitive recursive functions are very simple. Constant function, successor function, projection function. From these more complex recursive functions are obtained by composition and primitive recursion. These functions are trivially recursive also in p-adic context and satisfy the conditions of p-adic continuity and smoothness. Composition respects these properties tool. I would guess that same holds also for primitive recursion.

   It would seem that there is nothing new to be expected in the realm of natural numbers if one identifies p-adic integers as real integers as such. Situation changes if one uses canonical identification mapping p-adic integers to real numbers (for instance, $1+2+2^2 = 7 --- > 1+1/2+1/4 = 7/4$ for 2-adic numbers). One could think of doing computations using p-adic integers and mapping the results to real numbers so that one could do computations with real numbers using p-adic integers and perhaps p-adic differential calculus so that computation using analytic computations would become possible instead of pure numerics. This could be very powerful tool.

2. One can consider also real valued recursive functions and functions having values in (not only) algebraic extensions of rationals. Exponent function is an interesting primitive recursive function in real context: in p-adic context $exp(x)$ exists p-adically if x has p-adic norm smaller than 1). $exp(x+1)$ does not exist as p-adic number unless one introduces extension of p-adic numbers containing e: this is necessary in physically interesting p-adic group theory. $exp(x+kp)$ however exists as p-adic number. The composition of exp restricted to p-adic numbers with norm smaller than 1 with successor function does not exist. Extension of rationals containing e is needed if one wants successor axiom and exponential function.

3. The fact that most p-adic integers are infinite as real numbers might pose problems since one cannot perform infinite sums numerically. p-Adic continuity would of course allow approximations using finite number of pinary digits. The real counterparts of functions involved using canonical identification would be p-adic fractals: this is something highly non-trivial physically.

   One could also code the calculations at higher level of abstraction by performing operations for functions rather than numbers. The finite arithmetics would be for the labels of functions using tables expression the rules for various operations for functions (such as multiplication). Build a function bases and form tables for various operations between them like multiplication table of algebra, computerize the operations using these tables and perform pinary cutoff at end. The rounding error would emerge only at this last step.

The unexpected success of deep learning is conjectured to reflect the simplicity of the physical world: only a small subset of recursive functions is needed in computer simulation. The real reason could be p-adic physics posing for each value of p very strong additional constraints on recursive functions coming from p-adic continuity and differentiability. p-Adic differential calculus would be possible for the p-adic completions of integers and could profoundly simplify the classical theory of computation.

Quantum states realize finite measurement resolution themselves

Conceptualization means hierarchies and one can say that TGD Universe performs this conceptualization for us! In fact, one can say that quantum state provides its own description. This implies that finite measurement resolution is not a property of description of quantum state but of quantum state itself! For instance, the larger the number of partonic 2-surfaces and string world sheets is, the better the "half-discretization" of 4-D space-time surface by these 2-surfaces is, and the more precise is the conscious experience of system about itself. For instance, magnetic flux tube networks with flux tubes accompanied by strings and with maximally entangled at the ends of nodes would give rise to a universal proprioception. The experience about 3-space would emerge from entanglement rather, not the 3-space as some colleagues fashionably argue.

Simplicity in cosmology

This extreme simplicity is most dramatic in cosmology. The microwave temperature is essentially constant. This cannot be due to the causal interactions but reflects something deeper. Inflationary scenarios are one attempt to explain this but have not led to a breakthrough. A more radical explanation is that macroscopic quantum coherence even in cosmological scales is possible at the space-time sheets of cosmic size scale with large value of Planck constant characterizing phases of ordinary matter behaving like dark matter. The key idea is generalization of point-like particle to 3-surface: particle and 3-space are one and same thing. Particles as 3-surfaces can have even cosmological size.

Deep learning neural nets could be seen as supporting the idea of computer consciousness is involved and therefore would be encouraging also from the point of view of IIT. In a well-defined sense these systems are intelligent, and one can even make them to mimic free will by using random generators. They are however not intentional and I think that this is the fatal failure. They are like some brain patients with a damaged frontal lobes. These persons are intelligent but cannot intend and realize their intentions in the time time scales needed in say everyday life.

Chapter 7

Questions about IIT

7.1 Introduction

I received a link to a very interesting article by John Horgan in Scientific American with title "Can Integrated Information Theory Explain Consciousness?" [J47] (see `http://tinyurl.com/h7btppb`). Originally IIT is a theoretical construct of neuroscientst Giulio Tononi (just Tononi in the sequel). Christof Koch is one of the coworkers of Tononi. IIT can be regarded as heavily neuroscience based non-quantum approach to consciousness and the goal is to identify the axioms about consciousness, which should hold true also in physics based theories. The article of Horgan was excellent and touched the essentials and it was relatively easy to grasp what is common with my own approach to consciousness and comment also what I see as weaknesses of IIT approach.

To my opinion, the basic weakness is the lack of formulation in terms of fundamental physics. As such quantum physics based formulation is certainly not enough since the recent quantum physics is plagued by paradoxes, which are due the lack of theory of consciousness needed to understand what the notion of observer means. The question is not only about what fundamental physics can give to consciousness but also about what consciousness can give to fundamental physics.

The article "Consciousness: here, there and everywhere" of Tononi and Koch [J75] (see `http://tinyurl.com/zgm985f`) gives a more detailed summary about IIT. The article "From the Phenomenology to the Mechanisms of Consciousness: Integrated Information Theory" [J60](see `http://tinyurl.com/z9s4k7n`) gives a more techanical description of IIT. Also the article of Scott Aaronson [J68](see `http://tinyurl.com/zarjfzz`) was very helpful in providing computer scientific view about IIT and representing also mathematical objections.

In the article [J60] it is emphasized that IIT is a work in progress. This applies also to TGD and TGD inspired theory of consciousness. Personally I take writing of TGD inspired commentary about IIT as a highly interesting interaction, which might help to learn new ideas and spot the weaknesses and imperfections in the basic definitions of TGD inspired theory of consciousness. If TGD survives from this interaction as such, the writing of these commentaries have been waste of time.

7.1.1 Criticism of the axioms of IIT

Consider first a brief critical review of the axioms of IIT.

Philosophical assumptions

1. Consciousness is regarded as as an intrinsic property of matter like mass or charge. This view restates essentially materialistic world view and its problems are well-known (qualia, free will, intentionality).

2. Panphysicism is accepted. This is quite a big step from neuroscience, which tries to reduce consciousness to a property of brain. The motivation probably comes form the idea that computers might be conscious systems too.

There is no mention of hierarchies although hierarchical structures have turned out to be important also in neuroscience as the success of deep learning programs relying on hierarchies shows. The standard failure of conscious theorists seems to be the assumption that matter is either conscious or not. In physics the notions of scale hierarchies and hierarchies of systems with subsystems with... are standard and this would suggest that also conscious entities form a hierarchy.

Causal evolution and the notion of information

One considers a network and decompositions of system (say brain) into two parts A and B and considers causal evolutions between states of A and B. They could be specified by collections of bits with individual bit telling whether a given neuron fires in given region. A and B could correspond to input and output of computation or to sensory input and motor response (or response at the level of brain in case that there is not motor response (locked-in patient)).

Causal evolutions between A and B are considered: they might correspond to nerve pulse patterns leading from state of A to that of B. One can define information for a causal evolution from A to B as difference of entropies: $I(A,B) = S(A|B) - S(B)$ Conditional entropy for the state of A with that for B subtracted. Φ corresponds to $I(A,B)$ for a pair for which it is a maximum.

One can critizize this view.

1. The precise identification of the network and of states of the network remains unclear. In the case of computers this is not a problem and one can calculate Φ and decide whether a computer running given program is conscious or not.

2. In the definition of Shannon entropy one implicitly assumes external conscious observer and information corresponds to her information gain as she learns what the state of B is. This notion of conscious information circular and identifies the conscious information of system about itself with that of external system about it.

3. Intuitively it is clear that this information is maximal if A and B corresponds to input and output of a deterministic computer program assigning to each input an output such that all outputs are different and $H(A|B)$ vanishes so that a measure for the complexity of the input is in question. To my opinion this tends to restrict the property called consciousness to be property of classical computers.

To make the criticism more precise, one can look at the expression for $I(A,B) = S(A|B) - S(B)$ with conditional probabilities defined by $p(A|B) = p(A,B)/p(B)$. If A and B are independent events that is if the output has no correlation with input as in the case of thermodynamical system, one has $p(A,B) = p(A) \times p(B)$ and one has $I(A,B) = S(A) - S(B)$. Second law tells that the information is negative. In thermal equilibrium $I(A,B) = 0$. Quite a reasonable result.

Intuitively optimal situation is achieved when $S(A|B)$ having interpretation as the entropy associated with the causal evolution is zero: evolution would be completely deterministic as in classical computer programs or quantum computer programs during computation. Therefore classical computer programs, which do not map two inputs to same output would be ideal (the error correction program mentioned by Scott Aaronson) as far as consciousness is involved: this is not surprising taking into account the idea about neuron as bit.

The situation would be optimal for the maximally entropic initial state: this looks admittedly strange. Printing of a page of text about whose content I know nothing would be a highly conscious process! If I knew the content of the page, it would not be a conscious process! Obviously this is true but for me, not the system claimed to be conscious! The circulatory definition of conscious information leads to this non-sensical result. All definitions of conscious information based on ordinary Shannon entropy lead to the same result. One should have genuine definition of information.

Causal networks and the assignment of qualia to the links of the causal network

Causal network is assumed with motivations coming from neuroscience and qualia are assigned with the links of this network. They would correspond to axons or neural pathways in neuroscience.

Also this view can be criticized.

1. The idea that various sensory qualia could be understood in terms of topological structure of a network formed by neurons and and axons is old but has not led to the understanding of qualia. The neural network looks exactly the same in various sensory areas. Also the sensory pathways look the same.

2. Causal interactions between parts of brain are assumed to give rise to consciousness. People having no corpus callosum have synchronous left and right hemispheres [J39] (see `http://tinyurl.com/3gjhtgb`)! One might expect that causal interactions between hemispheres must be responsible for the synchrony. There seems to be something like "boss" forcing both hemispheres to synchrony.

Exclusion axiom

Exclusion states the decomposition (A,B) with maximum of Φ contributes to conscious experience. There would be competion for consciousness.

Exclusion axiom cannot make sense for arbitrary system since it always allows decomposition with maximum Φ. Exclusion axiom also leads to a strange situation if their is also competition between systems of different sixes. The larger one takes the overall system size to be, the smaller the probability of a system with given size to be conscious. A way to escape the situation is to assume hierarchy of consciousness with levels naturally characterized by length and time scales so that one considers systems smaller than given scale at given level.

7.1.2 Comparison with TGD view

TGD inspired theory of consciousness is essentially quantum measurement theory in Zero Energy Ontology (ZEO).

7.1.3 Self as generalized Zeno effect in Zero ENergy Ontology

1. In ZEO physical states are replaced by pairs of states analogous to physical events: the members of state pair are localized to 3-surfaces at opposite light-like boundaries of causal diamond (CD) defined as intersection of future and past directed light-cone and replacing its points with CP_2. Causal diamonds form a hierarchy and this implies self hierarchy with subselves as subselves assignable to sub-CDs. In twistor lift of TGD ZEO and CDs forced by finiteness of the action [L11].

   The assumption that the states having vanishing total conserved quantum numbers and classical charges realizes conservation laws and allows consistency with physics without loss of non-determinism required by free will (subject to constraints of state function reduction). Negentropy Maximization Principle (NMP) is the basic variational principle of TGD inspired theory of consciousness.

2. Self as generalized Zeno effect corresponds to a sequence of state functions leaving the state at "passive" boundary of CD and the passive boundary itself unaffected and changing the state at active boundary and moving it father away from the passive boundary. This shift is quantum process involving localization for the positions of active boundary and reducing to a sequence of discrete unitary time evolutions defining the analog of unitary time evolution in ordinary quantum theory. This shift of active boundary of CD gives rise to the experience about flow of time. The passive boundary gives rise to experience about the existence of permanent self. Subselves as mental images give rise to qualia as their unchanging part.

3. Self dies as the first state function reduction to the opposite boundary of CD is forced by NMP but is predicted to re-incarnate as time reversed self. A possible interpretation for sensory-motor cycle is as sensory mental image and its time reversal identified as mental image assignable to motor action. Motor action would mean sensory input in reversed direction of time at some level of self hierarchy. This conforms with the Libet's finding that conscious decision about motor action is preceded in geometric time by neural activity.

Criterion for consciousness

The notion of conscious self relies on the notion of quantum entanglement to which one can assign information measures.

1. Conscious self would correspond in zero energy ontology (ZEO) to negentropically entangled system at the passive boundary of CD and would not decompose to tensor products of unentangled systems. Selves can be assigned with causal diamonds (CDs), and the simplest option is that CD corresponds to single self. Sub-CDs correspond to sub-selves experienced by self as mental images. This condition decomposes the system uniquely to conscious entities and it is not sensible to ask whether arbitrarily chosen subsystem is conscious or not. Only the state at the "passive" boundary of causal diamond (CD) correspond to self in this sense. The state at the active boundary of CD which moves reduction by reduction farther away from the passive boundary is entangled and one cannot decompose it in this way. Note that self has sub-selves, which represent sub-CDs and these contribute to mental images of self.

2. The notion of many-sheeted space-time is essential. Subselves correspond to smaller space-time sheets "glued" to space-time sheet assignable to self. They represent subsystems but not as a tensor factor as in standard quantum theory based on single-sheeted space-time. The theory of hyperfinite factors allows more general notion of tensor product, and it seems that this kind of tensor product is in question.

   This relates closely to the notion of measurement resolution. Self experiences subself as mental image but the mental images of subself are experienced as an average. This prevents self from drowning to conscious information. Second implication of this notion of subsystem forced by many-sheeted space-time is following: two selves at the same hierarchy level are by definition un-entangled. Their subselves can however entangle to single subself shared as mental image by both. This could be behind stereo vision and "stereo consciousness" and could be essential for communications. Also remote mental interactions would involve stereo consciousness.

The fundamental criterion for consciousness would be therefore formulated in terms of entanglement. At the level of living systems betabolic energy feed would be a more practical criterion to decide whether some living system is conscious at some hierarchy level. Self-organizing systems are systems in which the feed of energy to the system leads to a complex self-organization patterns. Are these systems conscious? Does the feed of energy lead to a generation of negentropic entanglement (NE) and metabolism leading to a dynamics analogous to that in biochemistry (NE is always present in p-adic sectors). Any system has magnetic body (MB, also a new element) and one must consider seriously this possibility. The time scale of this dynamics could be quite slow. Second important factor is the coupling of dark matter at MBs to ordinary matter. If this coupling is small, consciousness does not have much causal power.

Negentropic entanglement as the counterpart of Φ in TGD

In TGD framework information (Φ) is associated with NE for which the sum of number theoretic entanglement negentropies assignable to p-adic primes is maximal [L15] [K45]. The notion of NE and precise formulation of NMP has taken a long time. The recent formulation is in terms of adelic physics combining real number based physics of sensory experience with various p-adic physics of cognition. The key realization was that there is just single number theoretically universal entanglement. In real context it has always non-negative entropy and measures the lack of information of outsider about the system . In p-adic contexts the p-adic variant of entropy can be negative and has interpretation as information and measures the conscious information of system about itself.

1. Both real entropy and its p-adic variants in algebraic extension of rationals defining the coefficients of Hilbert space is used (this is essential and forced by number theoretical existence). In p-adic context the definition of entanglement entropy relies on a modification of Shannon entropy satisfying same axioms as in real case. For given p-adic prime this entropy can be negative and is identified as negentropy associated with entanglement. The superposition of state pairs (a_i, b_i) can be identified as an rules with pairs as instances of the rule. Information

can be said to be in the quantum relationship between A and B - not about A or B. One finds also now the pair for which NE is minimal. State function reduction can occur for this pair and reduce the entropic entanglement or produce more NE.

2. Number theoretical universality is an important additional restriction demanding that the entanglement probabilities in various p-adic sectors are of form $P_i = X_i/N$, where N is the number of state pairs in the superposition and X_i depend only on the algebraic numbers defining the extension having unit p-adic norm but do not involve ordinary p-adic integers and therefore have unit p-adic norm. This implies that the sum of p-adic negentropies is maximal and depends on N only and equals to the real entropy associated with maximal entanglement with $p_i = 1/N$. the sum of p-adic negentropies is not smaller than real entropy and equals to it for rational entanglement $p_i = 1/N$.

Could the paradoxical situation encountered in IIT (printer is conscious when it prints file about contents of which no one knows and unconscious otherwise) make sense in TGD framework somehow?

1. Conscious entity - self - would live in adelic world and would be negentropically entangled subsystem - superposition of several state pairs. Self can be regarded as generalized Zeno effect in ZEO. NMP does allow state function reduction during its lifetime to the passive boundary of CD so that outsider could not learn what it's state is!

2. Real entanglement entropy would describe this missing information and the sum of p-adic negentropies the conscious information posssessed by the self (for rational entanglement probabilities these two measures would have same value). In TGD inspired theory of consciousness the paradoxical statement would thus make sense! Schrödinger cat remains conscious as long as no-one is able to measure the state of cat (note that here dead-alive dichotomy as a metaphor is not good). Conscious systems would be secretive!

The correlation produced by causal evolution in IIT is replaced with NE in TGD. Hence the two views look rather different as far as conscious information is considered. On the other hand, classical physics is exact part of TGD and quantum classical correspondence is realized by strong form of holography (SH). Quantum computation accompanies self and quantum computation is accompanied by a quantum superposition of classical computations. Therefore one can ask whether the generalization of the formula for $I(A, B)$ could be meaningful in TGD and even relate to consciousness.

1. In TGD framework the superpositions of classical space-time surfaces identified as preferred extremals connecting the positive and negative parts of zero energy states at opposite boundaries of CD define the counterparts of causal evolutions. Quite generally, classical deterministic evolution is highly analogous to a classical computer program.

2. The analog of $I(A, B)$ in TGD could be assigned with the evolution zero energy state based on time evolution of the space-time surfaces: A and B would correspond to the positive and negative energy parts of states at opposite boundaries of CD (initial and final states of classical time evolution) defining self. B would correspond the passive boundary of CD and A to the active boundary, which moves farther from B during the reduction sequence and states at it experience a discretized variant of unitary time evolution. The evolution for the active boundary of CD is the analog of unitary Schrödinger evolution and analogous to quantum computer program.

   Note: In TGD framework quantum theory is purely classical theory formally! WCW spinor fields representing zero energy states are indeed purely classical spinor fields formally. Only state function reduction is something genuinely quantal.

3. $S(A|B)$ could be interpreted as entropy generated by evolution analogous to classical computation. The time evolution however fails to be strictly deterministic and particle reactions represented topologically in terms of generalized Feynman diagrams would naturally relate to this non-determinism. Hence $S(A|B) > 0$ is expected to hold true and could be very much like entropy generated by particle decays and creation and the interpretation in terms of thermodynamics would be natural.

4. The very existence of self thus breaks second law (note however that state function reductions occur for sub-CDs assignable to mental images which die and are reborn). As self dies, thermodynamical entropy increases since this reduction is non-deterministic. On the other hand, new time-reversed self is born and carries NE and there is negentropy gain by NMP [K45]. Second law holds true in time scales longer than the life time of the long-livest self. $I(A,B) > 0$ could be thus assigned with selves during their life-time. Since the state function reduction to the opposite boundary of CD is non-deterministic, the conjecture that $I(A,B)$ equals to negentropy gain in this reduction, does not make sense.

5. The definition of $I(A,B)$ is non-trivial problem and discretization implied by finite measurement resolution at fundamental level is necessary in order to avoid mathematical difficulties in the case of deterministic evolution.

The counterparts of networks in TGD

In TGD framework the networks emerge naturally as networks of magnetic flux tubes [L15].

1. The "boss" forcing the synchrony of disconnected left and right hemispheres would be magnetic body (MB) of brain [L18]. Magnetic bodies appear in all scales. NE between nodes of this network is what is more significant.

2. The so called tensor networks [B11] [L12] (see `http://tgdtheory.fi/public_html/articles/tensornet.pdf`), which have emerged as realizations of error correction codes in quantum computation and realize holography can be seen as a realization of NE. One can say that each node is unitary in generalized sense and that the nodes at the ends of lines are unitarily entangled. The realization in terms of magnetic flux tubes could define kind of template for the dynamics of bio-systems. Magnetic body (MB) would define both geometric and dynamical template for bio-chemistry and even genetic code could be reduced to this level. MB would extend the organism-environment duality to trinity. It has been proposed that entanglement between the nodes leads to the emergence of 3-space. What would emerge in TGD framework would not be 3-space but proprioception - conscious experience about 3-space. These networks would define "magnetic spine" of an organism.

3. The dynamics of MB (motor actions of MB as reconnections, contractions of flux tube, changes of the topology of the network inducing NE transfer) and also the dynamics at MB (supra currents, dark photons propagating along flux tubes in targeted way) would define the analog for the causal dynamics appearing in IIT. ADP-ATP transition attaching phosphate to ADP has interpretation as transfer of NE. Phosphate-X (X some large system) flux tube is attached to ADP to give ATP-X NE and when ATP gives phosphate to bio-molecule Y one obtains Y-X NE (for what Y could be, see below). Metabolic energy could go basically to transfer NE between systems. This would mean that the local dynamics of the network would be central for what it is to be living.

4. This picture would suggest that the changes of topology making possible transfer of negentropy are crucial for consciousness in living systems. Dynamics of bits in static networks represents only the classical communications associated with genuinly quantal system.

Bio-photons identified as decay products of dark photons with large value of Planck constant h_{eff} is an essential element of resonant like precisely targeted communications along flux tubes of MB. It must be made clear that TGD has had an interpretational problem related to the identification of bio-photons as decay products of dark protons [**?**, K58]. The resolution of this problem leads to conclusion that MBs with field strengths assignable to Earth's *resp.* galactic magnetic fields control living matter and have EEGs related by scaling: for details see [L15].

What the mysterious looking entity X could then be?

1. The MB of Earth assignable with Earth's mass via $h_{eff} = h_{gr} = GMm/v_0$, where v_0 is a parameter with dimensions of velocity, is the first candidate for X but for it EEG would be scaled down since the flux tubes would correspond to those of galactic magnetic body with $B_{gal} \sim 10^{-9}$ Tesla: 10 Hz alpha band would correspond to 72 minute time scale and natural periodicity would be given by sidereal day.

2. What puts bells ringing is that Spottiswoode observed that sidereal day defines periodicity for precognition [J48]. A mass $M_D \simeq 5. \times 10^{-5} M_E$ forming a spherical layer at the distance of Moon from Earth associated with the magnetic Mother Gaia controlling bio-dynamics would correspond to the ordinary EEG. This would also predict that 1 s cyclotron time for DNA sequences in $B_{end} = .2$ Gauss corresponds to 12 h cyclotron time for $B_{gal} = .63$ nT.

The presence of these two MBs be a dramatic manifestation of non-locality and profoundly change neuroscience views about consciousnes. These MBs would make life possible at Earth. 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 their 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.

Qualia in TGD framework

In TGD the qualia correspond to the eigenvalues assignable to the observable measured during repeated state function reductions leaving the states at the passive boundary of sub-CDs representing mental images of self invariant. Non-locality and new view about time allows to consider also the possibility that qualia can be assigned with the sensory organs [K30]. One cannot of course exclude the possibility that also neurons can have primary sensory experiences rather than just sharing the primary sensory mental images assignable to the sensory organs.

Sensory qualia reduce in principle to quantum numbers assignable to the maximally commuting set of observables, which in turn would reduce to Cartan algebra for the Lie algebra of symmetries. This algebra is infinite-dimensional in TGD framework since the mathematical existence of the theory demands maximal possible symmetries at the level of "World of Classical Worlds" (WCW). If this view is correct, sensory qualia would be universal.

Panphysicism in TGD

Pan-physicism is basic prediction of TGD approach. Entire hierarchy of selves is predicted. The mental images of self are identified as subselves and there is p-adic length scale hierarchy defining a cognitive hierarchy and hierarchy of Planck constants $h_{eff} = n \times h$ defining a hierarchy of dark matters. Our mental images correspond to conscious entities and we ourselves are mental images of higher level self. The hierarchy of space-time sheets of many-sheeted space-time is essential element and lost in the GRT-gauge theory limit of TGD. One can say that length scale reductionism is replaced with fractality.

This kind of scale hierarchy would immediate allow to answer quastions like "Is cerebellum conscious?" and "Are we conscious during sleep?". The answer would be "yes, but in different scales than brain in wake-up state". The duration of mental images of cerebellum would be measured in perhaps milliseconds. The conscious motor actions of cerebellum would correspond to fine details of motor actions. During sleep absence of sensory input and motor output would mean that corresponding mental images are absent. In TGD framework this alone explains why we do not have memories about sleep periods!

7.1.4 Are the following questions addressed in IIT?

There are many questions, which the articles about IIT that I have seen does not address.

1. What directed attention means in IIT? Could one assign this to a link of network?
2. What, if anything, free will means in IIT?
3. What intentionality means in IIT? Can computer behave intentionally?
4. What could serve as correlate of cognition?
5. Why metabolism?
6. Why EEG?

TGD answer to some of these questions can be found from [L15]. For a more detailed TGD based criticism of IIT see [L19].

7.1.5 Some abbreviations

In the sequel I will answer the questions raised by Lian Sidoroff about IIT, by Patrizio Tressoldi about intention and energy, and by Ben Goertzel about IIT and possibility of post-quantum physics.

To help the reader I list some abbreviations to be used in the sequel. Zero Energy Ontology (ZEO), Causal Diamond (CD), World of Classical Worlds (WCW), Strong (Form of) Holography (SH), Negentropy Maximization Principle (NMP), Negentropic entanglement (NE), Magnetic Body (MB), Biological Body (BB).

7.2 Questions about IIT, remote mental interactions, intentionality, and need for post-quantum theory to describe consciousness

In the following are my TGD inspired responses to the questions posed by Lian Sidoroff - mostly about IIT and remote mental interactions, to the questions of Patrizio Tressoldi related to the notions of intentionality and energy, and to the questions of Ben Goertzel about IIT and remote mental interactions and possible need for post-quantum physics to understand consciousness. I do not copy below the full questions of Lian since they would take too much space. The chapter about non-locality in TGD framework [L15] summarizes TGD bakground. I have also written about two chapters related to IIT [L19, K76].

7.2.1 Basic TGD based criticism of IIT

IIT in its basic form seems to regard consciousness and life as rather independent properties of system. For computers the value is maximal when the output of program distinguishes between all inputs and - rather counter-intuitively - if the entropy of the initial state identifiable as lack of information of the external observer about the state of system is maximal.

It is of course an open question how many common properties conscious and living systems share but my intuitive view is that life is prerequisite of intelligent consciousness able to receive information about environment and react to changes in it. Also the TGD view about self implies that conscious system eventually dies and is living in this minimal sense not yet implying genetic code. One could therefore test the street plausibility of IIT by evaluating Φ reliably for some system and finding whether other plausible signatures of consciousness familiar from living systems are present when the value of Φ is high.

There is a long list of such signatures: abilities to self-organize under energy feed, to attend, to intend, and to respond via sensory-motor loop, behavior suggesting free will and cognition,... At the physical level there is metabolism, EEG, biochemistry involving bio-catalysis, perhaps even some kind of genetic code at level deeper than chemistry, replication, etc...

To my opinion, IIT would be very natural description of consciousness if AI systems were conscious. These systems perform algorithms written by programmers. So called deep algorithms with many hierarchical levels have been unexpectedly successful: this has been seen as a message that the physical Universe is in some sense very simple and has natural hierarchical structure (see `http://tinyurl.com/hz2jp8z`). These programs can even rewrite themselves but also this is based on program written by a programmer. In a well-defined sense these systems are intelligent, and one can even make them to mimic free will by using random generators. They are however not intentional and I think that this is the fatal failure. They are like some brain patients with damaged frontal lobes. These persons are intelligent but cannot intend and realize their intentions in the time time scales needed in say everyday life.

7.2.2 Questions by Lian Sidoroff

Responsiveness

Q1: How do we define consciousness phenomenologically? Could responsiveness serve as a signature of consciousness?

The motivation for the question comes from Aaronson's observation that a system doing mere parity check can be much more conscious that human brain if Φ is used as criterion. To my opinion Scott is quite right. Something is missing from IIT: Φ cannot serve as sole criterion for what it is to be conscious. The following considerations are strongly TGD centered reaction to the idea.

1. Responsiveness means essentially motor action induced by sensory input. The problem is that any system responds to perturbations. For instance, computer programs can respond by learning and can even by rewriting themselves. I would not conclude from this that the computer running this kind of program is conscious. To my opinion one should characterize what the responsiveness of conscious system does mean.

   Perhaps it could mean response, which is somehow unexpected. Say, my PC doing something that it is not programmed to do. Or a response of a computer network in a scale much larger than one would expect to a perturbation that the system is not programmed to notice at all. In TGD framework it would reflecting non-locality involving essentially entanglement in long scales.

2. Conscious response requires directed attention selecting some preferred target. Also computers can be taught to direct respond to specific features and this could be called directed attention. What makes the directed attention conscious? That it is directed in an unexpected manner? A computer responding to signals which it is not programmed to respond?

3. Can the system with large Φ direct its attention? To my TGD inspired opinion the change of the topology of the network occurring by state function reductions in appropriate scales is absolutely essential for directed attention. At given level of hierarchy it has interpretation as changing focus of attention. Φ is defined for a fixed network. I see this as a problem (, which might be easily removable).

   At the fundamental ATP level directed attention corresponds to the transfer of NE involving the change of topology of network in molecular scale: this would be responsiveness in molecular scale. Metabolic energy is needed to make possible NE transfer and therefore the rate for the use of metabolic energy looks like a reliable criterion for being consciousness. The axiomatics of IIT seems to miss this aspect totally.

   Also general self-organizing systems involve feed of energy. Are they conscious and in what time scale? Is this time scale too long/short for human observer? Could general self-organizing systems have motor actions as reactions to stimuli?

4. In TGD Universe response involves sensory message to MB and the message inducing motor action sent as signal in reverse time direction. In ZEO this corresponds to a state function reduction to the opposite boundary of sub-CD in which subself "dies" and reincarnates as time reversed self. This time reversed subself corresponds to a signal to geometric past, which initiates neural activities (Libet's findings find explanation). Besides responsiveness and intentionality can be seen as a characteristic of consciousness and I find difficult to see how a computer with large Φ could have it.

   I would thus argue that conscious response involves the time reversed reaction (creation time reversed subself) giving rise to motor action allowing to distinguish it from the response of a non-conscious systems.

5. Locked-in patients are conscious but have no motor activities so that the naïve behavioristic dogma fails. To be responsive in TGD Universe it is however enough for MB to respond by generating a control signal, which would normally induce neural activities leading to a motor response but remain now only an imagined motor action (maybe). This cannot happen for locked-in patients but does not mean that the patient is unconscious since there would be

reaction also at neuronal scale. Could general self-organizing system or even computer have MB carrying dark matter as $h_{eff} = n \times h$ phases, which reacts and responds but the response is not visible to us because we are not yet able to observe dark matter?

To my opinion responsivity is only one signature of consciousness. The ability to intend and realize intentions, and free will reflecting itself as a non-deterministic behavior, are additional criteria. In TGD Universe one cannot talk about systems which are conscious but dead and I tend to believe that this is true universally. Living systems self-organize and presumably so also conscious systems.

MB is essential piece of the story about living conscious systems in TGD framework. EEG and its variants in various scaled up frequency ranges make possible communications between various onion like layers of MB and biological body (BB) using dark photons. It looks natural to assign to a conscious and living system MB carrying dark matter matter as $h_{eff} = n \times h$ phases making the system macroscopically quantum coherent: this would make possible for the system to generate macroscopic quantum entanglement and behave like a single coherent unit.

1. Can one assign scaled variant EEG to systems like ant nest or bee flock, or even Internet. Could one measure the analog of EEG experimentally?

2. In human EEG there is clear decomposition to quasi-stationary periods of duration of order .3 seconds (roughly) separated by sharp transition periods (see [J31] and [L2]). These could be identified as correlates for mental images as sub-selves. Could one distinguish between the EEG counterparts of subself and its time-reversal? If one can identify the analog of EEG for say ant nest, could one identify also these correlates of mental images of ant nest?

Could one use these criteria tell whether classical computer is conscious?

1. There is energy feed but can one say that computer is self-organizing system? The defining feature of classical computer is that it has fixed circuitry and it does just what the program tells it to do: this does not look like self-organization. There are programs able to rewrite themselves but also these are based on programs.

2. Could classical computer have MB, which self-organizes and can act as intentional agent and therefore force the computer to do something original?

3. Could classical computer have something analogous to EEG? Is classical computer like locked-in patient? If one requires also NE, it seems that the idea about classical computer as a conscious entity can be forgotten unless one regards life and consciousness as completely independent phenomena.

4. Could the two big MBs (assignable to Earth and galaxy) come in rescue and blow spirit to the classical computers? Maybe but this spirit might not have anything to do with the computation running in it.

In the case of quantum computers situation changes in TGD. Self can be in very abstract sense be seen as a quantum computer program, which runs as long as generalized Zeno effect lasts and dies when the program halts. What is new is the reincarnation as time-reversed self making possible computation able to overcome the standard limits for ordinary computation and computation not possible in standard positive energy ontology could be carried in ZEO in finite time.

Network perturbation as variant of responsivity

Massimini [J35] has suggested a kind of microscopic variant of responsivity. Perturb brain directly by say transcranial magnetic perturbation and find whether there is a response in the scale of brain. Massimi found that TMS perturbation allowed to distinguish between sleep and awake states. This option would apply also to locked-in patients and looks rather reasonable. Again one must however remember that also the scale matters. Part of brain could allow consciousness in some scale and this scale could be rather small, even that for single neuron or pair or neurons connected by axon.

Q2: Could sensitivity to network perturbations be scaled to GCP network. Could it be possible to wake it up in major global events such as catastrophes and could this wake-up state be detected?

A: Perturbation would be now a major global event. GCP includes also the users might be essential so that one could not regard GCP as independent conscious entity. The connections in the network are dynamical in the sense that two participants can be connected or not and in this sense this brings in mind biomatter. TGD framework also MB of this network would be responsible for reacting to global stimulus and possibly inducing some synchronous reaction visible in the entire network but I would suspect that one cannot treat the network as separate.

Integration

Q3: Where does Remote Viewing perception fall on the spectrum of consciousness? Where does intent/target focus fit in this AIM (Hobson)/IIT (Tononi) phase space and what kind of influence does it exert on the state of consciousness?

A: Lian argues that the perception of RV viewed target is something very different from that postulated in IIT. This difference could reflect also the fact that RV percept is gradually evolving. Ordinary percepts are stimulated by waking up already existing standardized mental images.

Stereograms could provide a good analogy for how RV evolves. The stereograms contains a lot of wrong cues and if you direct attention to these details you are lost. There is however a method: look at the picture very near so that you are not able to direct your left-brainy attention to the details and suddenly with the help of your holistic right brain you see the beautiful 3-D picture! After than you can fill in the details.

This process means an emergence of totally new mental image, discovery, and I think that what people are achieving in science now and then is just this. Interestingly, a 40 Hz peak in EEG accompanies the ermgence of the 3-D picture [J16]. It accompanies also the transition to a meditative state. The elimination of small scale details is essential part of the process and meditative practices do this.

Here the weakness of IIT in its static form becomes obvious. What would be needed is emergence of a totally new kind of network pattern. This experience cannot be described assuming a fixed network: computers do not have enlightenment experiences. In TGD this would mean emergence of new negentropically entangled subsystem in state function reduction to opposite boundary for some sub-CD.

Note that the integration of conscious experience corresponds naturally to NE in TGD framework.

La Bete

Why are spontaneous non-local conscious phenomena (telepathy, precognition) associated with meditation and dreaming? The absence of sensory and motor component in conscious experience would not mask the mental images involved with remote mental interactions. The explanation for the emergence of stereogram could also help to understand. One develops holistic view getting rid of details and is able to see the big picture. Ability to see in given resolution is also an implication of the scale hierarchy for conscious entities.

a) Could one test non-locality in long scales?

LS mentions examples about non-locality in remote mental interactions. Persinger *et al* have published a lot of articles related to biophotons, EEG, and long length scale entanglement between brains. See for instance [J36, J37, J38]: for TGD interpretation see [L3].

Spottiswoode found evidence that the probability for the occurrence of precognition is maximum at a fixed hour of sidereal day [J48]. On the other hand, the condition that the cyclotron frequencies for h_{gr} assignable to Earth mass correspond to the energy scale of bio-photons requires that the flux tubes of galactic MB with $B_{gal} \simeq .36$ nT mediate the gravitational interaction of Earth.

This implies that the cyclotron frequency 10 Hz for "endogenous" dark magnetic field .2 Gauss is scaled down by factor 5×10^{-5} and corresponding time scale is 36 minutes. EEG time scales in the range 1 s -.01 s correspond to a scaled up time scale range 7.2 min - 12 hours -

typical time scales assignable with daily conscious activities. Ordinary EEG would correspond to h_{gr} assignable with a mass shell at distance of Moon for which there is also other evidence [K58]. Also this is a rather dramatic prediction.

The existence of a scaled down variant of EEG in this frequency range in the em spectrum of brain could be tested. The crucial test would be whether the day associated with this EEG is sidereal day (mean duration is 23 hours, 56 minutes, 4.0916 s) rather than solar day. The rotation period of Earth around galactic center is 26,000 years: could this period reflect itself as a periodic modulation in the evolution of human consciousness? Milankovic theory for ice ages involving also the rotation around galactic nucleus predicts 21,000 year astronomical periodicity giving the period for the occurrence of ice ages (see `http://tinyurl.com/qhnzt5r`). This could provide very concrete reasons for the modulation.

Q4a:: Can we test the IIT hypothesis on a nonlocal scale - and thus break free of the neuro-centric definition of consciousness?

A: I would ask can one test non-locality, which as such does not provide support for IIT, which relies still physicalistic picture about consciousness as a property of physical system.

b) Complexity,telepathy, power amplification, a replicate of RV

Lian suggests a detailed protocol for an analog of RV experiment testing various aspects of non-locality but to my view it tests non-locality but not IIT.

A very brief summary of the experimental protocol proposed of Lian goes as follows. The experiment involves 8 different stimulations of 4 mouses A,B,C,D and mouse F not familiar with other mouses and without any stimulation. For A,B,C,E but not D the stimulation involves stimulation of fear circuit. For A,B,C,D but not E also the image of cat is shown. Also the image of some other mouse is shown; A sees B or C; B sees A, C sees A; D sees E; E siis B. This stimulation creates a associations fear-presence of cat- presence of some other mouse for some sub-association of this. Mouse C is activated in additional manner strengthening the fear-cat-mouse A association. The reactions of other mice are monitored as one of them, mouse A, is isolated from others receives a stimulus activing the fear circuit.

Q4b: Telepathy. Is the fear transferred telepathically to the mouses and does it induce also the associations? There are also subquestions.

Q4c: Power amplification. Will repeated application of the experimental stimulus (power amplification) increase/ broaden the activation at the receiver's end?

Q4d: Replica of RV. One encloses mouse B generating fear association in mouse A to a black box. If mouse A is able to remote view the presence of B in the box, the fear circuit should activate. Does this occur? What if mouse C with larger association basin is in the box. Is the telepathic effect stronger?

A: My own answer to the questions is in general affirmative if the telepathic communication really occurs. I dare not predict whether it does!

This experiment would test non-locality of consciousness but it is not clear to me whether this test can provide evidence pro or con IIT.

c) Is sleep conductive to nonlocal network activation?

A similar experiment could be run with any dreaming mammals to test the effect of particular brain states on facilitation/ inhibition of these nonlocal resonant loops and the ability of the ensuing "dynamic coalition of adaptively resonant populations of neuron" to reach conscious dominance,

Q4e: Would activation of fear at the "sender mouse" while the receiver is in various sleep stages (nREM S2, S3-4, REM) result in more rapid/ more powerful activation at the receiver's end?

If metabolic energy interpreted as energy going to re-orgnized network connections, metabolic energy does not go during sleep (rather than dreaming) to the build of mental images related to sensory and motor activities, and must go to something else and building up and activating of network connections in longer length scales would be natural target. EEG is indeed concentrated to theta and below which would mean that the scale of the layers of MB involve would be roughly 4-10 times longer (1-4 Hz dring sleep) than usually (10 Hz). The four states of sleep would correspond to different length scales for MB. Activation would mean that cyclotron radiation and generalize Josephson radiation generated in neuronal neuronal membrane proteins acting as generalized Josephson junctions propagate along flux tubes. A possible interpretation for MB would be as counterpart for the third person aspect of consciousness.

What the telepathic activation of sensory and fear circuits during sleep could the mean? The natural guess is that it wakes up some sensory areas and by association fear circuit so that one would have analog of REM sleep manifesting as the activation of higher EEG bands serving also as signature for the telepathic response.

Is Φ dependent on brain's phase space - can the brain alternate between classical and quantum computational modes?

Q5a: What role do you think microtubules play in gating and reshaping brain computational patterns?

A: I see microtubules as one layer in the self hierarchy and proposed for about two decades ago a vision in which microtubules act as quantum antennas [K55] sending and receiving signals and performing frequency modulation by modulating their lengths.

I have also considered a model of microtubules inspired by the findings of Bandyonophyay *et al* [J44]. This model [L10] leads to rather concrete ideas about aromatic rings as basic units of molecular consciousness and would explain why aromatic rings are so important (contained by all DNA nucleotides and by some amino-acids and typical for neuro-active molecules such as psychdelics [L7]).

External AC perturbations of microtubules at critical frequency would induce what I have interpreted as a quantum phase transition between two configurations A and B of microtubules: only the configuration B for which helical symmetry is broken is observed in laboratory (objection against Penrose-Hameroff hypothesis) but the configuration A with helical symmetry would be created in this phase transition increasing h_{eff} and quantum coherence length as helical symmetry suggests [L10].

Quantum criticality is in accordance with the general vision about living systems as quantum critical systems and would make possible large h_{eff} phases and dark photons with energy scaled up by h_{eff}/h so that it is above thermal threshold - perhaps in the range of bio-photon energies - and can induce molecular transitions. Topological quantum computations [K2] involving braiding of the flux tube connections between microtubuli and axonal membranes such that nerve pulses induce re-braiding as a kind of memory representation can be also considered.

The second question concerns the roles of classical and quantum computations for brain. Brian Millar has suggested that the brain contains both classic and quantum computational functions. The fact that nonlocal conscious interactions may and do occur superimposed on routine diurnal consciousness (the operator in a typical RV session is a perfect example of such a superimposition of rapidly alternating states or computations activities; spontaneous telepathy has been reported in both nocturnal and diurnal contexts; and studies of distant mental interactions with living systems, including human receivers, do not require the target to achieve any particular mental states, although many operators find it more effective to go through a cool-down or meditative phase at the beginning of the session) suggests that both of these computational processes occur simultaneously – however, in the highly competitive environment of brain activity, it may be that the power of such alternative (possibly MT-mediated) resonant circuits may remain below the threshold of awareness under most circumstances, being brought into the spotlight only by deliberate suppression of classic neuronal activity, coupled with the power amplification derived from persistent target focus. The question is following.

Q5b: Could there be a connection between the effects of slow wave sleep and meditation on the global gating configuration of the brain - perhaps leading to a reshuffling and eventually more favorable, more "sensitive" quantum computational state - whether based on MTs or another interface (Millar's quantum brain)? Could circadian rhythms play a role in such a daily balance between classical and quantum brain computational modes?

A: Before answering the question some background.

1. I would not see classical and quantum computations as alternatives. Self represents quantum computation like process having analogs of quantum and classical computation as its aspects, which could be also seen as dual representations in the sense of holography. Here I however understand with classical computation something much more general than that occurring in my PC.

2. MB and braiding of flux tubes makes possible quantum computation type activities: quantum computation in standard sense is probably quite too restricted metaphor. Classical computation in the sense as I understand it, is even more dangerous metaphor. Classical computationalism involves many assumptions, which seem to guarantee that ideal computer is un-conscious: the notion of memory storage and deterministic program represents too such notions. In TGD framework there are no files in which data would be stored [K70]. There is no deterministic classical program running in brain.

3. I would compare self as a generalized Zeno effect to a quantum computation, which halts as self dies and reincarnates at the opposite boundary of CD and a new quantum computation proceeding in opposite direction of clock time using the wisdom gained as NE is performed (the temporal distance between tips of CD increases all the subjective time). Each mental image would be kind of quantum computation and repeated re-incarnations might make it possible to overcome the usual restrictions on what one can do in finite time [L16] (see `http://tinyurl.com/jpzd6xq`).

4. The space-time surface connecting initial and final 3-surfaces at the boundaries of CD would define classical time evolution analogous to classical computation serving. More concretely, the dynamical time like braiding of flux tubes (dance metaphor) would generate a space-like braiding (think of dancers with threads from the feet to wall: dance is coded to a memory about the dance) [K2].

5. One would have quantum superposition of these space-time surfaces and it would represent self-organization pattern in 4-D sense. The state function reduction sequence during the life period of self would lead to asymptotic pattern. A space-time representation for function, skill, or memory understood as learned skill would be in question. The experiments with flatworms [I17] demonstrate that the both ends of flatworm can inherit the memories in this sense: the replication of MB could explain this [K62]. The classical space-time surfaces have therefore several interpretations: as space-time correlate for intentional action, behavior, function, classical computation, etc...

The dominance of slow wave EEG during sleep would mean that magnetic bodies with weak magnetic fields and larger size roughly defined by the wavelength associated with EEG frequency would dominate. These would correspond to more non-local and more abstract conscious information and information processing. The difference to daytime situation would be quantitative: the spatial and time scales would be longer.

The absence of sensory input during both meditation and slow wave sleep would give for MB a more pronounced role. It can use brain for its purposes and probably does so since brain uses metabolic energy also during sleep and is conscious in some, probably different scales that at day-time. What could be those purposes? Do we entangle with other brains perhaps and give rise to entangled self formed by the sleeping brains - representing perhaps "human condition"?

Φ and Ueber-Φ

Q6: How do you see the interplay between the consciousness of Self and the ability to participate in such nonlocal conscious phenomena in terms of Phi?

My answer reflects by belief system. This may sound dogmatic but I just cannot take Φ as the solution to the riddle of consciousness for the reasons that I have explained. Therefore I am unable to answer the question.

7.2.3 Questions by Patrizio Tressoldi

There are actually two questions by Patrizio Tressoldi related to intentionality and energy.

Q7a: Is it possible to measure the "mental energy" underlying both local and non-local mind-matter interactions? Is it also possible to investigate the characteristics of these interactions, e.g. do these interactions look like a single shot or like a long-lasting wave of energy? Could this line of investigation shed light on the basic "stuff" of our mind?

What has been observed by Tressoldi *et al.* (in press) after one pilot, one failed and one positive replication can be summarized as follows: mental entanglement (ME) at distance with a photomultiplier reveals its effects by increasing the bursts of photons exceeding by more than 6σ the average count, corresponding to bursts with more than ten photons. In other words, it seems that ME effects correspond to very fast bursts of light of approximately 20 photons/sec equivalent to an energy estimated in 65 eV, at approximately 788 THz, a really non trivial energy. Furthermore, these effects seem to appear even after a delay of approximately 35 minutes.

A: My view is that remote mental interactions involve both quantal and classical aspects. Classical aspect requires a contact of magnetic bodies of the two systems by reconnection - correlate for directed attention. Classical signals would propagate along the flux tubes connecting the two systems. Reconnection would occur for instance in experiments of Persinger's group involving rotation magnetic fields and bio-photons discussed in [L3]. Reconnection is made more probable if the magnetic field of either system or both is dynamical, say rotating. After the reconnection classical dark photon signals would flow between the two systems, and also supra currents of say dark electrons are possible. Classical signals require metabolic energy. For instance, EEG would correspond to this kind of communications between biological and MB and the dark photons with $h_{eff} = n \times h$ of EEG would have energies in the range of bio-photon energies.

Teleportation can be seen as communication - in particular communication of mental images - and requires also classical communication. Could maximally entangled subsystem representing mental image be teleported without destroying the original mental image? No-cloning theorem tells that complete cloning is not possible for a general quantum state. There are however exceptions: a quantum state with maximal entanglement can be cloned (see `http://tinyurl.com/h48qjp8`). Maximal entanglement - entanglement probabilities are identical - corresponds p-adically to maximally negentropic entanglement. Maximally negentropic entanglement is p-adic notion (cognition) and much more general than maximal entanglement. Is it possible to clone also it?

Q7b: Human (external qi) intention is a form of information. There are many reports on this. The first few white papers by William Tiller are interesting (see `http://tinyurl.com/j5xyjn8`).

What if intention is simply thought-like energy? See our study "*Can Our Minds Emit Light at Distance? A Pre-Registered Confirmatory Experiment of Mental Entanglement with a Photomultiplier*" in press in Neuroquantology (see `http://tinyurl.com/h4eoxgw`).

A: I identify energy as a physicists and what comes in mind is metabolic energy. I see metabolic energy as a prerequisite for intention but cannot identify it as intention. Intention has inherent directedness but energy as a notion does not have it. My own proposal is based on ZEO in which zero energy states have as correlates (quantum superpositions of) space-time surfaces connecting 3-surfaces at past and future boundaries of CD. Zero energy states are asymmetric with respect to the exchange of boundaries. The state at other boundary is reduced and unaffected during the sequence of state function reductions as also this boundary. The state at other boundary changes and also the boundary shifts farther away. Zero energy states would be by their directedness natural correlates for intentions and space-time surfaces could represent the classical space-time correlates of intentions. They can be seen also as correlates for functions (in biological sense) and behaviors.

7.2.4 Questions by Ben Goertzel

The first question of Ben Goertzel relates to IIT. The remaining questions are subquestions inspired by a general question "*Is recent quantum theory enough?*".

Could integrated information help to undersand Psi phenomena?

Q8: Could looking at integrated information on the quantum level (or in the context of some extension of current quantum theory) yield insight regarding Psi phenomena? Might there actually be subtle integrated information spanning systems that are currently thought of as "disentangled" from each other? Could this provide the foundation for some sort of "universal consciousness"?

Answer: As I have already explained, I do not see the measure for integrated information as internally consistent. In TGD framework integrated information is replaced with entanglement negentropy. Negentropic entanglement (NE) in large scales is an important aspect of remote mental interactions since it binds conscious entities to larger conscious entities temporarily and is central element of directed attention and also of remote mental interactions which do not differ in any radical manner from those occurring between MB and BB. In this framework consciousness and even cognition are universal.

Post-quantum physics?

Q9. Supposing that some sort of non locality going beyond what is allowed in classical physics is required to explain Psi phenomena - is quantum theory actually enough? Or do we need some broader form of non locality? If so, what additional aspects must the non locality needed to explain Psi possess?

A: To my opinion the prevailing quantum theory is not enough.

1. To develop a new theory it is best to start from a problem of old theory. The basic problem to start from is now quantum measurement theory. The identification of experienced time with the geometric time and therefore of the corresponding causalities leads to the basic paradox and to the plethora of "interpretations" trying to overcome the problem. In TGD framework zero energy ontology (ZEO) allows to overcome the paradox. ZEO predicts also temporal non-locality and by holography 4-D dynamical patterns become basic physical objects as they indeed are in biology and neuroscience.

2. The non-locality in ordinary quantum mechanics has no classical (geometric or topological) space-time correlate. The non-locality at space-time level emerges in TGD framework from the replacement of point like particles with 3-D surfaces (or pairs of them at opposite boundaries of CD. Particle is classically space-time quantum, one might say. This allows to understand classically non-locality as it appears in EPR and also in remote mental interactions: magnetic flux tubes serve as a geometric correlate for entanglement so that situation ceases to be so "spooky".

   At the level of WCW one has locality. Apart from state function reduction the theory is even classical formally: WCW spinor fields are formally classical free spinor fields satisfying the analog of massless Dirac equation realized as a generalization Super Virasoro conditions familiar from super string models and expressing generalization of conformal invariance.

3. Quantum consciousness theories demand macroscopic quantum coherence but standard quantum theory does not give much hopes about this: Planck constant is too small. The anomalous quantal effects of ELF em fields on vertebrate brain led originally to the idea about hierarchy of Planck constant $h_{eff} = n \times h$ labelling dark matter as phases of ordinary matter. This hierarchy is strongly suggested also by the generalization of super-conformal symmetries in TGD framework gives rise to a hierarchy of quantum criticalities labelled by the values of h_{eff}. The hierarchy would also have a concrete geometric interpretation in terms of the topology of many-sheeted space-time. The latter is possible only if one assumes that space-times are representable as 4-surfaces.

Q10: Will the standard "scientific method" as now practiced and understood (involving gathering empirical data that is considered as "provisionally true" in an objective sense, and validated as such by members of the scientific community) be adequate for understanding Psi phenomena? Or might an understanding of Psi phenomena require a shift to a new understanding of science, involving a more radical subjectivity, a more relational interpretation of observations or — something else?

A: I believe that this not the case. I believe that remote mental interactions as also those crucial for living matter are quantum critical phenomena. This makes it difficult to replicate the experiments. First of all, the experimenter must know that a critical system is in question. If dark matter indeed corresponds to large h_{eff} phases generated at criticality, the attempts to detect dark matter identified as some exotic particle are bound to fail and have indeed failed. Dark matter could be detected only transforming it to ordinary matter or vice versa and this would occur at quantum criticality. Quantum criticality would also make possible long range correlations and the interaction between experimenter and the experimental arrangement including subject persons in experiments carried out in medicine (interactions between magnetic bodies). Therefore the idea about possibility to completely isolate observer and observed system in principle fails in quantum critical case (TGD Universe is quantum critical meaning that any system is quantum critical in some time scale!).

Q11: Are our current notions of "causation" and "correlation" adequate to understand Psi phenomena? Or need they be extended somehow? If so, how?

A: My belief is that the problems of quantum measurement theory can be solved by distinguishing geometric and subjective time and corresponding causations. The first causation is that of field equations and the latter causation that of free will and can be assigned with quantum jump/state function reduction. This causation replaces superpositions entire geometric time evolutions with new one and this is something new (note however Wheeler's delayed choice experiment). ZEO based quantum measurement theory would be the manner to describe it.

Correlation assignable to geometric time (or between space-time-time points or their generalization to 3-surfaces) is a generalization of that applied in quantum field theories. Correlation have any meaning with respect to subjective time since it does not correspond to continuous coordinate at fundamental level although one can assign to it clock time in ZEO as increasing distance between the tips of CD.

Q12:. Can we make scientific (or some sort of meaningful post-scientific) sense of the notion of a broader universe beyond our physical universe? How does the mystical notion of a world beyond our world, relate to the higher-dimensional aspects of physical reality postulated in modern physics theories? What properties would a broader "world beyond our world" need to have, in order to have useful explanatory value for phenomena we observe in this world, or for experiences we have and report that hint at the existence of realities beyond this physical world?

A:. I see several levels in the geometric hierarchy of geometric objects. Besides space-time surfaces, which are dynamical objects, there is embedding space and WCW, which are non-dynamical geometric objects and dictated by general arguments highly uniquely.

1. The minimal generalization is to keep space-time 4-D but assume that it is 4-surface in a higher-dimensional space-time - call it H - having standard model symmetries and explaining corresponding quantum numbers elegantly. The minimal choice is 8-D $H = M^4 \times CP_2$. The emerging space-time concept - many-sheeted space-time - is topologically extremely rich and leads to new notions like MB and space-time surfaces having interpretation in terms of dark matter as $h_{eff} = n \times h$ phases. MB extends the system-environment double of biology to the triple MB-system-environment and is responsible for most non-trivial elements of TGD inspired biology.

   Also the embedding space H plays a central role. In ZEO also the hierarchy of causal diamonds (CDs) in H serving as correlate for self hierarchy is important and is needed to realize holography and its strong form. The pairs of 3-surfaces with members at opposite boundaries of CD is correlate for (classical) event and WCW spinor field representing zero energy state is the analog of Schroödinger amplitude in this space of classical events. The twistor lift of TGD [L11] requires ZEO and CDs: the action for infinitely-sized space-time surfaces in H would be infinite because of the volume term implied by the twistorial life and identifiable in terms of cosmological constant: for CDs it is finite.

   Strong form of holography (SH) implied by strong for of general coordinate invariance implies that string world sheets and partonic 2-surfaces carry the data needed to construct zero energy states and also space-time surfaces as preferred extremals of Kähler action. They would act as "space-time genes".

   WCW would represent the highest level of hierarchy and has decomposition to sub-WCWs assignable to CDs in their size scale hierarchy with levels labelled by integer characterizing the size scale of CD (by number theoretical universality argument).

   Therefore space-time surface would be replaced with a hierarchy of strings, string world sheets and partonic 2-surfaces, pairs of 3-surfaces at opposite boundaries of CD and connecting 4-surfaces, hierarchy of CDs, embedding space, WCW!

2. A further generalization is required by the need to have space-time correlates for cognition and imagination. Here p-adic number fields provide a natural candidate and one ends up with an extension of real physics to p-adic physics involving p-adic variants for the above geometric structures. The physics in various number fields are in turn combined to give rise

to adelic physics in which one replaces space-time surface with the Cartesian product of its variants in various number fields obeying same field equations and having even same formal representation at the level of "space-time genes".

The space of quantum states is however common to all sectors of the adelic world and the coefficient field of this Hilbert space must be in intersection of all number fields and thus consist of numbers identifiable as algebraic numbers in some extension of rationals inducing finite-D extensions of p-adic number fields. There exists an infinite number of extensions of rationals and they define naturally an evolutionary hierarchy so that evolution corresponds to increase in algebraic complexity.

Q13: How useful is Sheldrake's notion of "morphic resonance"? Is it too vague to be used to draw concrete conclusions about practical situations? How might it be refined into more precise ideas? How does it relate to quantum mechanics?

A: My answer to this question has developed during last half year and dicussions with Sheldrake in SSE-2016 conference inspired to find a concrete interpretation for the action of morphogenetic field. I have considered morphogenesis in earlier articles [L6, L21, L20, L13]. Below I describe the most important aspects of TGD model as I see it now.

1. Magnetic body as template for the dynamics of the ordinary matter

I would understand "morphic resonance" as one implication of ZEO and of the notion of MB (MB). The ZEO replaces 3-space as basic geometric object with a pair of 3-surfaces with members at opposite boundaries of CD. By holography this pair is equivalent with 4-D space-time surface. MB can be seen also as 4-D field pattern satisfying the conditions defining preferred extremal of basic action principle and actually implying strong form of holography (SH). MBs as 4-D objects would serve as space-time correlates for functions/behaviors/habits and even intentions. 4-D self-organization by quantum jumps would lead to asymptotic 4-D MB. Note that also geometric past also changes in each quantum jump. This time-non-locality was realized already in the context of ordinary quantum theory by Wheeler (delayed choise experiment). The effect has been verified.

MBs have a rich topological dynamics. Flux tubes contract or expand in h_{eff} changing phase transitions bringing molecules near each other; U-shaped flux tubes reconnect to form flux tube pair connections between distant molecules are larger systems in bio-catalysis - this is also basic mechanism of directed attention; the braiding of flux tubes defines space-time realizations for topological quantum computer programs; the replication of MB would be behind replication of DNA and of transcription and also behind the replication in longer scales. The dark matter at magnetic flux tubes would be in macroscopically quantum coherent phases and the idea is that it would control ordinary matter having dynamics of MBs as a template. Biochemistry would be to some extend shadow for the dynamics of MB. For instance, the already mentioned strange findings about split flatworms could be understood in terms of the replication of MB in 4-D sense: not only BB but also functions and behaviors would be replicated.

Morphic resonance could represent a special instance about the replication of MB in 4-D sense. An important aspect would be that MBs in question are really large: the part of MB corresponding to alpha frequency could correspond to Earth size. This makes possible large scale non-local effects and racial learning. One can even consider the idea about MB associated with entire species. Spottiswoode reports that enhanced precognition occurs with period of sidereal (galactic) day. One ends up also to the proposal that the magnetic field of about 10 Hz and galactic MB corresponds to scaled variant of EEG with periods varying from few minutes to 12 hours. These periods would correspond to ordinary day-time consciousness.

Dark matter as large $h_{eff} = h_{gr}$ phases at flux tubes would be the connection to new quantum mechanics.

2. Morphogenesis and generalized Chladni mechanism

What would be the concrete realization of morphogenesis in this picture?

1. Chladni mechanism is a clever trick to make the nodal curves associated with standing waves visible. This mechanism could transcend to a basic mechanism of morphogenesis [L20]. The idea is very simple. Biomolecules could end up to the nodal surfaces for a standing waves of say electric field since the force on them would vanish at the nodal surfaces. This would

give stationary structures. MB could control morphogenesis by using this kind of standing waves forcing the formation of various structures at their nodal surfaces. The structures condensing around nodal surfaces could be also magnetic flux bodies themselves and one could have hierarchical structure. Magnetic bodies carrying Bose-Einstein condensates of charged ions would not experience any electric force at nodal surfaces and magnetc force would be parallel to the nodal surface.

2. The induced fields associated with the simplest "topological light rays" ("massless extremals", MEs) are of form $sin(\omega(t-z))\epsilon(\rho)$, $(c=1)$. $\epsilon(\rho)$ is polarization function and ρ is a coordinate varying in the direction of local polarization and can be chosen rather freely. Now it is taken to be the radial cylindrical coordinate. $\epsilon(\rho)$ can have zeros, which makes possible stationary nodal surfaces also in the case of propagating MEs.

3. The objection is that TGD does not allow single-sheeted realizations of standing waves needed for instance to realize the standing waves assignable to induction coil and wires of electric circuits. This objection is not lethal. In many-sheeted space-time one can realize effective sinusoidal standing waves as 2-sheeted structures from two MEs propagating to opposite spatial directions and carrying plane waves with a fixed frequency. These two-sheeted structures would serve as basic building bricks. The test particle having necessarily wormhole contacts to both MEs would experience the force caused by the sum of the induced gauge fields assigned to the two MEs. The force would be same as that caused by a standing wave with separable temporal and spatial dependence not realizable as preferred extremal: that is a product of trigonometric functions - say product of form $sin(\omega t)sin(\omega z)\epsilon(\rho)$.

   MEs have also always constant direction of polarization. Circularly polarized effective fields could be generated by pairs of MEs for which one has two linear polarizations in orthogonal directions with a phase lag of $\pi/2$.

4. The electric force would vanish at nodal surfaces, which would thus define naturally the shape of a stationary structure defined by molecules or parts magnetic bodies which serve as templates for them. These surfaces would correspond to the vanishing of $sin(kz)$ factor and to the vanishing of $\epsilon(\rho)$ factor.

   One can take several primitive MEs and allow them to have different directions but common frequency. One would obtain effective standing wave with common factorized time dependence and spatial dependence given by the sum of spatial parts of the sinusoidal waves. The nodal surface for this wave would correspond to the nodal surface for the sum of the spatial waves and one would obtain arbitrarily complex nodal surfaces.

   The nodal surfaces for these waves would naturally associated with the nodes of the tensor network, where the flux tubes of MB indeed meet. Fractal structure with tensor networks with nodes of tensor networks can be assumed in TGD framework.

5. There is a connection with holography in which reference wave and the wave of same frequency reflected from the target interfere. Now all waves can be regarded as standing reference waves coming from different directions and generated by magnetic body and propagating along flux tubes of magnetic body. Bio-structures would be formed to the nodal surfaces of this hologram.

3. The classical dynamics of TGD as dynamics of avoidance

Chladni mechanism is essentially dynamics of avoidance. Charged particles go to the nodal surfaces, where electric forces vanish. The twistor lift of TGD of the generalization of Kähler action adding to it volume term. Amazingly, the dynamics for this action can be seen as a generalization of the dynamics of avoidance.

The addition of the volume term to Kähler action implied by the twistor lift of TGD [L11] has very nice interpretation as a generalization of equations of motion for a world-line extended to a 4-D space-time surface [L13]. The field equations generalize in the same manner for 3-D light-like surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian, for 2-D string world sheets, and for their 1-D boundaries defining world lines at the light-like 3-surfaces. For 3-D light-like surfaces the volume term is absent. Either light-like 3-surface is freely choosable in which case one would have Kac-Moody symmetry as gauge symmetry or that the extremal property for Chern-Simons term fixes the gauge.

The known non-vacuum extremals are minimal surface extremals of Kähler action and it might well be that the preferred extremal property realizing strong form of holography quite generally demands this. The addition of the volume term could however make Kähler coupling strength a manifest coupling parameter also classically when the phases of Λ and α_K are same. Therefore quantum criticality for Λ and α_K would have a precise local meaning also classically in the interior of space-time surface. The equations of motion for a world line of U(1) charged particle would generalize to field equations for a "world line" of 3-D extended particle.

This is an attractive idea consistent with standard wisdom but one can invent strong objections against it in TGD framework.

1. All known non-vacuum extremals of Kähler action are minimal surfaces and the minimal surface vacuum extremals of Kähler action become non-vacuum extremals. This suggest that preferred extremals are minimal surface extremals of Kähler action so that the two dynamics apparently decouple. Minimal surface extremals are analogs for geodesics in the case of point-like particles: one might say that one has only gravitational interaction. This conforms with strong form of holography (SH) stating that gauge interactions at boundaries (orbits of partonic 2-surfaces and 2-surfaces at the ends of CD) correspond classically to the gravitational dynamics in the space-time interior.

   Note that at the boundaries of the string world sheets at light-like 3-surfaces the situation is different: one has equations of motion for geodesic line coupled to induce Kähler gauge potential and gauge coupling indeed appears classically as one might expect! For string world sheets one has only the topological magnetic flux term and minimal surface equation in string world sheet. Magnetic flux term gives the Kähler coupling at the boundary.

2. Decoupling would allow to realize number theoretical universality since the field equations would not depend on coupling parameters at all. It is very difficult to imagine how the solutions could be expressible in terms of rational functions with coefficients in algebraic extension of rationals unless α_K and Λ have very special relationship. If they have different phases, minimal surface extremals of Kähler action are automatically implied. If the values of α_K correspond to complex zeros of Riemann ζ [L9], also Λ should have same complex phase, in order to have genuine classical coupling. This looks somewhat un-natural but cannot be excluded.

   The most natural option is that Λ is real and α_K corresponds to zeros of zeta. For trivial zeros the phases are different and decoupling occurs. For trivial zeros Λ and α_K differ by imaginary unit so that again decoupling occurs.

3. One can argue that the decoupling makes it impossible to understand coupling constant evolution. This is not the case. The point is that the classical charges assignable to super-symplectic algebra are sums over contributions from Kähler action and volume term and therefore depend on the coupling parameters. Their vanishing conditions for sub-algebra and its commutator with the entire algebra give boundary conditions on preferred extremals so that discrete coupling constant evolution creeps in classically from the spectrum of quantum critical coupling constants!

   The condition that the eigenvalues of fermionic charge operators are equal to the classical charges brings in the dependence of quantum charges on coupling parameters. Since the elements of scattering matrix are expected to involve as building bricks the matrix elements of super-symplectic algebra and Kac-Moody algebra of isometry charges, one expects that discrete coupling constant evolution creeps in also quantally via the boundary conditions for preferred extremals. Coupling would be forced by boundary conditions!

The above arguments seem to kill the idea that the dynamics of Kähler action and volume term could couple in space-time interior. The coupling between the two dynamics would be induced just by the condition that the space-time surface becomes an analog of geodesic line by arranging its interior so that the U(1) force vanishes! This would generalize Chladni mechanism! The interaction would be present but be based on going to the nodal surfaces! One would have dynamics of avoidance! Also the dynamics of string world sheets is similar: if the string sheets carry vanishing W boson classical fields, em charge is well-defined and conserved. One would also avoid the problems produced by large coupling constant between the two-dynamics present already at the classical level. At quantum level the fixed point property of quantum critical couplings would be the counterparts for decoupling.

To sum up, it seems that the complete decoupling of the dynamics of Kähler action and volume term in the interior is favored by both SH, realization of preferred extremal property (perhaps as minimal surface extremals of Kähler action, number theoretical universality, discrete coupling constant evolution, and generalization of Chladni mechanism to a dynamics of avoidance.

7.3 Comments about Ben Goertzel's Eurycosm approach to consciousness

Ben Goertzel considers a highly interesting proposal for a theory of consciousness relying on what he calls euryphysics. Goertzel formulates euryphysics by listing 23 principles. The notions involved are certainly central to consciousness and in the following I will comment this approach from TGD point of view trying suggesting TGD counterparts for the notions introduced (this is the only manner that I can learn!). I restrict my attention to the basic principles and make only brief comments about the proposed applications involving peaked distribution and morphic resonance as key notions. Most of these notions have natural TGD counterparts. My basic criticism concerns the relational interpretation of quantum mechanics.

I have discussed non-locality in TGD framework at [L15], IIT of Tononi and Koch at [L19] and the questions raised by Lian about IIT and Eurycosm theory at [K76].

7.3.1 Relational interpretation of quantum mechanics

Goertzel adopts so called relational interpretation of quantum mechanics (see `http://tinyurl.com/mo25l86`).

1. The motivation comes from the fact that in special relativity time perception depend on the state of motion of O relative to S (time dilation, Lorentz contraction). Also the Unruh effect suggests that the an observer O in accelerated motion relative to S sees thermal spectrum of photons emerging from S. To my opinion this does not however serve as justification for the assumption that entanglement or lack of it is observer dependent notion.

2. Relational interpretation postulates that state function reduction is not real and that quantum state is observer dependent concept characterizing the relationship of observer O and measured system S. This interpretation is encouraged by conflict between the non-determinism of state function reduction and unitary time evolution emerging in the Copenhagen interpretation and forcing to give up ontology altogether so that wave function describes only the knowledge about the system. In this framework relational interpretation would be natural. One can however argue that this makes the notion of quantum state rather complex.

3. Since an interpretation of quantum theory is in question, consistency suggests that entire Universe obeys unitary time evolution although it is not observed at the level of O+S pairs. State function reduction effectively occurs for sub-system pairs in the sense that second member - observer - perceives itself and second system un-entangled although the external observer perceives them as unentangled system. The density matrix for entangled system pair defines a natural observable in the sense that its eigenstates define preferred state basis for O (or by symmetry for S).

4. A third system not entangled with O+S perceives it as entangled system. One can therefore ask whether the entangled pair gives rise to a superposition of several conscious entities formed by observer-system state pairs. It is difficult to see why this would not be the case. If so, then any entangled system pair would represent superposition of parallel conscious sub-universes and there would be a close connection with Everett's interpretation.

What objections can one invent against relational interpretation?

1. Suppose that observer and system (O+S) are maximally entangled spin 1/2 systems in spin singlet state so that the density matrix is 2×2 unit matrix. By the rotational symmetry any choice of quantization axis for spin is equally good. There is no obvious criterion making possible to choose a unique quantization axis and to decide what is the state of S perceived by O or vice versa. One can of course ask that exact rotational symmetry is impossible in practice and there is always a small mixing with spin 1 state with same spin projection implying that the density matrix deviates from identity matrix. One cannot however demand internal consistency in statistical sense only.

2. If one assumes separate unitary evolution for all O-S pairs one ends up with infinite number of consistency conditions: my guess is that they cannot be satisfied. If one that only the state of the entire universe obeying unitary evolution, one can ask whether this notion has any operational meaning. This makes the application of the theory rather difficult.

7.3.2 The notion of eurycosm

Eurycosm is introduced as a key notion. Its precise meaning is however left open. Eurycosm would contain space-time as we understand it as a subset. Eurycosm would be a structure possessing topology, geometry, and various order relations. One the other hand, it is noted that it probably has no dimensional structure characterizing manifolds. If I have understood correctly, the ordering relations for eurycosm would characterize various key aspects of consciousness rather than serving as mere correlates.

In TGD framework one analog of eurycosm would be the 8-D embedding space containing space-time as 4-surface, and more generally would adelic space-time as surface in adelic embedding space. World of Classical Worlds (WCW) and its adelic analog would also serve as TGD analogy for eurycosm. They would however be zombies and provide only classical correlates for various aspects of conscious experience associated with state function reductions not assumed in Goertzel's approach.

Adelic Universe means that instead of reals as basic number field one consideres adeles, which are Cartesian product of reals, and finite-dimensional extensions of various p-adic number fields induced by an extension of rationals. Rationals allow both algebraic and non-algebraic extensions and there is infinite hierarchy of them so that adelic worlds at various levels (space-time, embedding space, WCW) form a hierarchy interpreted in terms of evolution.

p-Adic sectors of the adelic world correspond to space-time correlates for cognition and imagination. One can speak of p-adic space-time surfaces and they correspond rather closely to real space-time surfaces but the one can also have p-adic space-time surfaces with no real counterparts: imaginations are not always realizable. The reason is that due to the occurrence of p-adic pseudo constants p-adic partial differential equations are non-deterministic and allow much more solutions than their real counterparts. Strong form of holography (SH) allows to construct real and p-adic space-time surfaces from string world sheets and partonic 2-surfaces by algebraic continuation as preferred extremals for the basic action principle. There is strong analogy with analytic continuation in complex analysis: real function at real axis can be continued to analytic function in the entire complex plane.

7.3.3 Definition of consciousness

"Raw" consciousness is regarded as a property of any physical system and even of space-time and eurycosm rather than assigning it somehow to state function reduction or Zeno effect as in TGD. The identification of consciousness as a property of eurycosm identified as topological object leads to "boundary problem": where the mind begins and where the body ends?

The basic objections against the identification of consciousness as a property are same as in materialistic approach: there is no manner to distinguish between consciousness and any other physical property. Also free will suggesting that state function reduction is real would be an illusion.

Some comments are in order.

1. Relational interpretation would strongly suggest that "raw" consciousness corresponds to elementary observation identifiable in this interpretation as effective state function reduction.

If one assumes that state function reduction is real, one ends up with conflict between determinism of unitary evolution and non-determinism of state function reduction if the causality of free will is assumed to be same as that for laws of physics. One could call this problem "causality paradox". This in turn relates to the identification of experienced time as geometric time: an assumption which cen be only approximately true (second law).

2. To me quantum parallel conscious observers defined by entangled quantum state would look like a feasible notion in the framework of relational interpretation: conscious entity could correspond to this kind of system having no entanglement with environment. This interpretation would not be plagued by the "boundary problem". This would also mean panpsychism: any entangled system could be in role of conscious observer unless one poses some additional conditions to what it is to be an observer. I however understood that this interpretation is ot adopted.

In TGD framework Zero Energy Ontology (ZEO) and generalization of quantum measurement theory to a theory of observer as conscious entity leads to a resolution of "causality paradox". Consciousness is an (only) effectively a property of systems, which are negentropically entangled to entities stable under NMP and un-entangled from the environment. Actually the self is changing in every state function reduction and only the passive boundary of CD and the states associated with it remain unaffected. Regarding consciousness as a property is strictly speaking impossible albeit very practical. This delicacy does not have great practical significance but is of fundamental since it allows to solve a bundle of difficulties plaguing consciousness theories.

7.3.4 The notion of observation

Observation is taken as a key notion.

1. It is noticed that observation has directedness. This is certainly true in macro scales. The first guess inspired by quantum measurement theory is that state function reduction corresponds to observation in its simplest form. This does not however conform with the complete symmetry between O and S implied by the relational interpretation. The directedness would naturally follow if O is capable of intentional actions, in particular measuring the state of S by inducing genuine state function reduction. Now this is not possible now. Note that this relates also to the directedness of attention: there is the system with directs attention and the system which is attended.

   My understanding is that the perception of O+S by O as un-entangled system although it is entangled from the point of view of outside does not represent primitive observation.

2. Observations are proposed to have a hierarchical structure: observations within observations. Also the notion of complex observer is also introduced. The composition of entities is introduced as a basic principle.

3. The notions of simplicity (equivalently complexity), surprisingness, intensity, and notability as characterizers of the observations are introduced. Observations can be ordered by the degree for these attributes and allow to characterize basic notions related to consciousness. Also gradient of surprisingness is introduced as a key notion. Local time axis would be defined in terms of gradient of surprisingness.

4. Also the notions of representation and pattern are introduced. If A is intense when B is intense, A represents B. P is pattern if P represents S and is simpler than S. Pattern could be seen in terms of of inclusion of hyperfinite factors with included factor defining pattern which is simpler due to the lower measurement resolution. The notions of emergence and intelligence are mentioned.

5. Goertzel introduces the notion of persistent entity and speaks of causal arrows and network of them defining space.

6. Understanding the essence of intelligence is a fascinating challenge. For instance, what problem solving could mean at quantum level? Intelligent systems certainly form "stories" as

symbolic representations/simulation of the external world in various spatial and time scales so that fractality seems to be an essential element of intelligence. The emergence of symbolic dynamics seems to be an essential element of intelligence: one can predict the behavior of person for years just by knowing his role in society. Trying to compute it from all available data at molecular level would be completely hopeless task - even in principle.

What about the situation in TGD?

1. Also in TGD this the case - strictly speaking only observations exist and observer is only a useful idealization.

2. In TGD framework state function reduction represents the core element of observation and also now the challenge is to understand the directness of observation. U-shaped magnetic flux tube loops of the magnetic body of system define a concrete realization of directed attention using "magnetic tentacles". Directing attention to another system would mean reconnection of the U-shaped loops of the two systems to a pair of flux tubes connecting the systems so that they quantum entangled or can do so. The asymmetry would be due to the fact that the more complex system - observer - can perform intentional motor actions of magnetic body that is control flux tube thickness and therefore magnetic fields and corresponding cyclotron frequencies so that for suitable frequency resonant reconnection can occur (magnetic field strengths are same for the two reconnecting U-shaped flux loops). Directedness would basically come from self hierarchy. The self directing attention would perform intentional action forcing its sub-self to reconnect with the magnetic body (MB) of the attended system.

3. Self hierarchy is analogous to the hierarchy of observations. At the level of space-time surface the counterpart is hierarchy of space-time sheets glued to larger space-time sheets by wormhole contacts glued to.... The geometric counterparts are hierarchy of causal diamonds at the level of embedding space. Self has sub-selves which it experiences as mental images. Sub-subselves are experienced as kind of average. State function reductions take place as top-down cascades. A reduction of system decomposes it to two unentangled subsystems and for this NMP can force a further state function reduction and cascade stops when all resulting sub-systems are negentropically entangled.

4. In TGD framework measure of complexity for representations could be defined in terms of measurement resolution allowing definition in terms of inclusions of hyperfinite factors: included factor would have lower resolution and would be simpler. For p-adic cognition measurement resolution is unavoidable and increases as the complexity of the algebraic extension of rationals behind adeles increases.

   In TGD the hierarchies of Planck constants, p-adic length scales defines, algebraic extensions of rationals define evolutionary hierarchies with increasing complexity measured also by the entanglement negentropy. NMP states that negentropy gain is maximized in state function reduction and intensity of conscious experience could be measured as negentropy gain. To my view surprisingness demands ability to predict the time evolution so that the deviation from prediction would characterize surprisingness. In ZEO zero energy states have indeed 4-D space-time surfaces as correlates and these would define the predictions. Notability would perhaps might be characterized in terms of the value of negentropy gain in state function reduction.

5. Subjective time as sequence of repeated reductions at the same boundary of causal diamond corresponds to the experienced time in TGD framework but the negentropy associated with passive boundary of CD is not changing. The drift of the active boundary of CD farther away from the passive one defines clock time giving rise to experienced flow of time. One can say that the sequence of state function reductions defining subjective time is mapped to a sequence of increasing temporal distance between the tips of CD. Same is true for subselves/sub-CDs.

   During the period of reductions defining self subselves (sub-CDs) defining mental images are generated and the increase of negentropy assignable to them accompanies this flow of time (usually thermodynamical entropy defines arrow of time). In TGD p-adic entanglement negentropies correlate very closely with real entanglement entropy and the randomness assignable to reductions at opposite boundary of CD meaning death and reincarnation of self generate thermodynamical ensemble entropy.

6. Persistent entity corresponds in TGD naturally to the negentropic subsystems at passive boundary of CD defining the unchanging part of self responsible for self identity. These can be also seen as negentropy resources of the Universe, kind of Akashic records. The network of magnetic flux tubes carrying dark matter as large h_{eff} phase define a kind of neural network giving rise to experience about space and body as something distinguishable from environment. The flux tubes would meet at nodes and there would be NE between the nodes. One must clearly distinguish between space in purely geometric sense and system able to create the experience about space as 3-D structure, biological body.

7. What about understanding of emergence and intelligence? The number theoretic evolution realized in terms of algebraic extensions of rationals suggests first principle definition of emergence of intelligence as phase transitions making the extension more complex, increasing the value of h_{eff} and thus scale of quantum coherent, increasing the p-adic length scale, etc... Negentropy Maximization Principle would be the driving force and state that state function reductions tend to increase negentropic recources of the Universe: strong form states that the negentropy gain is maximal (see `http://tinyurl.com/gwaal5l`). One one identify several ingredients of intelligence (see `http://tinyurl.com/zcwa5jj`). What seems essential is that intelligent system is able to build "stories" as p-adically scaled variants of real event sequences so that simulations can be carried out in much shorter or also longer time scale than that for the real events.

7.3.5 The notions of peaked distribution and morphic resonance

Many other notions are introduced and the theory is applied to Psi phenomena, morphic resonance, and other candidates for anomalous phenomena. In the following I discuss the notions of peaked distribution and morphic resonance from TGD point of view.

1. The notion of peaked distribution is introduced. In TGD framework the notion of preferred extremal of Kähler action is an analogous notion. In ordinary quantum field theory one would have path integral over all 4-surfaces connecting initial and final states. By holography one does not have path integral now. Already ordinary holography produces effectively 3-D dynamics and SH produces effectively 2-D dynamics: the data about space-time geometry is carried by 2-D surfaces (apart additional discrete degrees of freedom very probably present.

   Preferred extremals satisfy powerful conditions stating that infinite number of Noether charges assignable to the symmetries of WCW vanish and guarantee that space-time sheets can be constructed from essentially 2-D data - space-time genes. These conditions leave extremely restricted set of space-time surfaces as preferred extremals representing kind of archetypal dynamical patterns. The actual space-time engineered from these and standard model + GRT limit of TGD lacks therefore this simplicity although it is topologically simple. These preferred extremals would be natural counterparts for the peaks of distribution. One might say that the space-time surface represent kind of dynamical archetypes possessing huge symmetries. EEG pattern would be a typical example.

   Brain is mentioded as a key example of system in which this kind of peaking occurs. In TGD brain would be a system building standardized mental images by virtual sensory input to sensory organs as feedback and 4-D self-organization would replace zero-energy state reduction by reduction with a new one approaching asymptotic pattern defining standardized mental image.

2. Morphic resonance as mechanism for the formation of habits is emphasized. In TGD context ZEO implies that magnetic bodies define 4-D temporal patterns connecting initial and final states at the opposite boundaries of CD serving as correlates for behaviors, functions, habits, etc... The replication of 4-D magnetic bodies analogous to what occurs for the elementary particle in the decay A→ B+C could lead to the morphic resonance and establishment of a

new skill. Ordinary DNA and cell replication would be 3-D shadow of morphic resonance in this sense. The reconnection would be also basic mechanism in various remote mental interactions such as telepathy and psychokinesis. To understand precognition also ZEO (signals propagating also in non-standard time direction) is needed.

Resonance aspect is actually very concrete. Dark photons at magnetic flux tubes are characterized by cyclotron frequencies and reconnection of two flux tubes requires that the magnetic field strengths and therefore also cyclotron frequencies are identical, which means resonance in concrete sense. The establishment of a habit would be based on reconnection of the flux tubes of the MBs associated with the members of the community. Since MBs can have size of order Earth size scale or even larger, the habit could be established at different sides of globe almost instantaneously.

7.3.6 Space-time as a metaphorical knot

Could problem solving have space-time correlate? Goertzel talks about space-time as a metaphorical knot. Opening a knot could serves as an attractive metaphor problem solving. I am not however quite sure whether Goertzel has exactly this in mind.

1. In TGD framework knottedness of space-time is much more than metaphor. Effectively one-dimensional (from the point of view of homology) magnetic flux tubes as basic space-time structures can get knotted in 3-space as also 1-D fermionic strings inside them. Braiding is another name for this process and defines classical counterparts of quantum computer programs. The special role of knots is solely due to the dimension D=4 of space-time. Even more: also the (effectively) 2-D orbits of fermionic strings (flux tubes) can form 2-knots in 4-D space-time. This brings additional topological reactions.

2. The idea about opening a knot without cutting it temporarily as a space-time correlate for problem solving in civilized manner is very attractive. 2-knots correspond to processes in which this is carried out in Alexandrian manner by cutting the knot temporarily: the portions of knots go through each other or are split and reconnected in a new manner. Reconnection processes for magnetic body in living matter would be rebuilding of communication network based on flux tubes.

3. The vision about scattering diagrams as space-time surfaces defining geometric and topological representations for algebraic computations is central in quantum TGD. Particle reaction can be seen as an algebraic computation connecting initial and final collections of algebraic objects (particles) with vertices defining algebraic operations $A + B \to C = A \circ B$. There is infinite number of equivalent ways to perform the computation and the simplest computation correspond to a diagram containing no loops. This gives infinite number of dualities between different but equivalent computations very much analogous to mirror symmetry in M-theory. Could the problem solving be understood as a process in which one finds the simplest possible representation of algebraic computation in terms of space-time correlates? There is an objection: if these dualities are complete symmetries, it should not be possible to speak about solving problem in this manner. Symmetry breaking is needed to make a difference. Maybe one must give up this very nice metaphor.

4. Strong form of holography (SH) suggests however an alternative view about problem solving. Problem solving involves imagination in an essential manner and means finding an imagination, which is realizable. By SH both real and p-adic space-time surfaces are constructible from 2-D space-time genes in the intersection of reality and various p-adicities (string world sheets and partonic 2-surfaces) by algebraic continuation. Due to the inherent non-determinism of p-adic partial differential equations much larger set of continuations is possible in p-adic sectors than in real sector. p-Adic imagination need not therefore be realizalbe. Could the solution of the problem mean finding a p-adic imagination having also real counterpart.

7.4 Further notions and ideas

Goertzel introduces also the notions of peaked distribution and morphic resonance and the idea about space-time as metaphorical knot.

7.4.1 The notions of peaked distribution and morphic resonance

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7.5 IIT and TGD: 7 years later

Gary Ehlenberg sent a link to an article about Integrated Information Theory of consciousness (IIT) [J43] (see this). The article gives a nice summary of IIT as it was 2015. Gary wondered whether quantum theory is completely left out. The suspicion of Gary was correct: there is no mention of quantum theory.

It is good to attach here the abstract of the article "Consciousness: here, there and everywhere?" of Tononi and Koch published in the Philosophical Transactions of the Royal Society B in to give a general perspective.

The science of consciousness has made great strides by focusing on the behavioural and neuronal correlates of experience. However, while such correlates are important for progress to occur, they are not enough if we are to understand even basic facts, for example, why the cerebral cortex gives rise to consciousness but the cerebellum does not, though it has even more neurons and appears to be just as complicated. Moreover, correlates are of little help in many instances where we would like to know if consciousness is present: patients with a few remaining islands of functioning cortex, preterm infants, non-mammalian species and machines that are rapidly outperforming people at driving, recognizing faces and objects, and answering difficult questions.

To address these issues, we need not only more data but also a theory of consciousness one that says what experience is and what type of physical systems can have it. Integrated information theory (IIT) does so by starting from experience itself via five phenomenological axioms: intrinsic existence, composition, information, integration and exclusion. From these it derives five postulates about the properties required of physical mechanisms to support consciousness.

The theory provides a principled account of both the quantity and the quality of an individual experience (a quale), and a calculus to evaluate whether or not a particular physical system is conscious and of what. Moreover, IIT can explain a range of clinical and laboratory findings, makes a number of testable predictions and extrapolates to a number of problematic conditions.

The theory holds that consciousness is a fundamental property possessed by physical systems having specific causal properties. It predicts that consciousness is graded, is common among biological organisms and can occur in some very simple systems. Conversely, it predicts that feed-forward networks, even complex ones, are not conscious, nor are aggregates such as groups of individuals or heaps of sand. Also, in sharp contrast to widespread functionalist beliefs, IIT implies that digital computers, even if their behaviour were to be functionally equivalent to ours, and even if they were to run faithful simulations of the human brain, would experience next to nothing.

The article lists the 5 basic postulates of IIT leading to a numerical measure for the level of consciousness of a system. I wrote about IIT years ago and compared it with the TGD inspired theory of consciousness [L19, K76]. It is interesting to take a fresh look at IIT since the mathematical and physical understanding of TGD has evolved dramatically during these 8 years.

1. The basic criticism is already raised by the idea that conscious experience means property of a system, consciousness. This reflects the materialistic view that conscious experience is a property of the system just as the mass and leads to the well-known philosophical problems. Materialism leads to problems with free will for instance.

2. The key problem is what subjective existence means and here materialism, idealism and dualism fail. Here quantum theory comes to the rescue and allows us to assign subjective existence as experience to state function reduction (SFR), or rather the interval between two SFRs. The SFRs would be those which in standard wave mechanics correspond to repeated measurements of the same observables and in that context would have no effect on the system. In the zero energy ontology of TGD the state of system changes and "small" SSFRs give rise to the experienced flow of subjective time correlating with that of geometric time .

3. Also the assumption that the consciousness just exists or does not, is too simplistic. Already Freud realized Id-ego-super-ego triality and physics based picture strongly suggests that conscious entities form hierarchies just as physical systems do. There would exist very naturally a hierarchy of selves. They would have subselves, perhaps as mental images, etc.. and being subselves of higher levels selves. This would however be a dramatic deviation from the western world view. Although IIT assumes panpsychism, the lack of this realization reflects the brain centered view of neuroscience very analogous to the Earth centered world view before the emergence of astrophysics.

4. I saw no mention related to the problem of time: what is the relation between geometric time of physicists and the flow of subjective time which is the essential element of conscious experience.

5. About what death and sleep mean, IIT does not say anything at the philosophical level. Loss of consciousness can be explained as a reduction of the level of integration (more or less connectedness of the system) measured by the number Φ.

6. Metabolic energy feed is essential for life and consciousness and I saw no mention of this.

There are 5 postulates which are proposed to give rise to a criteria for when the system is conscious.

7.5.1 Intrinsic existence

Cause-effect power is taken as a key criterion. Cause effect power is understood classically since quantum theory is not involved. Cause effect power has several corresponds in TGD.

1. In TGD the classical correlate of cause-effect power at the space-time level is holography stating that 3-D data (3-surface dictates the space-time surface as analog of Bohr orbit. There is however a slight failure of determinism and this forces us to take these 4-D Bohr

orbits as basic objects. They are classical correlates for almost deterministic behavioral patterns and SSFRs between different superpositions of Bohr orbits give rise to subjective time evolution.

2. In TGD "small" SFRs (SSFRs) are t quantum correlates of cause-effect power. "Big" SFRs (BSFRs) give rise to the death (sleep state) of the system and reincarnation with an opposite arrow of geometric time. Second BSFR means wake-up.

   BSFRs are essential for understanding biological processes like homeostasis. A pair of BSFRs means sleep period during which the entropy of the system is reduced and the system wakes up as a less entropic system. This is essential in the battle of the living systems against second law.

3. Causal diamond ($CD = cd \times CP_2$) is the correlate of the cause-effect power at the level of $H = M^4 \times CP_2$. cd has the geometry of causal diamond and the two light-like boundaries are in asymmetric relation. At the passive boundary the states do nt changes in SSFRs. It can be said to be the causal agent. At the active boundary they change. Also the size of CD increases in statistical sense and geometric time corresponds to the increasing temporal distance between the tips of CD. In BSFR the roles of active and passive boundaries of CD change.

   I must admit that I did not understand the illustrations of cause-effect structure involving Boolean algebra. Boolean functions are one way to see causality. In physics, classical deterministic time evolution defines a more general cause-effect structure.

7.5.2 Composition

Systems are structured. In standard physics, where space-time is infinite and without topological structure, there is no fundamental definition for what this means and only phenomenological models are possible. In TGD, many-sheeted 3-space decomposes to a union of 3-surfaces which can fuse and decay and these processes occur also in scales essential for life and consciousness and also we perceive the many-sheeted space-time and these processes directly but our education make it impossible to realize this.

7.5.3 Information

Cause-effect repertoire is taken as a basic concept behind the notion of information.

1. In TGD, a cause-effect repertoire corresponds to different 4-D Bohr orbits associated with the same 3-surfaces holographic data. These are the space-time correlates for the behaviours.

2. As the algebraic complexity of the space-time surface increases, the size of the repertoire increases. The dimension of extension of rationals assignable to the space-time regions measures this complexity and is assumed to define effective Planck constant which in turn gives a measure for the scale of quantum coherence serving as a measure for the evolutionary level of the system. This means deviation from the standard quantum theory with single Planck constant. Field bodies as carriers of dark phases of ordinary particles means a second deviation made possible by the new view of classical fields.

3. Number theoretic view of TGD is something completely new and allows to define the notion of conscious information. p-Adization and adelization in turn gives correlates of cognition and one can assign to the system an entanglement negentropy as the sum of its p-adic variants. Entanglement negentropy is positive and increases with the complexity of the system. It is larger than real entanglement entropy and its increase implies the increase of the latter: cognition produces unavoidably ordinary entropy.

4. The number theoretic entanglement negentropy could be seen as a counterpart of an integrated information and measures the cognitive level of the system and the level of cognitive consciousness.

Number theoretic evolution as an unavoidable increase of complexity in the sequence of state function reductions forces the increase of this entanglement entropy so that the potentially conscious information of the system necessarily increases.

5. The ZEO based view of quantum jump [L46, L66] [K100] allows to understand how systems are able to have memories about their states before SSFRs: in standard quantum theory this is not possible. Therefore Universe making SSFRs and BSFRs learns more and more about itself and is able to remember what it has learned (see this).

   In IIT, the qualia space is identified as cause-effect space. In the TGD framework SSFR leads to a final state containing information about the previous quantum state since it is identified as a superposition of classical space-time surfaces leading from the fixed initial state at the passive boundary of the CD to the active boundary of CD. The original proposal that qualia are simply labelled by the quantum numbers measured in SSFR is not quite correct. The qualia also involve classical information about the SSFR via the superposition of space-time surfaces between initial (fixed) and final classical states: this would be the counterpart for the cause-effect.

7.5.4 Integration

The counterpart of integration in the TGD framework is entanglement.

1. Entanglement entropy to which one can assign adelic negentropy measures the degree of entanglement and integration. In SFR the entanglement is reduced: the system decomposes to two parts. This is the basic aspect of conscious experience. About this says IIT nothing.

2. Monopole flux tubes connecting parts of the system to a single coherent whole provide a classical correlate for the entanglement and in SFRs the flux tube connections between the two parts of the system could split. More precisely, pairs of flux tubes connecting the subsystems reconnect to U-shaped flux tubes associated with the systems: the connection is split, SFR has occurred.

3. In biology reconnection is fundamental, for instance for bio-catalysis and for the recognition of molecules by the immune system. Death of the system means splitting of these flux tubes. These flux tubes carry dark matter as large h$_{eff}phases.Theremustbeametabolicenergyfeedtopreventthevaluesofh_{ef}$
   $shapedfluxtubessothatthesystemlosesthecontrolofitsenvironmentandreceivesinformationfromasmallervolume.$

7.5.5 Exclusion

Exclusion postulate states that cause effect structure must be definite. The notion is described in terms of a phenomenological set theoretic picture. I did not understand the Boolean illustrations of the cause effect structure. The notion of maximal irreducibility can be understood in TGD as maximal connectedness or at least connectedness of the 3-surface by connecting flux tubes (or in the weakest sense, the 4-surfaces as analog of Bohr orbit).

What precisely defined cause-effect structure could mean in ZEO? The state at the passive boundary of CD remains fixed during the sequences of SSFRs determining the life-cycle (wake-up period of self) so that one can can say that classically the almost deterministic evolution of the space-time surface is implied by the 3-surface at the passive boundary, it acts as a causal agent. The small failure of determinism means that there are also intermediate "agents" slightly affecting the time evolution. They also make possible memory and force ZEO solving the basic problem of the quantum measurement theory and allowing also free will.

7.5.6 What is missing from IIT?

The postulates of IIT are inspired by computationalism and materialistic neuroscience and have no connection to (quantum) physics or biology. The hierarchy of selves is a central notion missing completely in IIT and this hierarchy is essential for a real understanding of conscious entities. The levels of the hierarchy interact. For instance, the field body (magnetic body) carrying dark matter as large h_{eff} phases of dark matter serves as a boss of the biological body carrying ordinary matter.

Cognitive hierarchies as hierarchies of extensions of rationals giving rise to directed entanglement hierarchies are also something not possible in the standard physics.

These hierarchies are also essential for understanding evolution. In particular, classical gravitational and electromagnetic fields give rise to field bodies with very long quantum coherence lengths, even of astrophysical size and these scales are predicted to be fundamental for understanding life and consciousness in ordinary living matter.

The somewhat surprising prediction of IIT is that ordinary computers need not be conscious. In TGD this is possible only if the quantum coherence time is longer than the clock period but the contents of consciousness need not correlate with the program. The change of the arrow of time in BSFRs makes possible the analogs of feedback loops at various layers of the self hierarchy and learning by trial and error and would be the basic aspect of living systems.

Whether ordinary computers could be conscious is an interesting question and in TGD one ends up with a quantitative criterion for this in terms of the clock frequency [L64]. For the Earth's gravitational body, the lower bound for the clock frequency is 67 Hz. For the solar gravitational body, the clock frequency should be above 50 Hz which is the average EEG frequency and satisfied for the ordinary computers. Does this mean that the users of computers can entangle with them? It has been claimed that when a chicken entangles with a robot whose motion is based on a random number generator, the robot seems to take the role of Mother.

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 [L26, L27]. In the recent view of quantum TGD [L61], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L51, L52] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L46] [K100] 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) [L46, L54] [K100] 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 [A18] 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 [A13] 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

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , & e^1 &= \tfrac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \tfrac{r\sigma_2}{\sqrt{F}} \ , & e^3 &= \tfrac{r\sigma_3}{F} \ . \end{aligned} \tag{A-2.10}$$

The explicit representations of vierbein vectors are given by

$$\begin{array}{llllll} e^0 & = & \frac{dr}{F} \ , & e^1 & = & \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\ e^2 & = & \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 & = & \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ . \end{array} \tag{A-2.11}$$

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

$$\begin{array}{llllll} V_{01} & = & -\frac{e^1}{r} \ , & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} \ , & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r - \frac{1}{r})e^3 \ , & V_{12} & = & (2r + \frac{1}{r})e^3 \ . \end{array} \tag{A-2.14}$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{array}{llllll} R_{01} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} & = & e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} & = & -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\ R_{03} & = & 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} & = & 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{array} \tag{A-2.15}$$

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 [A11]. 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 [A22] 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

$$[X,[Y,Z]] \in t \text{ for } X,Y,Z \in t \ . \qquad \text{(A-2.22)}$$

$SU(3)$ 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 [B15] 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

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \qquad \text{(A-2.23)}$$

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

$$\begin{aligned} I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{aligned} \tag{A-2.28}$$

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

$$\begin{aligned} R_{01} &= -R_{23} = e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} &= -R_{31} = e^0 \wedge e^2 - e^3 \wedge e^1 \ , \\ R_{03} &= 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , \\ R_{12} &= 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{aligned} \tag{A-2.30}$$

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.

$$
\begin{array}{l}
W_{03} = W_{12} \equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\
W_{01} = W_{23} \equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\
W_{02} = W_{31} \equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 \ .
\end{array} \quad \text{(A-2.31)}
$$

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

$$
\begin{array}{rcl}
X & = & re^3 \ , \\
Y & = & \frac{e^3}{r} \ ,
\end{array} \quad \text{(A-2.32)}
$$

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

$$
\begin{array}{rcl}
\bar{\gamma} & = & aX + bY \ , \\
\bar{Z}^0 & = & cX + dY \ ,
\end{array} \quad \text{(A-2.33)}
$$

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

$$
\begin{array}{rcl}
A_{nc} & = & [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\
& + & [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ .
\end{array} \quad \text{(A-2.34)}
$$

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

$$c = -d \ . \quad \text{(A-2.35)}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \quad \text{(A-2.36)}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$
\begin{array}{rcl}
Q_{em} & = & \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} \ , \\
I_L^3 & = & \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ .
\end{array} \quad \text{(A-2.37)}
$$

The fields γ and Z^0 are defined via the relations

$$
\begin{array}{rcl}
\gamma & = & 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\
Z^0 & = & 4(a+b)\bar{Z}^0 = 4(X - Y) \ .
\end{array} \quad \text{(A-2.38)}
$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \qquad \text{(A-2.39)}$$

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

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) \ , \qquad \text{(A-2.40)}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0\wedge e^3 + e^1\wedge e^2) \ , \\ R_{12} &= 2(e^0\wedge e^3 + 2e^1\wedge e^2) \ , \\ J &= 2(e^0\wedge e^3 + e^1\wedge e^2) \ , \end{aligned} \qquad \text{(A-2.41)}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \qquad \text{(A-2.42)}$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \qquad \text{(A-2.43)}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \qquad \text{(A-2.44)}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + fJ^{\alpha\beta}J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2}Tr(F^{\alpha\beta}F_{\alpha\beta}) \ , \end{aligned} \qquad \text{(A-2.45)}$$

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

$$X = -\frac{K}{2g^2} + \frac{fp}{18} \ ,$$
$$K = Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ , \qquad \text{(A-2.46)}$$

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

$$K = \sum_i \left[-\frac{(18+2n_i^2)sin^2\theta_W}{9}\right] \ , \qquad \text{(A-2.47)}$$

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

$$sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18+n_i^2))} \ . \qquad \text{(A-2.48)}$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \ . \qquad \text{(A-2.49)}$$

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 [B3]. 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 [L67] 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

$$
\begin{aligned}
R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) = J + 2e^0 \wedge e^3 \ , \\
J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\
R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) = 3J - 2e^0 \wedge e^3 \quad , \qquad \text{(A-2.50)}
\end{aligned}
$$

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$
\begin{aligned}
\gamma &= 3J - sin^2\theta_W R_{12} \ , \\
Z^0 &= 2R_{03} = 2(J + 2e^0 \wedge e^3) \qquad \text{(A-2.51)} \\
per. & \qquad \text{(A-2.52)}
\end{aligned}
$$

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 [B4] .

   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

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \ .$$

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 [K36, K17, K73] [L55, L61].

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 super-conformal 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 [K36, K73].

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 [L28] [L55, L56, L57] 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 [A18] 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 [L61]. 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 [L61] 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 [L61] 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 [L61] 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 [L58] 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 [K46, K47]). 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 [L58], 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 [L58], 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 [L58].

3. p-Adic length scale hypothesis [L62] 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 [L61] 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 $\delta M^4_+ \times CP_2$ [K36, K17]. 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 [L60].

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 [K50, K41, K14]. The fusion of the various p-adic physics leads to what I call adelic physics [L26, L27]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K18, K19, K20, K21].

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 [L51, L52] 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 [L58, L60]. Also the ordinary 3→ 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 [L28] 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 [A10]. 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

$$|x| = p^{-k_0(x)} . \quad \text{(A-6.2)}$$

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

$$x = p^{k_0}\varepsilon(x) , \quad \text{(A-6.3)}$$

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:

$$d(x, z) \leq max\{d(x, y), d(y, z)\} . \quad \text{(A-6.4)}$$

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

$$d(x, y) \leq D . \quad \text{(A-6.5)}$$

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 [B13]. 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

$$\begin{aligned} y &= \sum_{k>N} y_k p^k \to x = \sum_{k<N} y_k p^{-k} , \\ y_k &\in \{0, 1, .., p-1\} . \end{aligned} \quad \text{(A-6.6)}$$

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 **??**) has changed considerably towards the end 2021 [L55] 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 $p^k \rightarrow m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L55] 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 [L55] 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 [L51, L52]. 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 $X^4 \subset M^8$ [L41]. 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 [L55]. 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 [L53] 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 [L55]. 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 [L46] [K100].

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 [L46].

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 [L39] in atomic scale can be explained by the same mechanism [L39]. 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 [J18] 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 [L40]. 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 [L44, L71].

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 [L44, L71]. 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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