TGD AND EEG: 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 $H = M^4 \times CP_2$ [L128]. 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 [L41, L56](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 [L129].

- 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 [K87, L72].

- 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 [K15, K39] [L120].

- 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 [L125]. 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 [L131].

- 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 [L39, L40] 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 [L130]. 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. 4.5**). 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 [L117], 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 [A10]. I have proposed [K34, K18, K84, K63, L129] 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 [K87, L72] 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 [L126]. 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 [L112, L113] 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 [L131].

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 [L122]. Quite generally, long range classical gravitational, electric and magnetic fields give rise to very large values of effective Planckl constants. The Nottale's hypothesis of gravitational Planck constant generalizes to electric interactions.

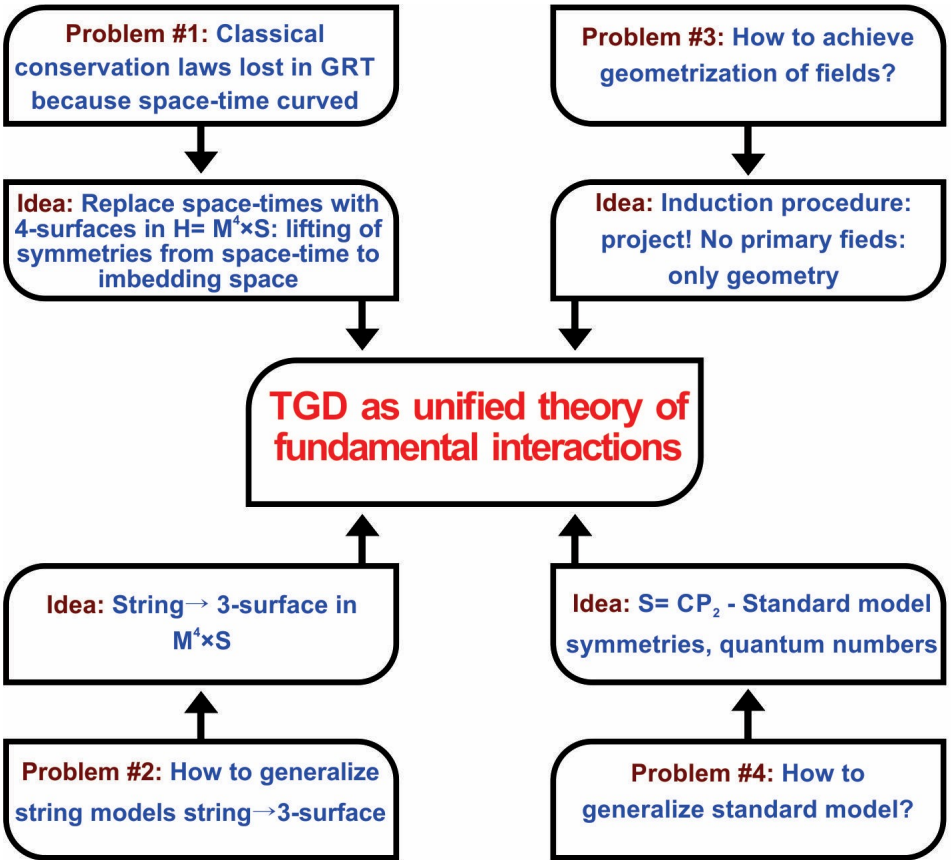

Figure 1: The problems leading to TGD as their solution.

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

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

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

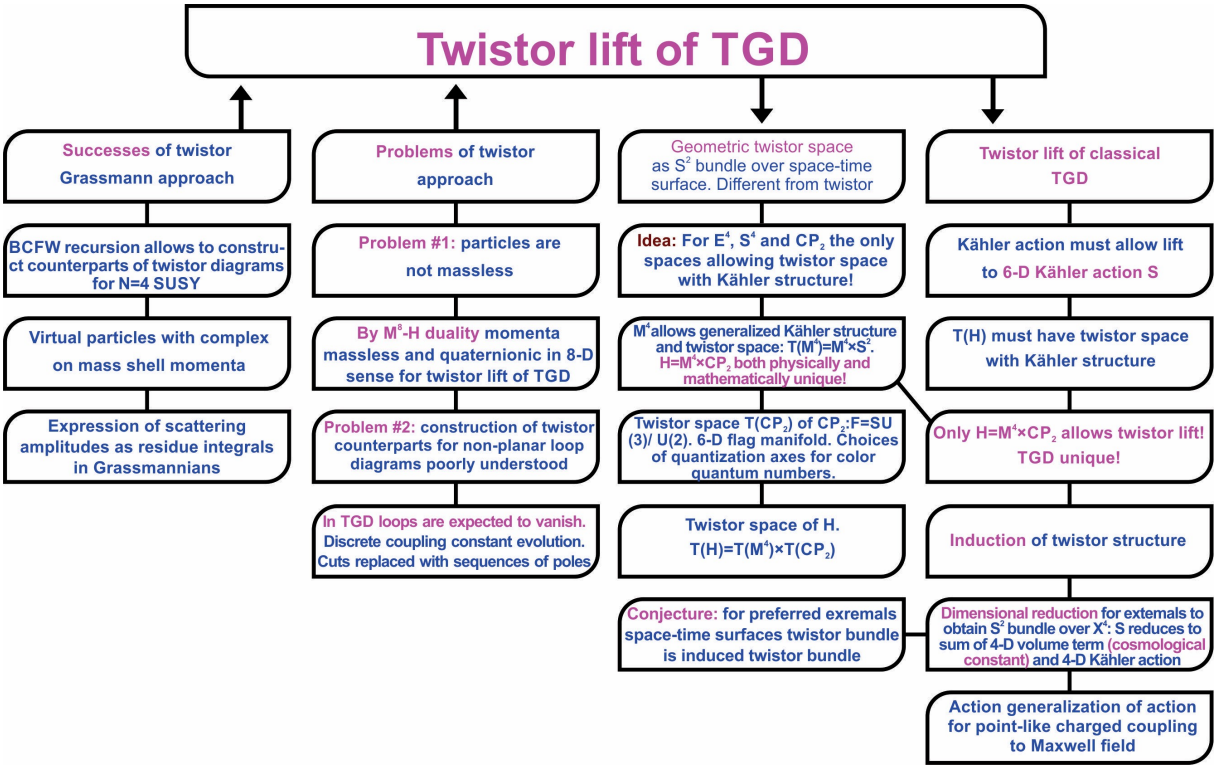

Figure 2: Twistor lift

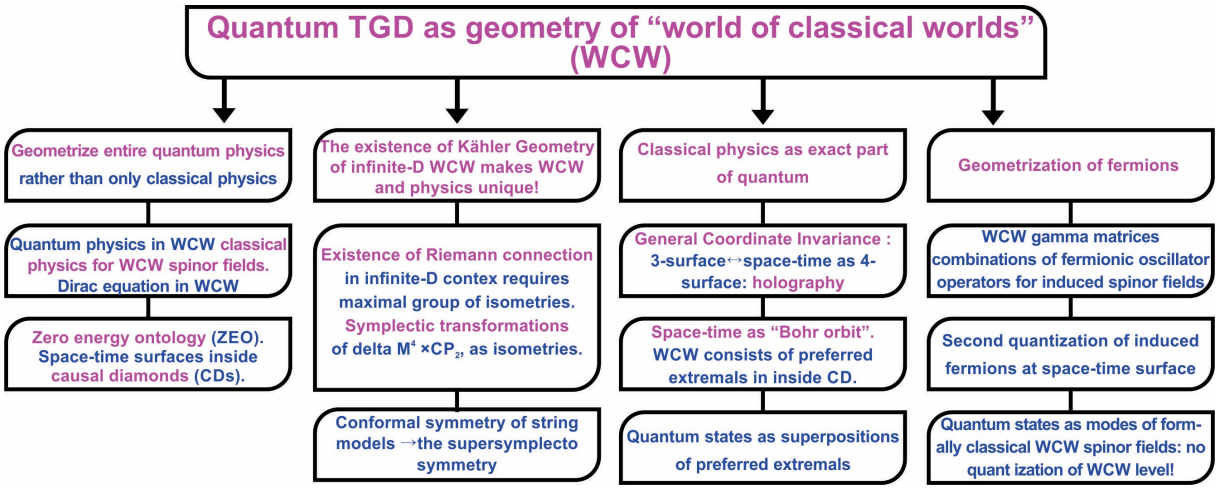

Figure 3: Geometrization of quantum physics in terms of WCW

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

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

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

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

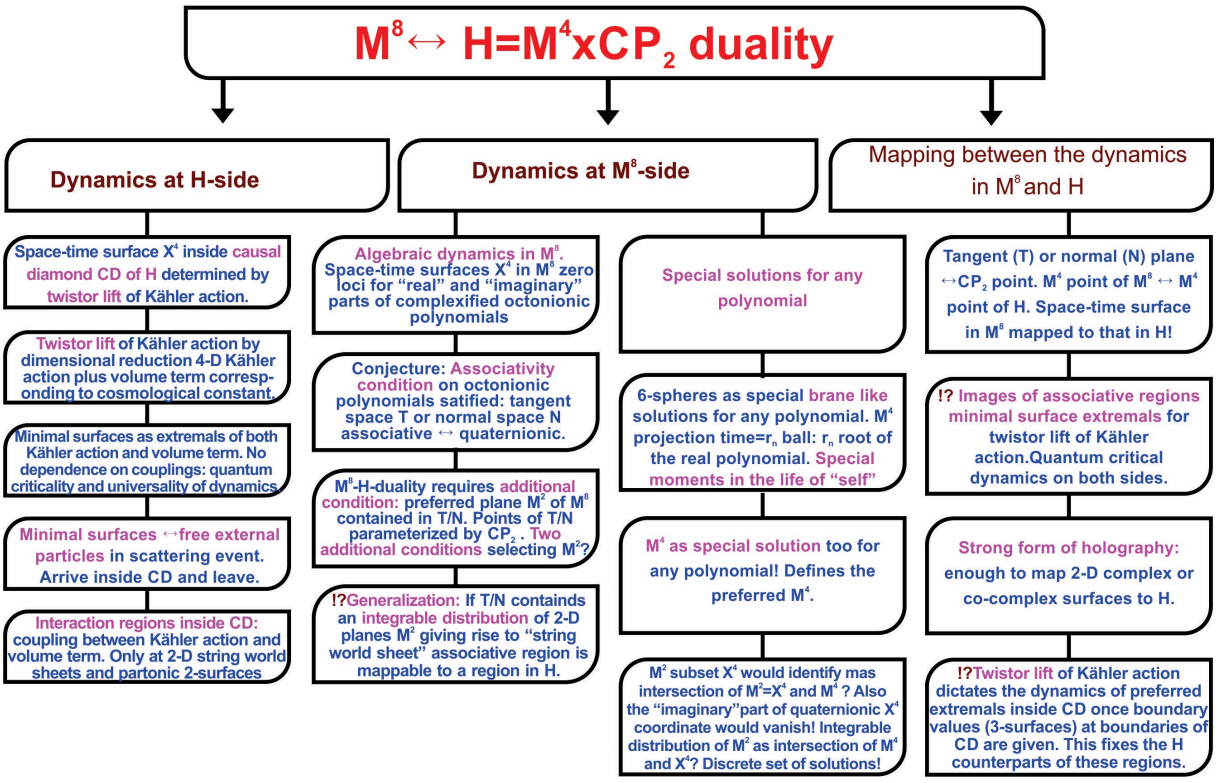

Figure 4: $M^8 - H$ duality

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

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

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

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

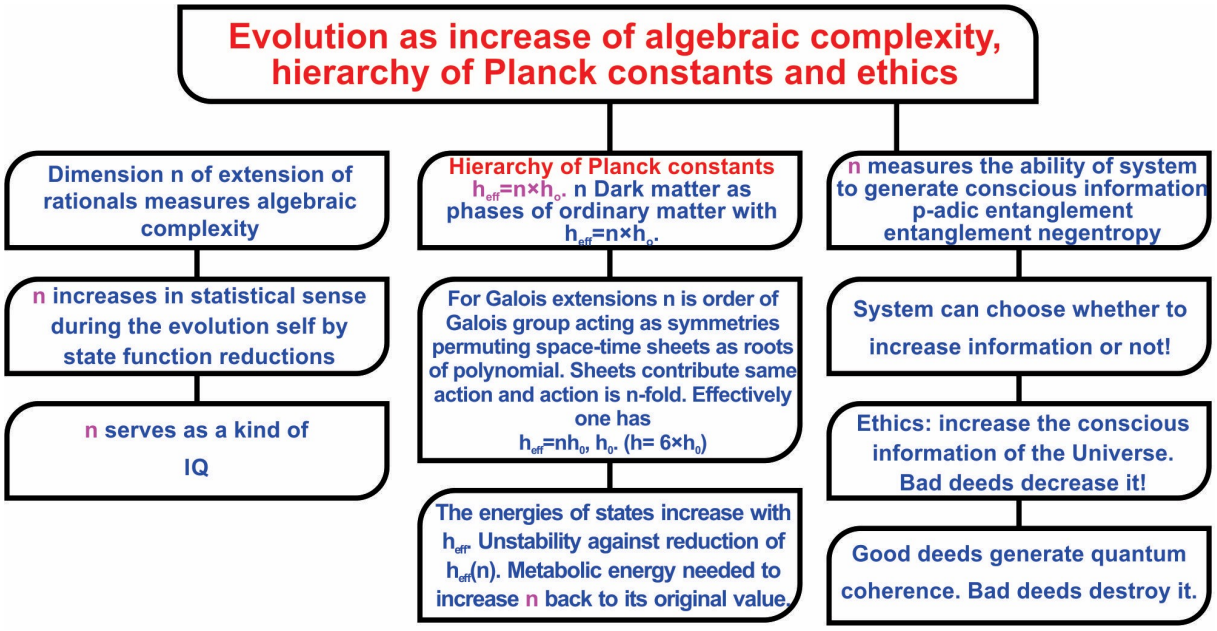

Figure 5: Number theoretic view of evolution

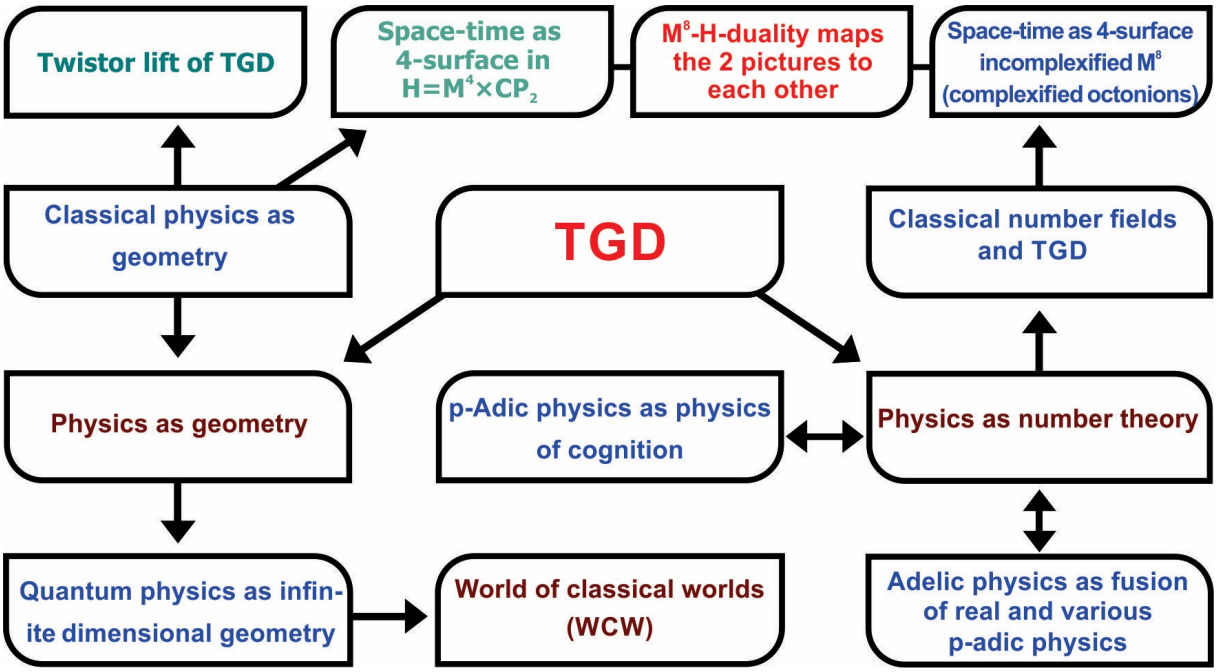

Figure 6: TGD is based on two complementary visions: physics as geometry and physics as number theory.

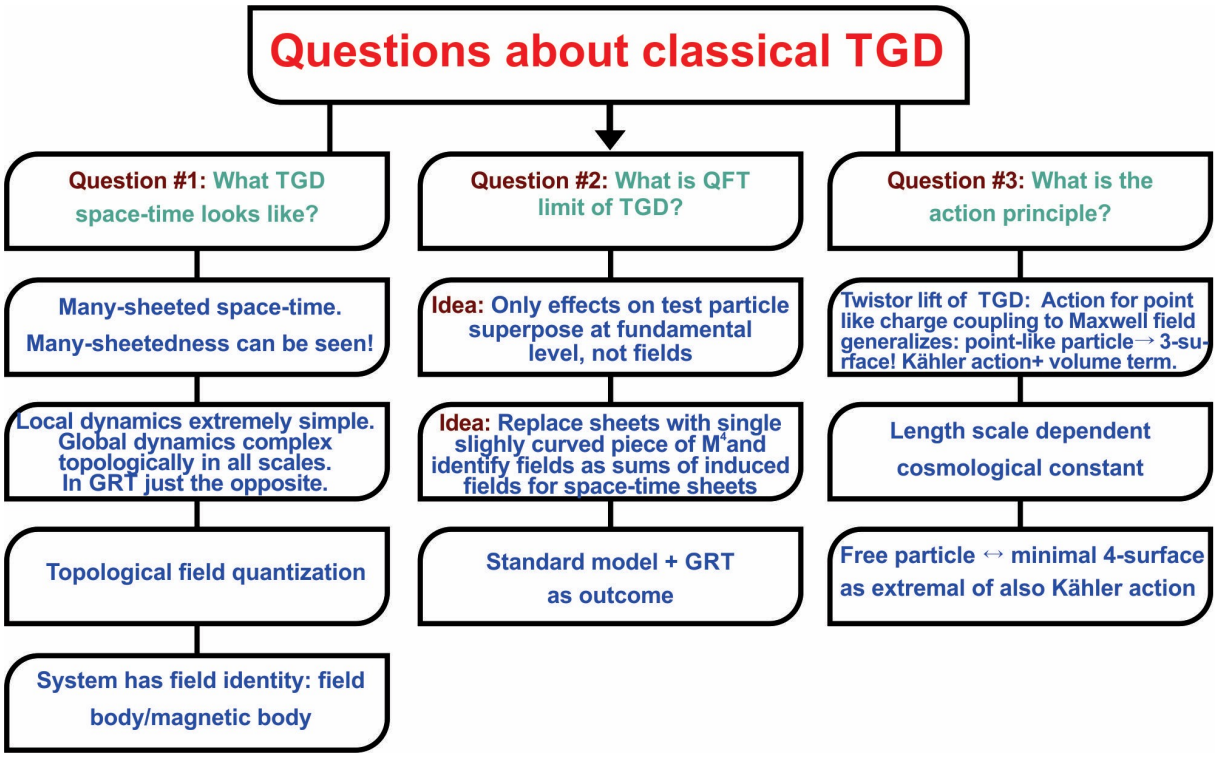

Figure 7: Questions about classical TGD.

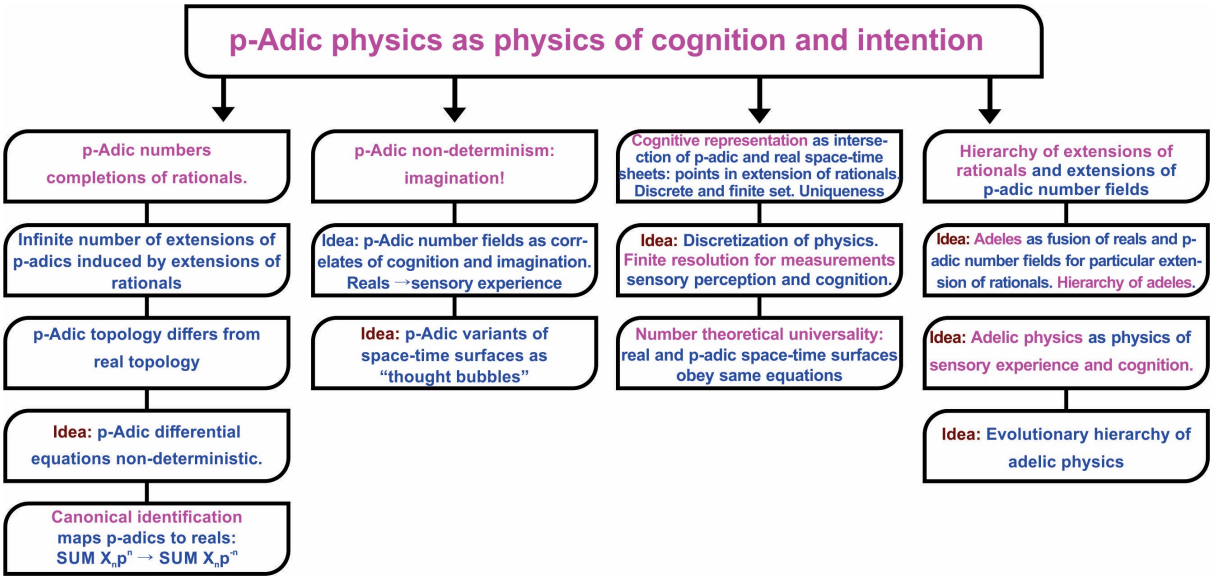

Figure 8: p-Adic physics as physics of cognition and imagination.

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

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

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

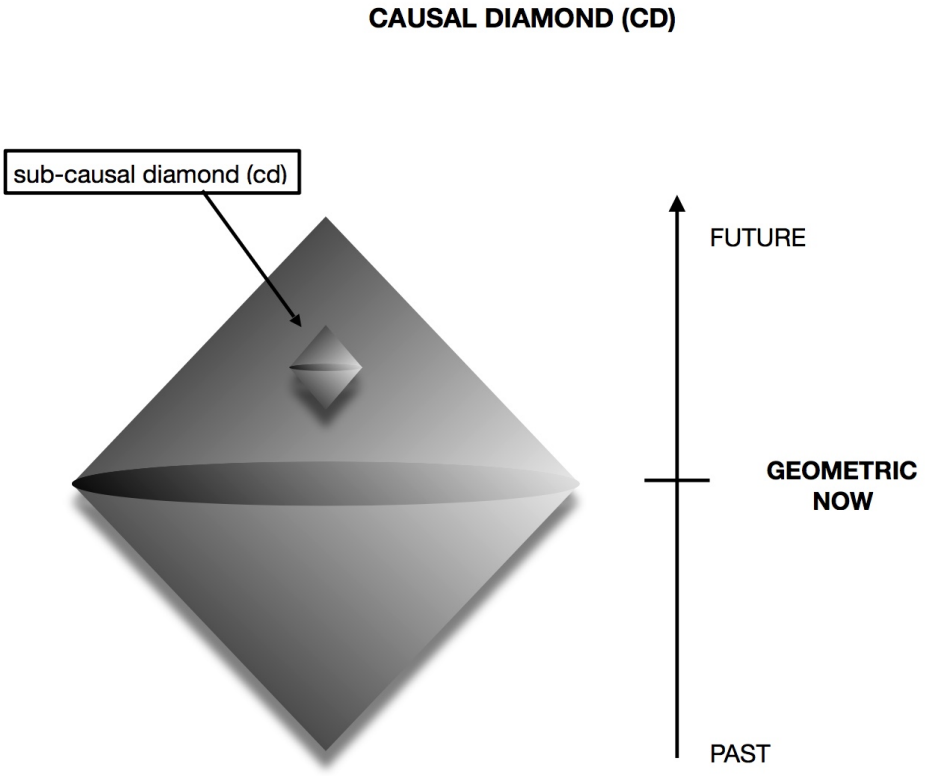

Figure 9: Causal diamond

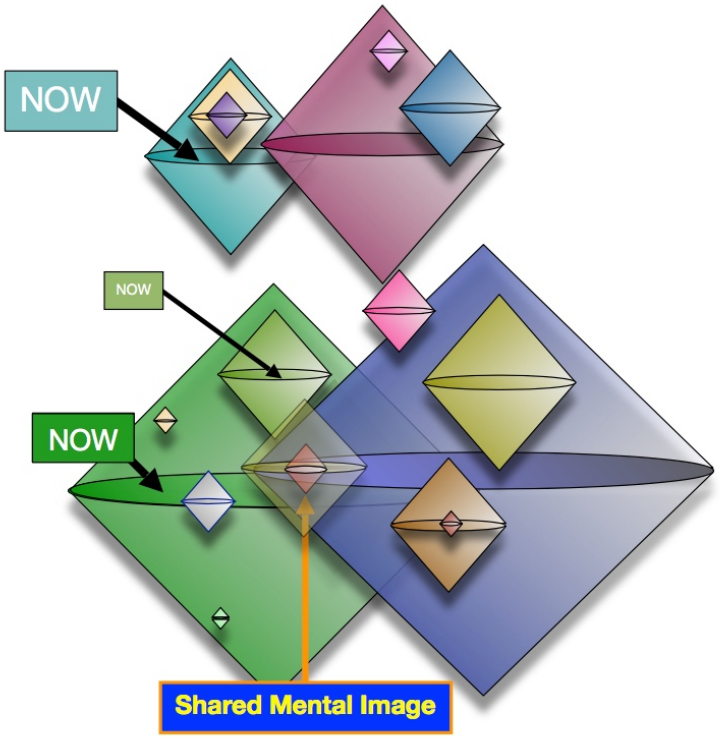

Figure 10: CDs define a fractal "conscious atlas"

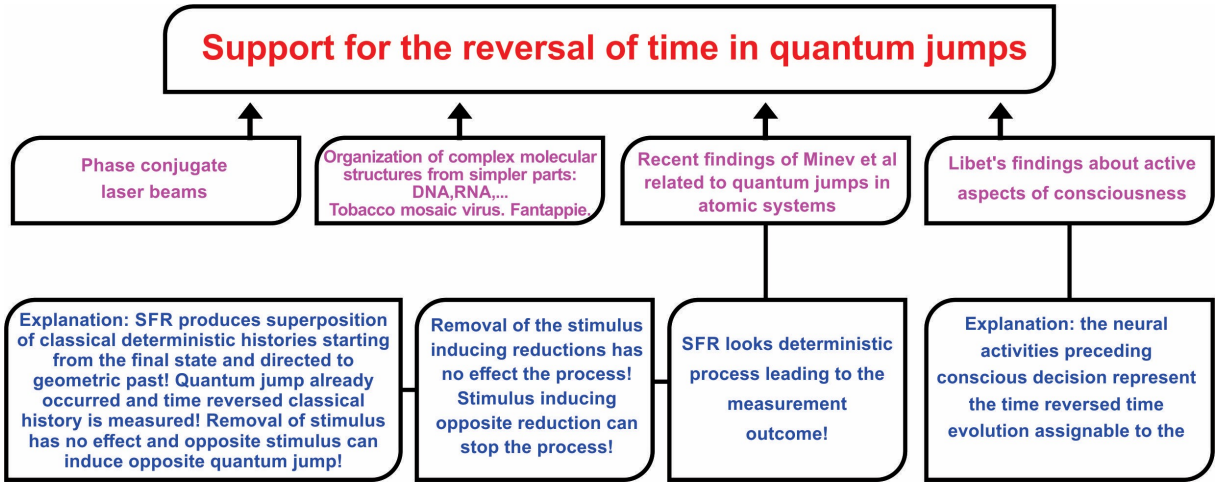

Figure 11: Time reversal occurs in BSFR

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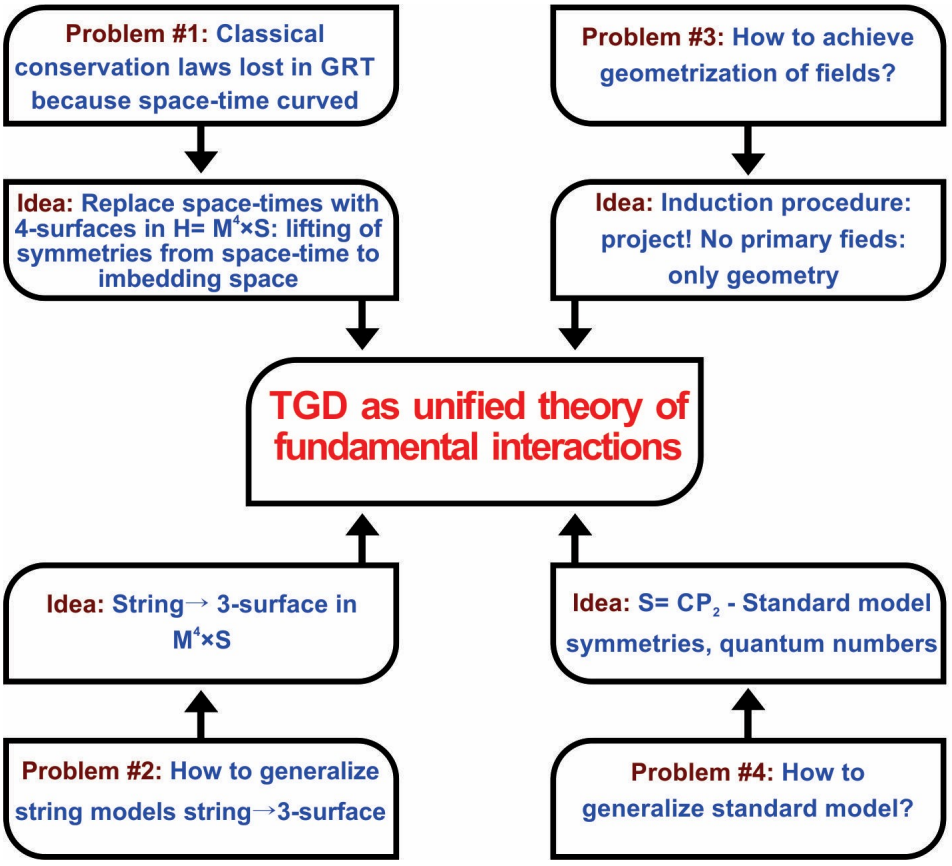


Figure 12: The problems leading to TGD as their solution.

TGD view of consciousness very briefly

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

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

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

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

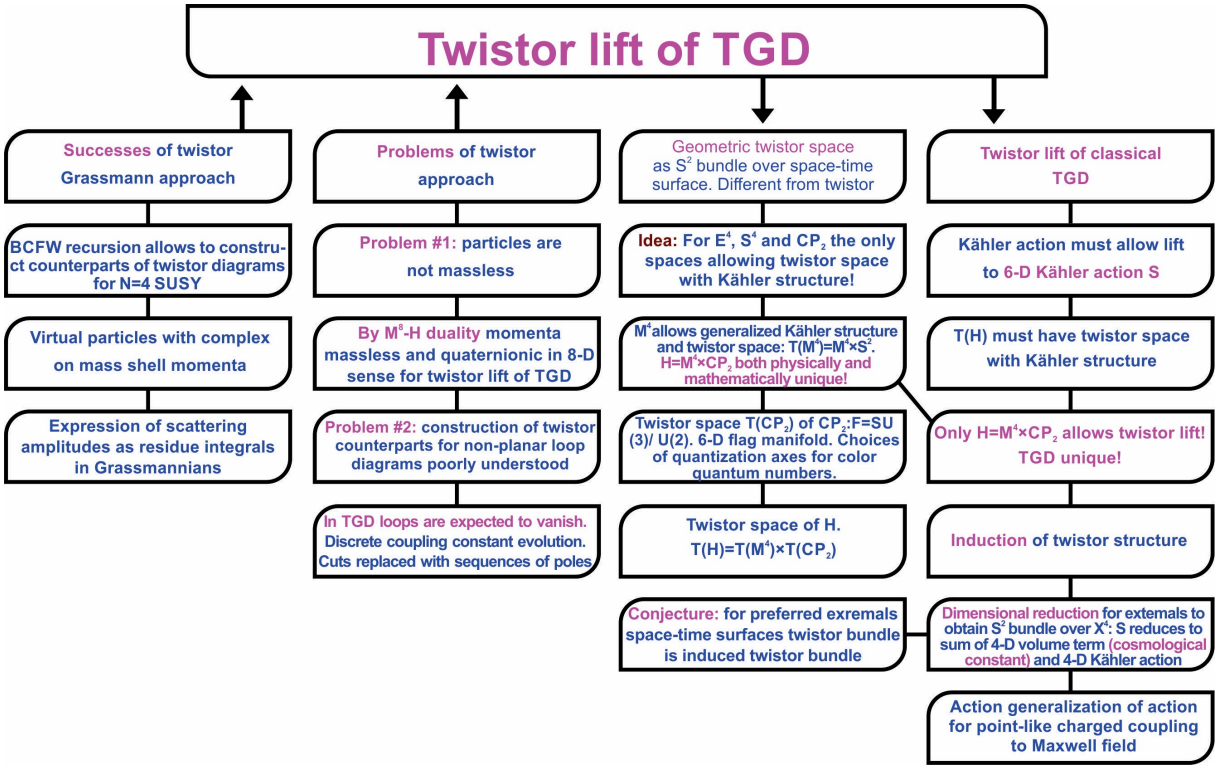


Figure 13: Twistor lift

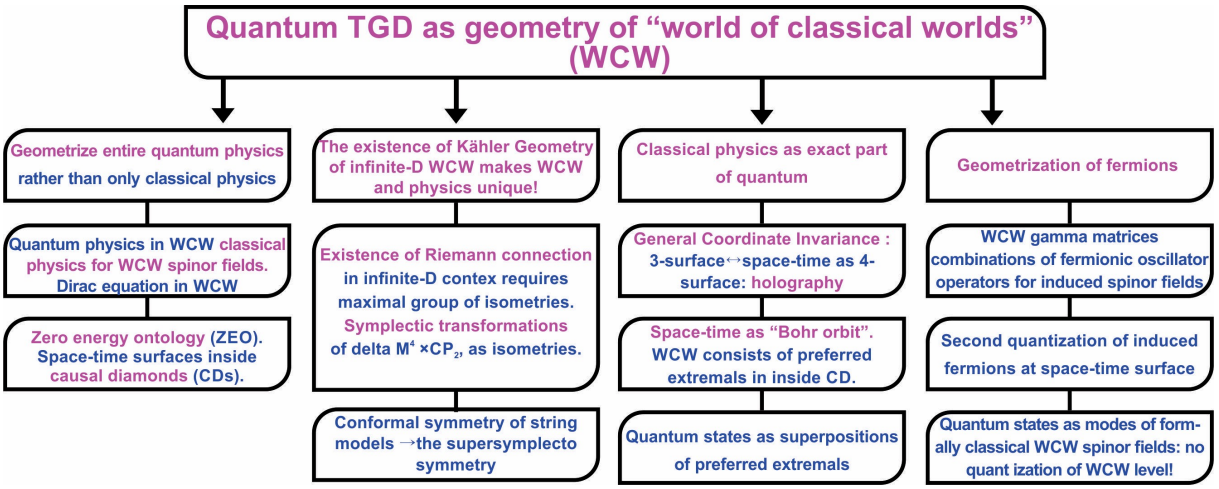


Figure 14: Geometrization of quantum physics in terms of WCW

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

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

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

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

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

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

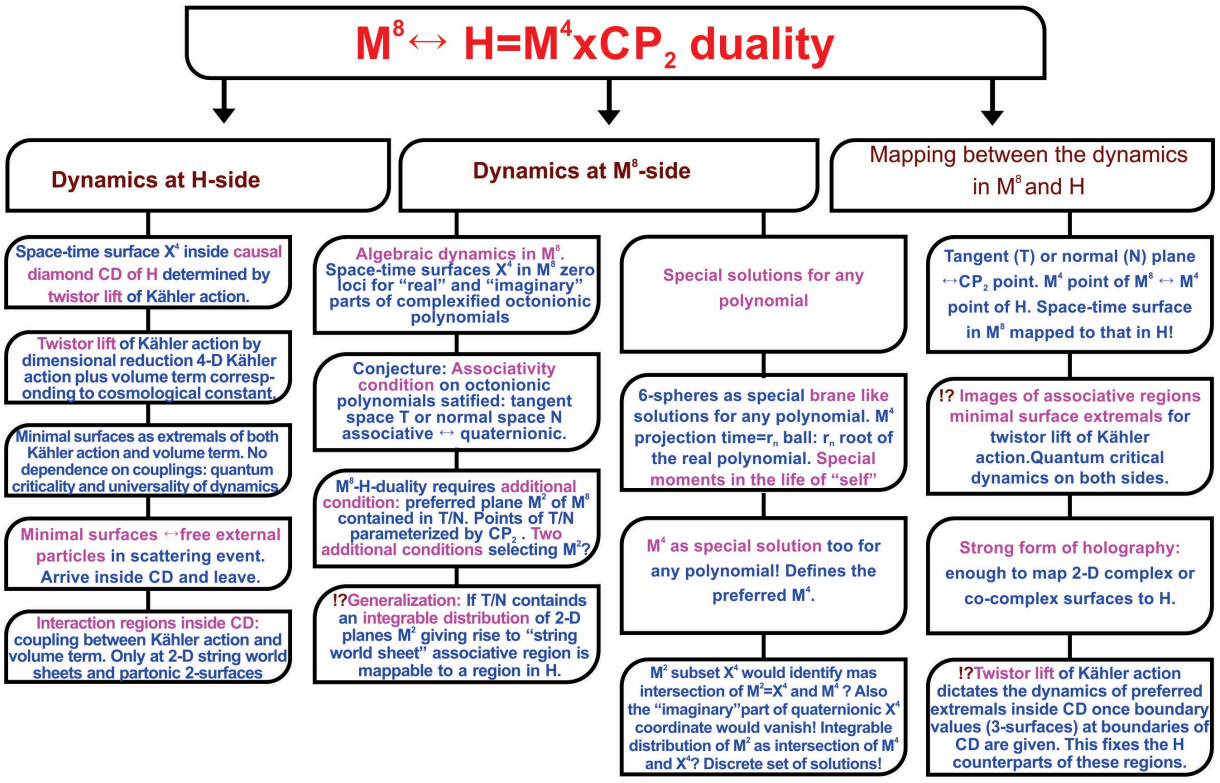


Figure 15: $M^8 - H$ duality

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

Figures

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

Karkkila, April 22, 2024, Finland

Matti Pitkänen

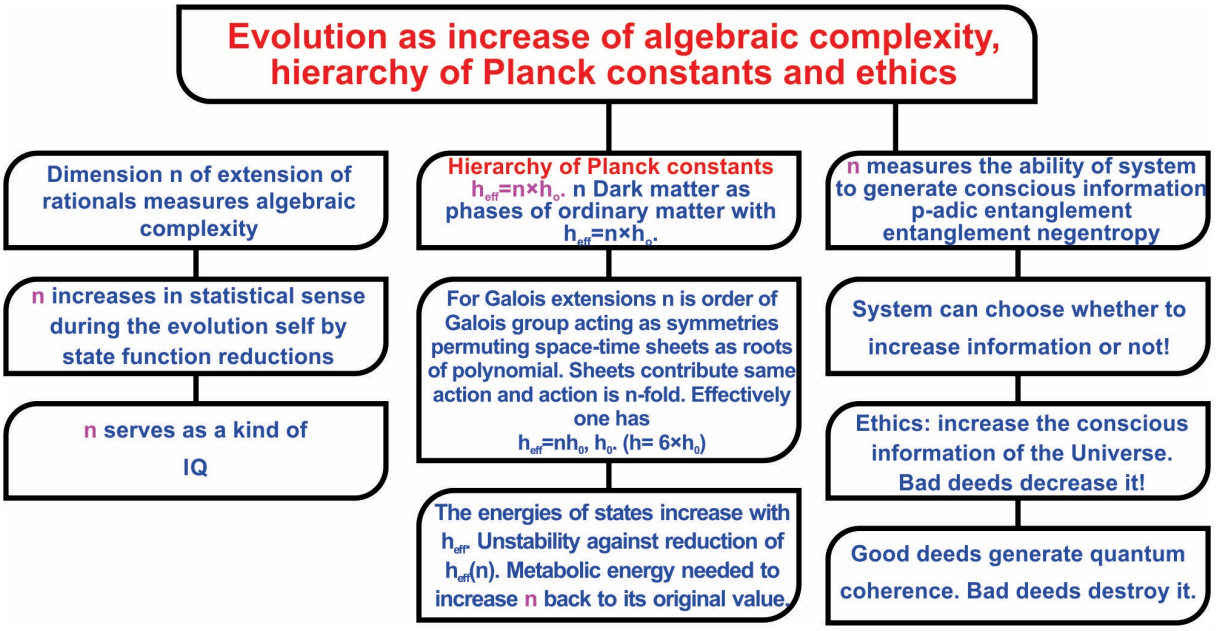
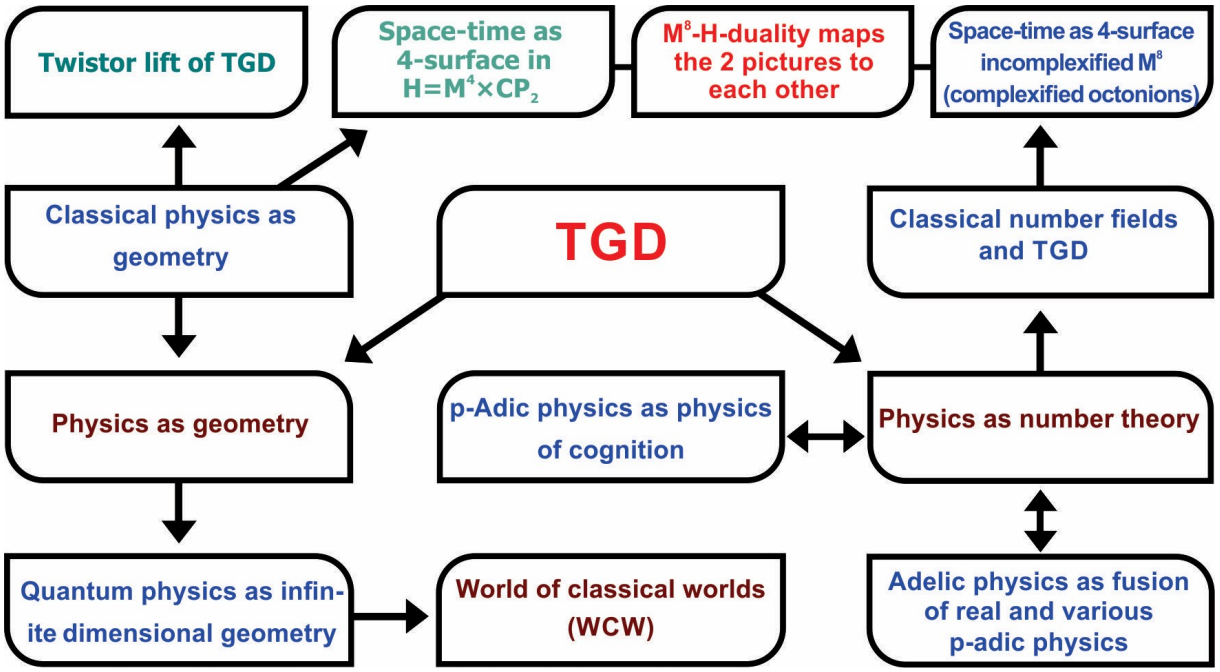


Figure 16: Number theoretic view of evolution



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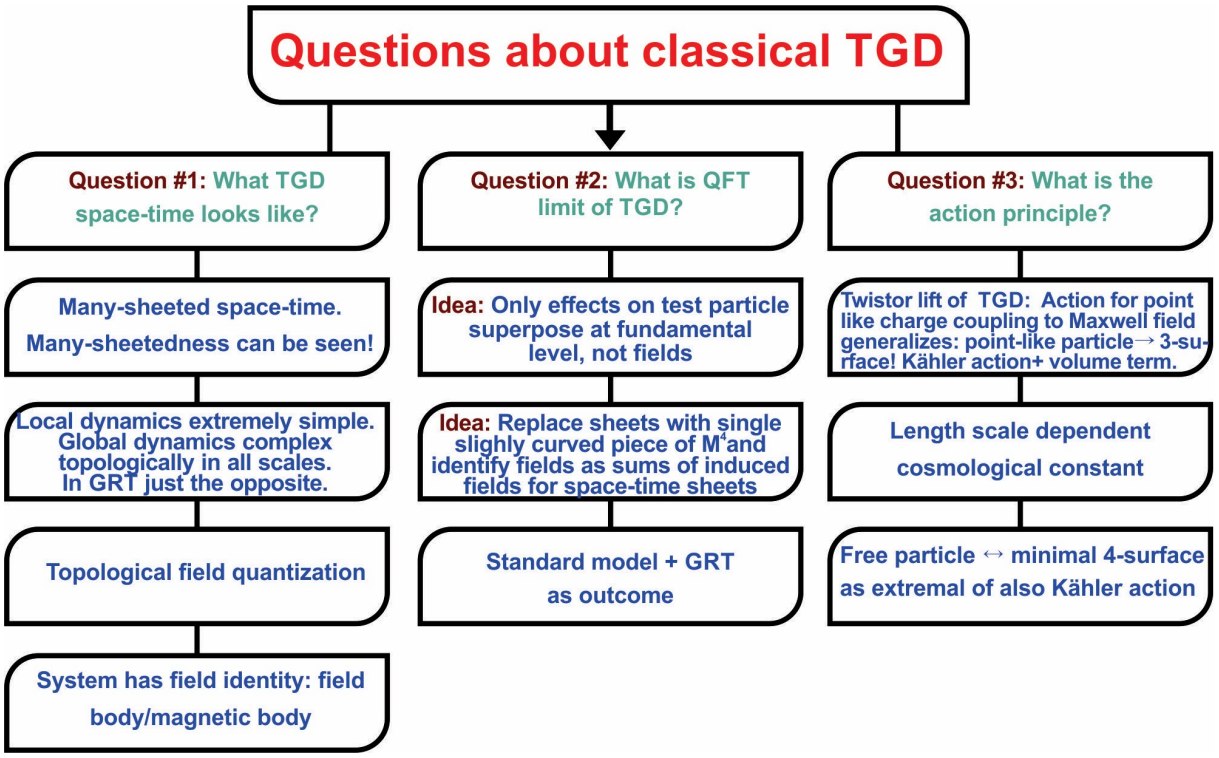

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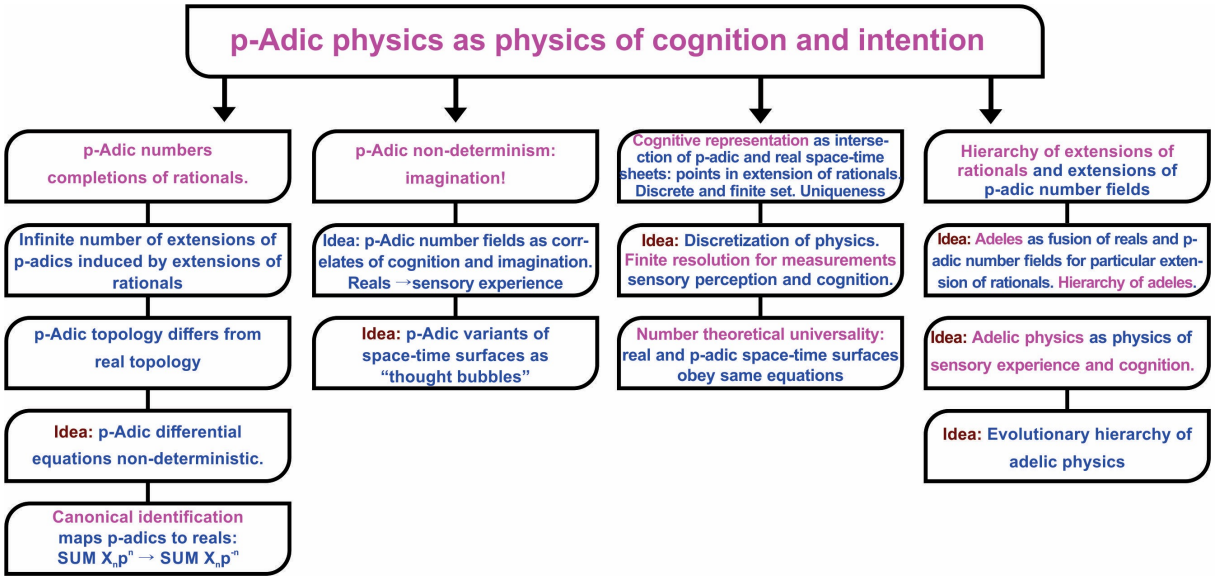


Figure 19: p-Adic physics as physics of cognition and imagination.

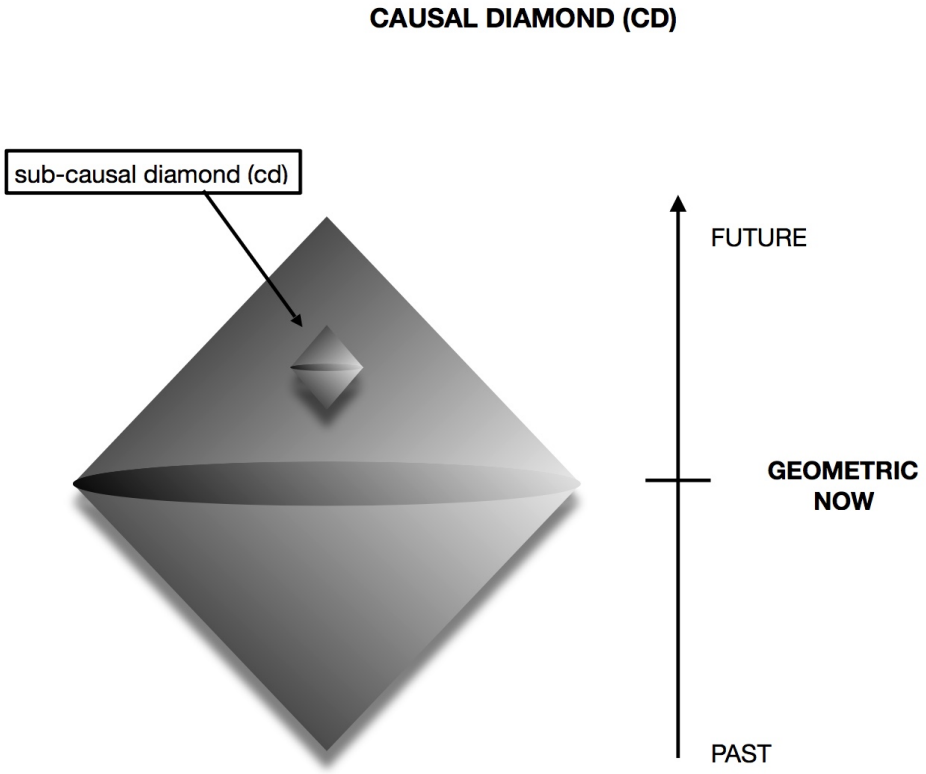
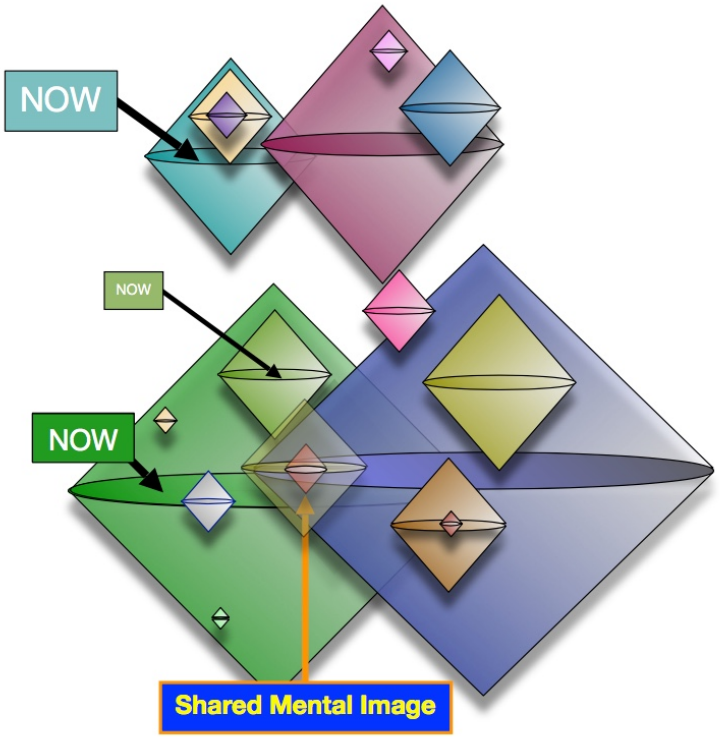


Figure 20: Causal diamond



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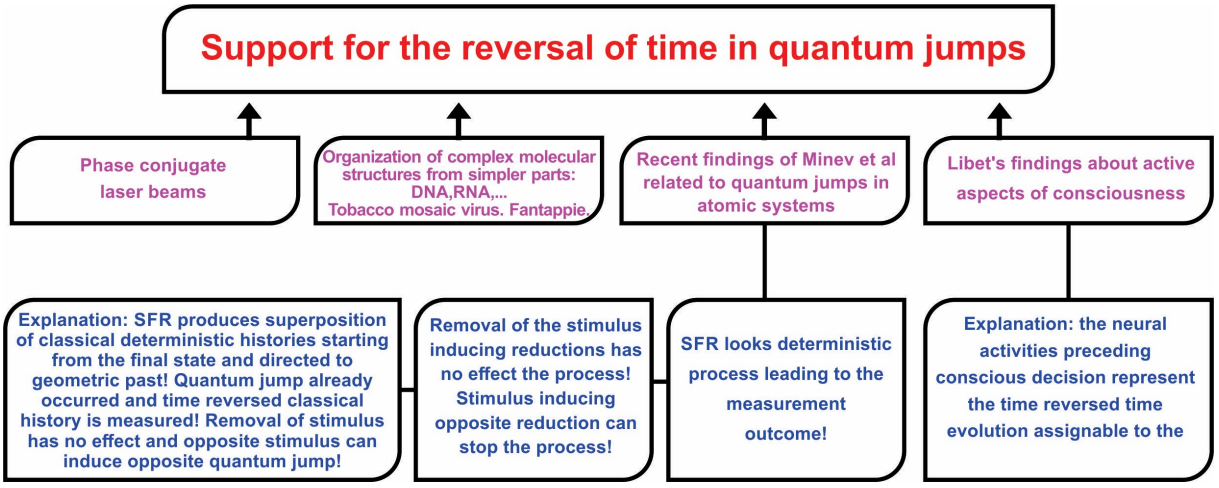

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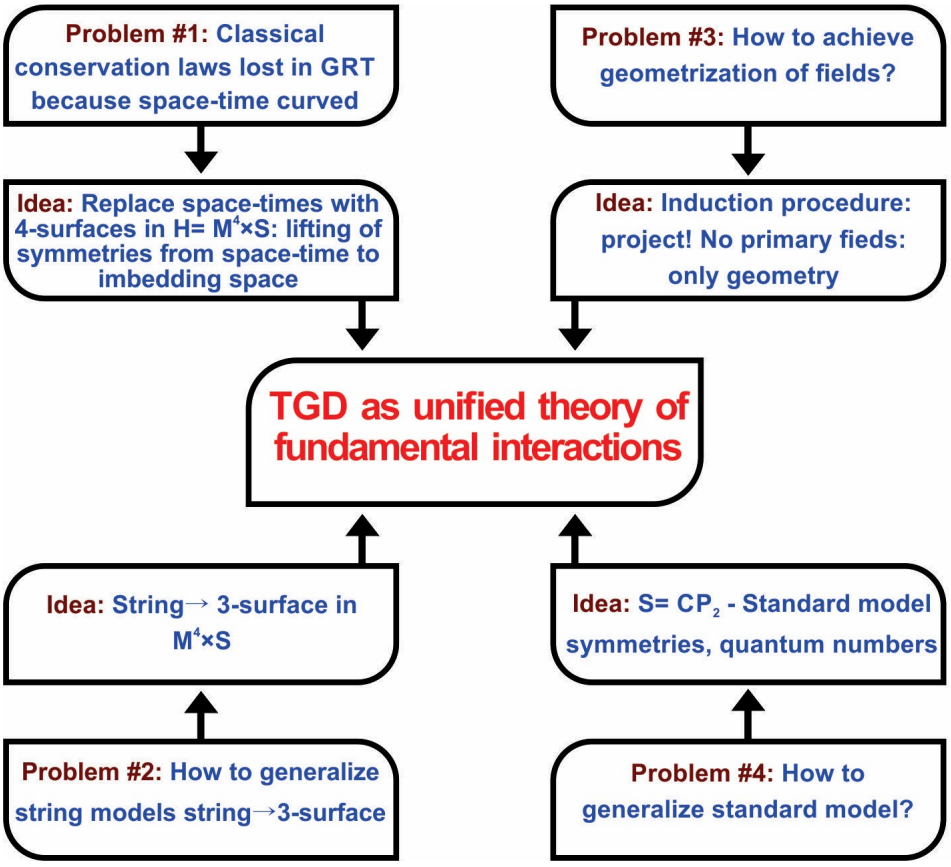

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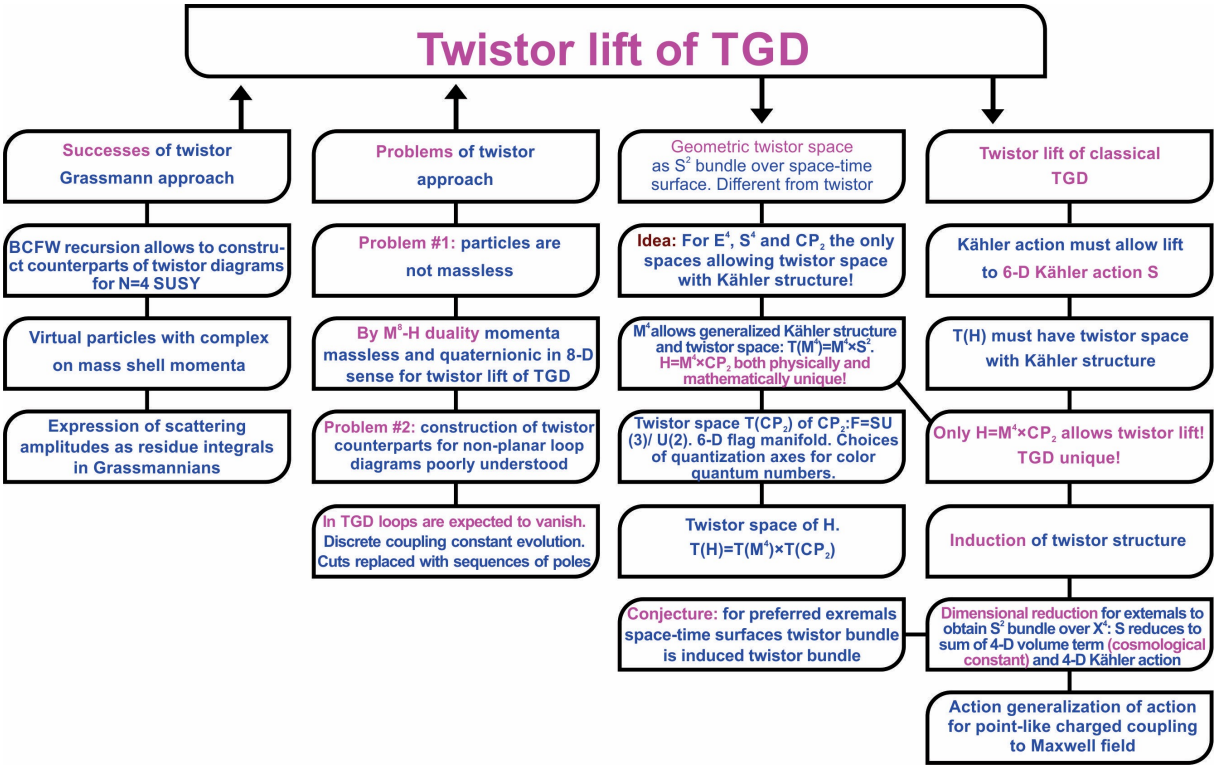

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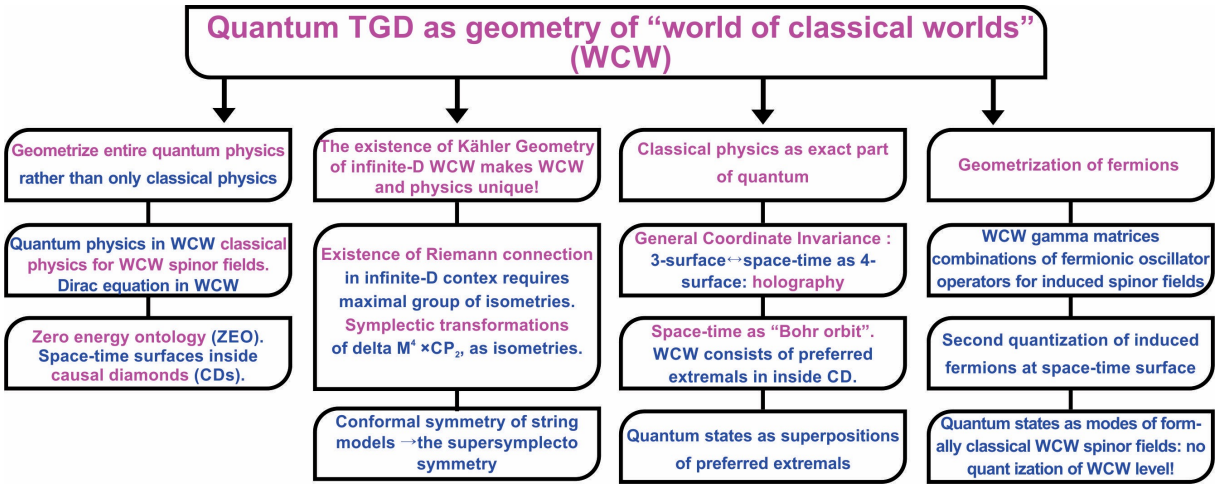

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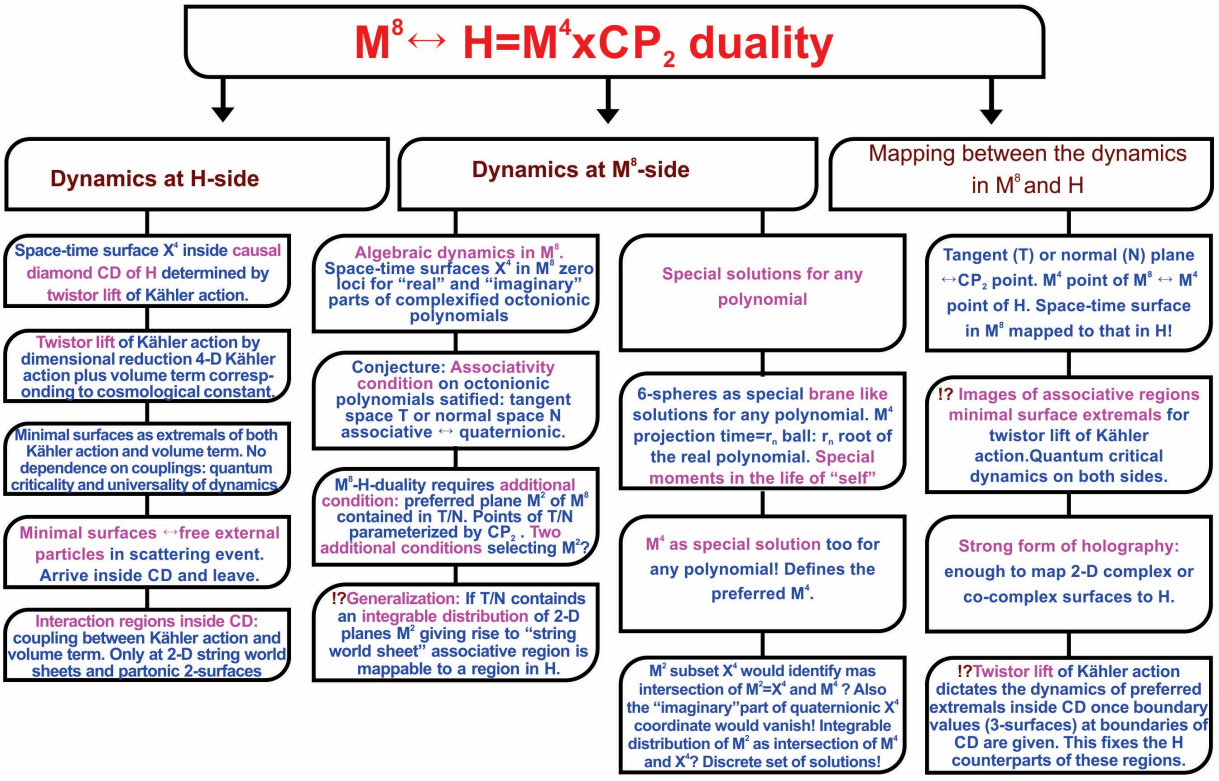
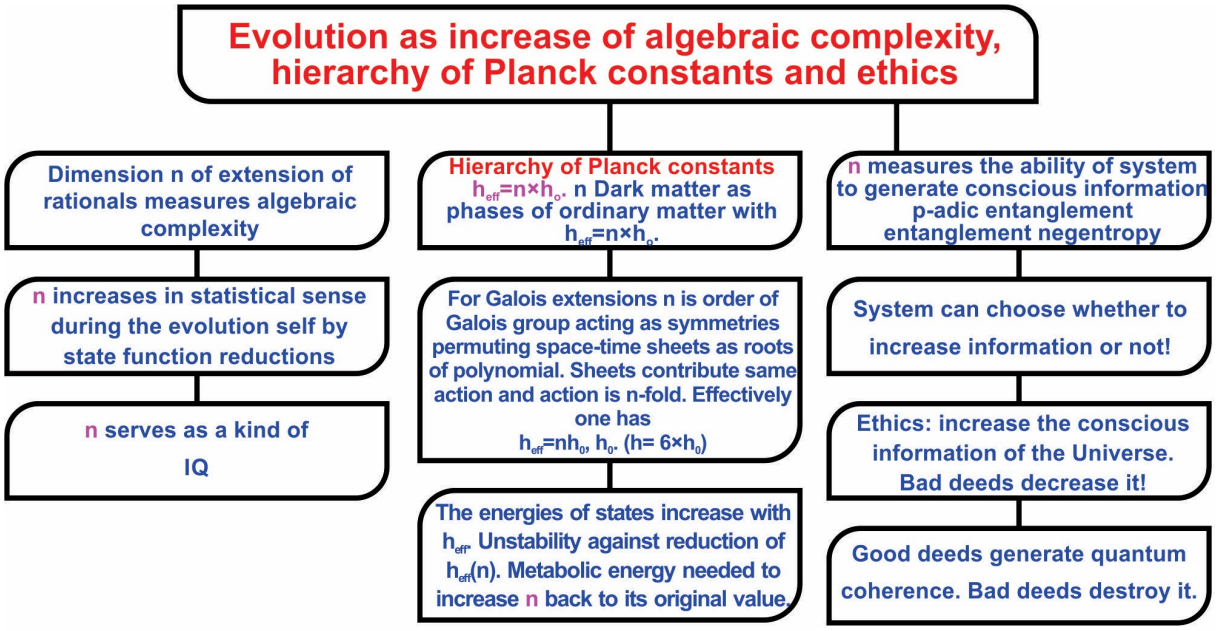


Figure 26: $M^8 - H$ duality



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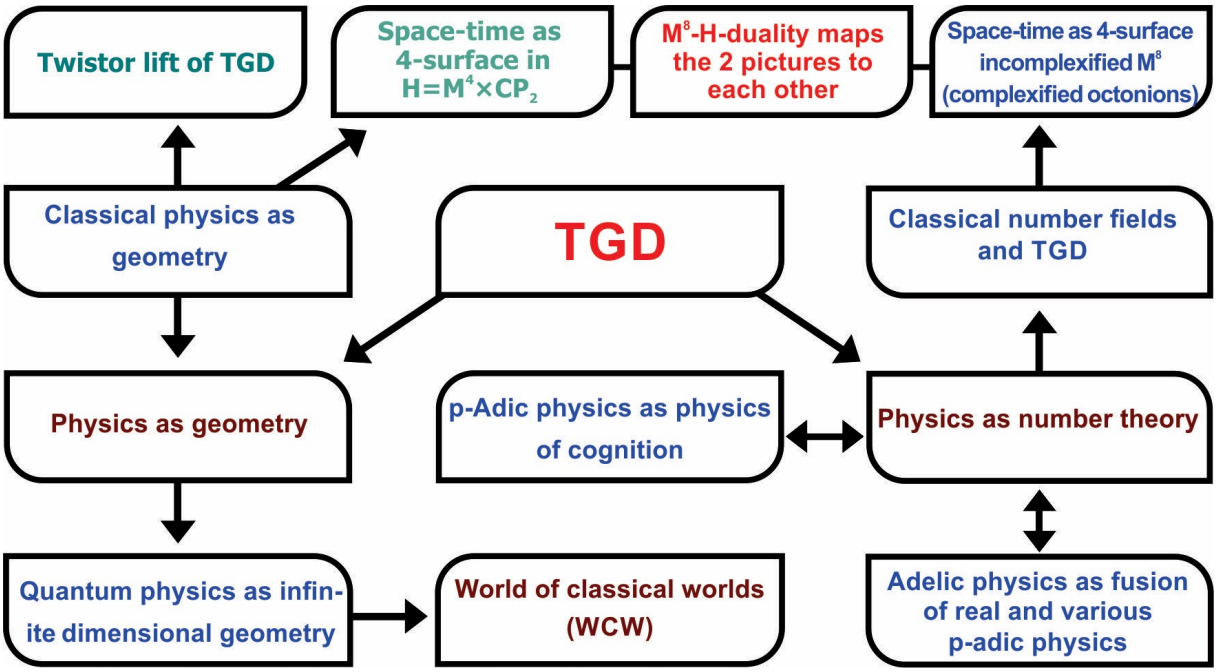

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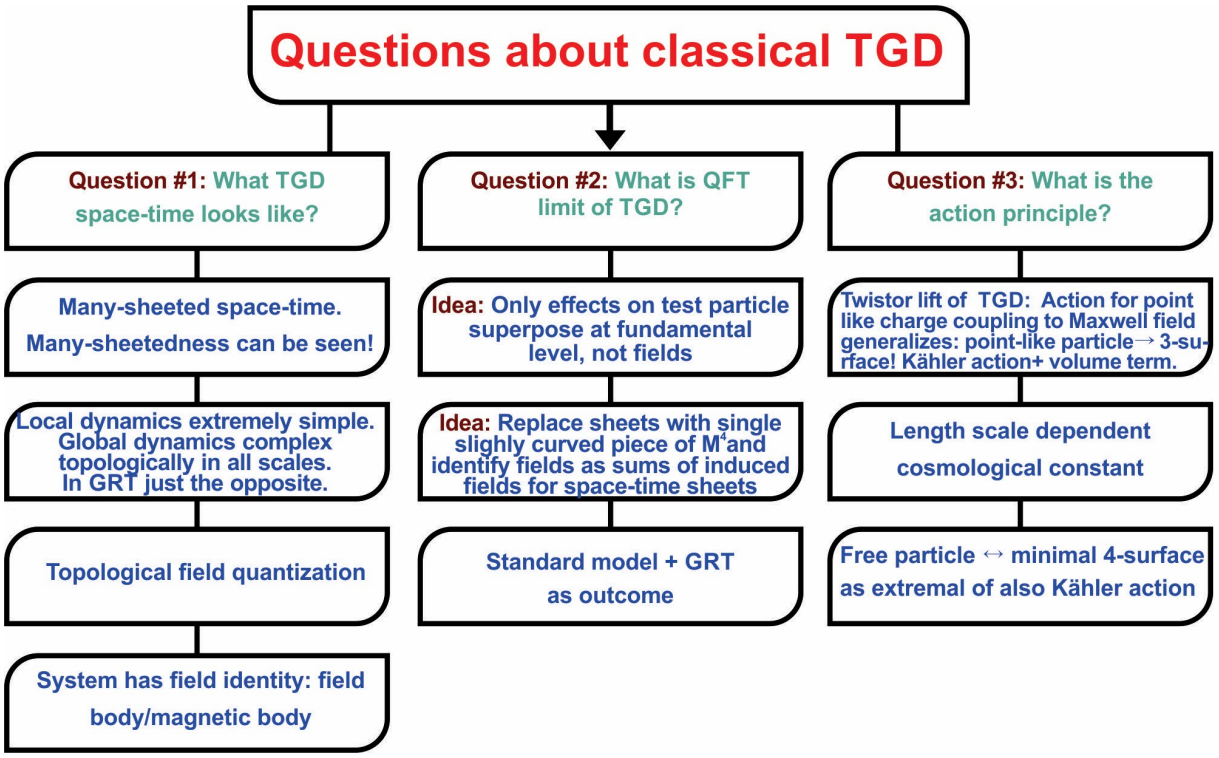

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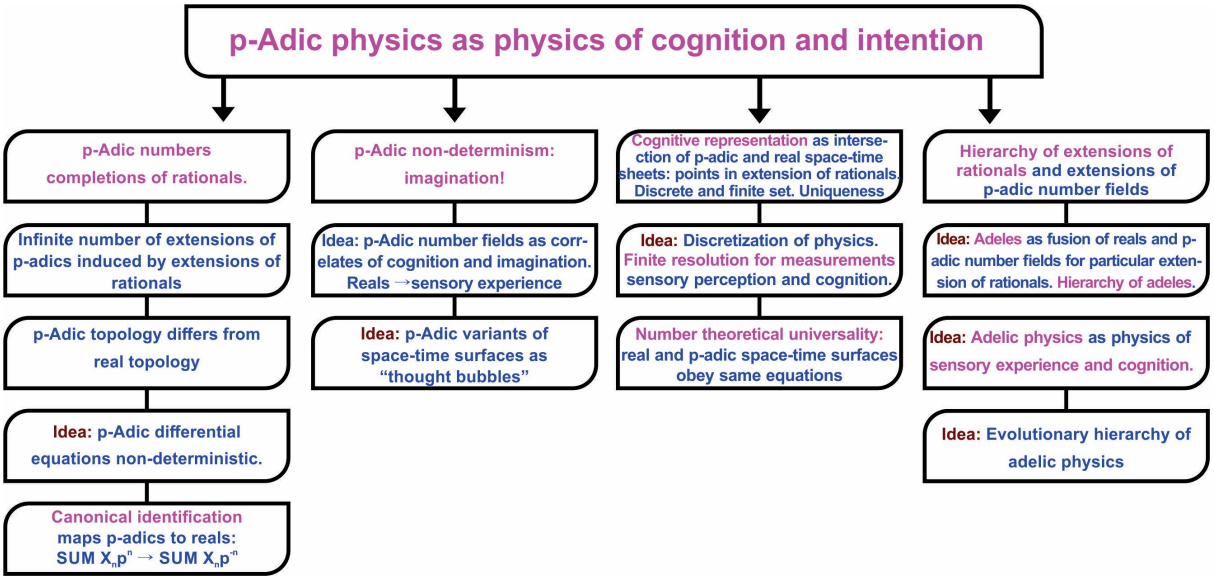

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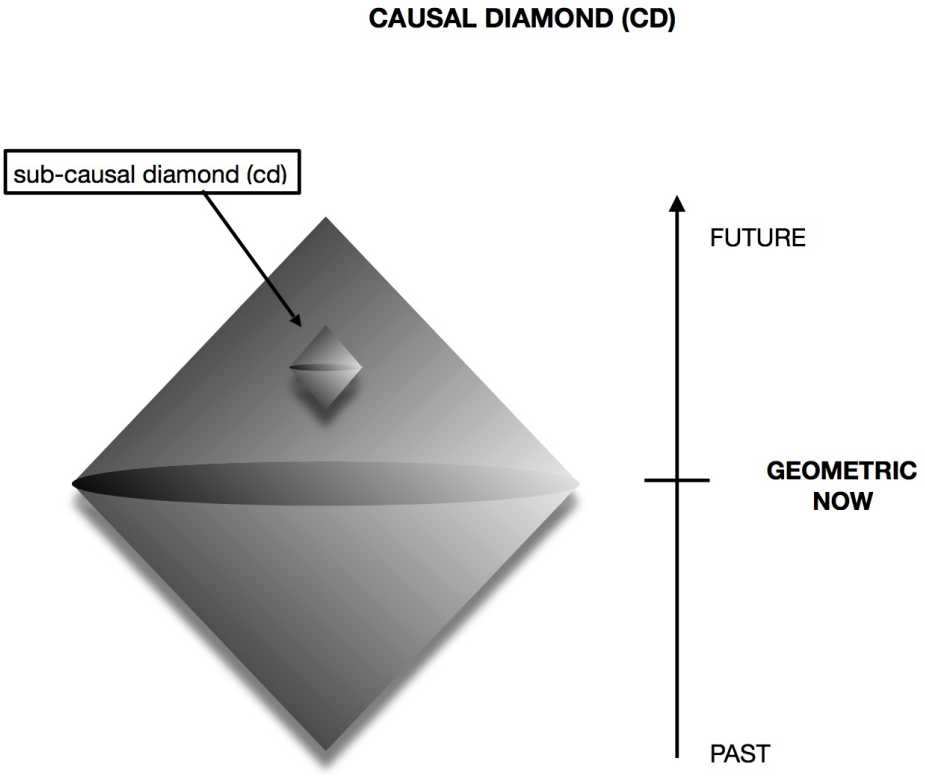

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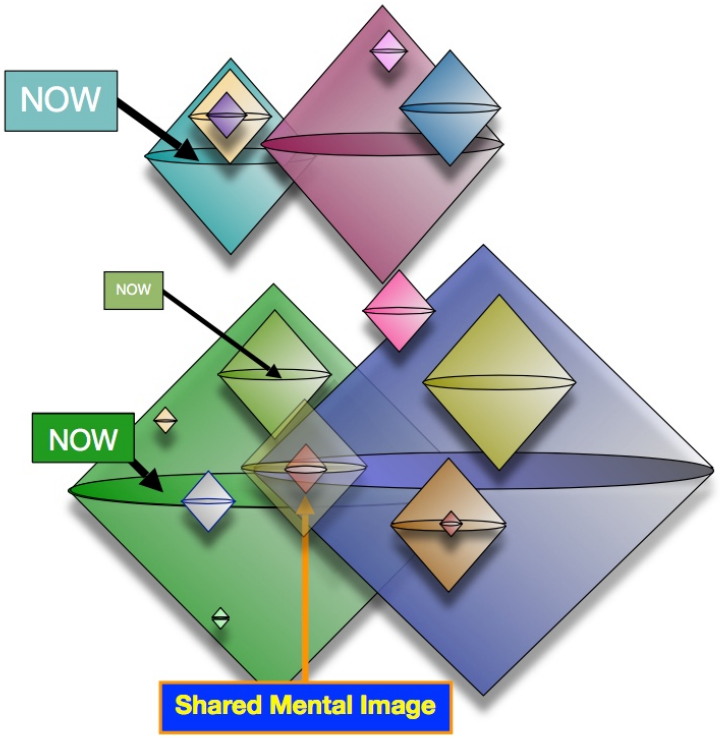

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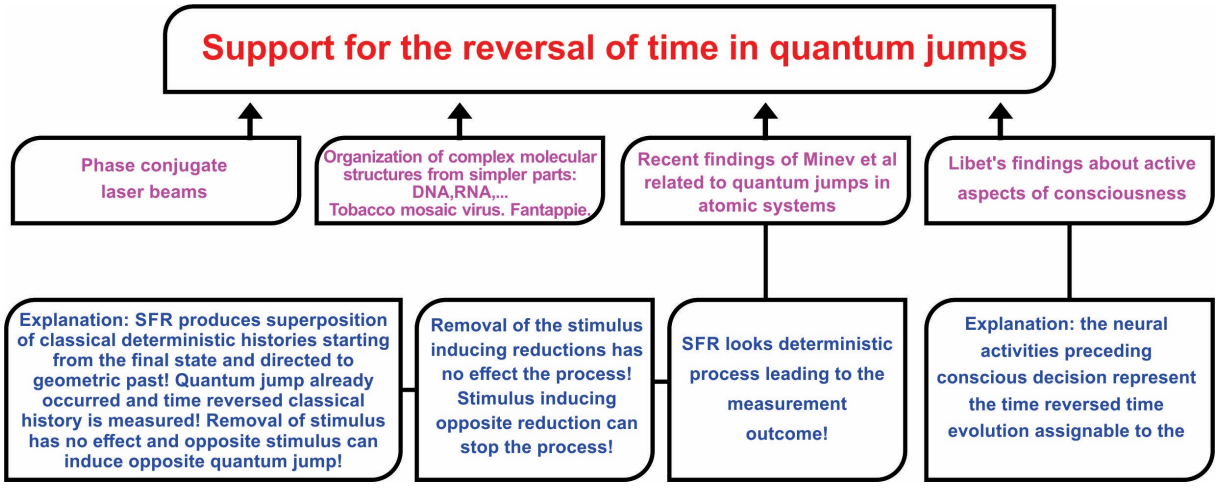

Figure 33: Time reversal occurs in BSFR

ACKNOWLEDGEMENTS

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

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

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

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

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

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

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

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

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

Karkkila, August 30, 2023, Finland

Matti Pitkänen

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Introduction

1.1 Basic Ideas of Topological Geometrodynamics (TGD)

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

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

1.1.1 Geometric Vision Very Briefly

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

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

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

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

Twistor lift of TGD means that one can lift space-time surfaces in H to 6-D surfaces a analogs of twistor space of space-time surface in the Cartesian product of the twistor spaces of M^4 and CP_2, which are the only 4-manifolds allowing twistor space with Kähler structure [A16]. The twistor structure would be induced in some sense, and should coincide with that associated with the induced metric. Clearly, the 2-spheres defining the fibers of twistor spaces of M^4 and CP_2 must allow identification: this 2-sphere defines the S^2 fiber of the twistor space of the space-time surface. This poses a constraint on the embedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces. The existence of Kähler structure allows to lift 4-D Kähler action to its 6-D counterparts and the 6-D counterpart of twistor space is obtained by its dimensional reduction so that one obtains a sphere bundle. This makes possible twistorialization for all space-time surfaces: in general relativity the general metric does not allow this.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3. TGD is *not* a gauge theory. In TGD framework the counterparts of also ordinary gauge symmetries are assigned to super-symplectic algebra (and its Yangian [A5] [B6, B4, B5]), 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 [B3]) 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 [A11, A15, A9, A14].

The identification of the space-time as a sub-manifold [A12, A18] 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 [A17, A19, A21]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \to B + C$. Classically this corresponds to a path of WCW leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

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

Construction of the counterparts of S-matrices

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

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

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

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

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

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

The notion of M-matrix

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

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

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

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

   The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to a representation matrix of scaling: $S(n) = S^n$, where S is unitary S-matrix associated with the minimal CD [K45]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

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

1.1.6 TGD as a generalized number theory

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

The Threads in the Development of Quantum TGD

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

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

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

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

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

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

Number theoretic vision very briefly

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K41].

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

Infinite primes

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

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

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

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

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

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

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

Holography in H

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

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

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

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

Number theoretic holography in M_c^8

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

What could the number theoretic holography mean physically?

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

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

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

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

Twistor lift of the holography

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

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

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

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

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

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

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

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

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

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

Dark Matter as Large $\hbar$ Phases

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

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

Nottale's hypothesis would predict a gigantic value of h_{gr}. Equivalence Principle and the independence of gravitational Compton length on mass m implies however that one can restrict the values of mass m to masses of microscopic objects so that h_{gr} would be much smaller. Large h_{gr} could provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K67].

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 [K56, K57, K54]) 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 [K77]. 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 [A16]. 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 co-incides 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 [L55].

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 [L40]. 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 Bird's Eye of View about the Topics of "TGD and EEG: Part II"

The general ideas of "TGD and EEG" are discussed in the first part of the book so that it is enough to explain the organization of "TGD and EEG: Part II". The book contains parts.

1. The first part represents chapters devoted to TGD inspired models for hearing, music experience, and language.

   Also included are two chapters about the notion of bioharmony which started as a model of musical harmony based on the properties of icosahedron and tetrahedron. Surprisingly, the model led to successful models for the genetic code. Gene would be analog of a music piece consisting of N codons represented as 3-chords of light. This led to an identification of the bioharmony for the "music of light" as a correlate for emotions. Bio-communications between genes can be seen as music based on 3N-cyclotron resonances for dark genes with N codons of dark gene generating dark 3N-photon.

   The latest discovery was that the bioharmony corresponds to the so-called icosa-tetrahedral tessellation of hyperbolic 3-space playing a central role in TGD. In many respects this tessellation is completely unique, and this could make s genetic code a universal way to represent information using 6-bit sequence as a basic unit.

2. The second part contains topics related to the arrow of time in neuroscience. A vision that sensory perception and motor action represent time reversals of each other in zero energy ontology (ZEO) is introduced. Also the notion of quantum statistical brain is discussed.

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1.3 Sources

The eight online books about TGD [K81, K78, K62, K48, K13, K46, K32, K69] and nine online books about TGD inspired theory of consciousness and quantum biology [K74, K12, K53, K10, K28, K38, K40, K68, K71] 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.

1.3.1 PART I: QUANTUM MODEL FOR HEARING AND LANGUAGE

Quantum Model for Hearing

The quantum model of hearing has evolved through several twists and turns. The emergence of zero energy ontology, the explanation of dark matter in terms of a hierachy of Planck constants requiring a generalization of the notion of embedding space, the view about life as something in the intersection of real and p-adic worlds, and the notion of number theoretic entanglement negentropy led to a breakthrough in TGD inspired quantum biology and also to the recent view of qualia and sensory representations including hearing allowing a precise quantitative model at the level of cell membrane. This also modified dramatically the speculative ideas about the role of neutrinos in hearing.

Also in the recent view long range weak play a key role. They are made possible by the exotic ground state represented as almost vacuum extremal of Kähler action for which classical em and Z^0 fields are proportional to each other wheras for standard ground state classical Z^0 fields are very weak. Neutrinos are present but it seems that they do not define cognitive representations in the time scales characterizing neural activity. Electrons and quarks for which the time scales of causal diamonds correspond to fundamental biorhythms, take this role.

The ensuing general model of how cell membrane acts as a sensory receptor has unexpected implications for the entire TGD inspired view about biology.

1. TGD inspires two views about cell membrane: the wiews need not be contradictory. For the first model cell is far from vacuum extremal, for the second model nearly vacuum extremal with classical Z^0 fields in key role.

   (a) There are several constraints on the first model coming from the TGD based identification of bio-photons as energy conserving decay products of dark photons and one ends up to a new view about metabolism and gneralization to of the notion of Josephson junction so that Josephson energy includes besides electrostatic energy also the difference of cyclotron energies at two sides of the membrane. It seem that that the first model might be enough when generalized along lines inspired by Pollack's findings about the fourth phase of water.

(b) It has been clear from the beginning that the nearly vacuum extremals of Kähler action could play key role key role in living systems. The reason is their criticality making them ideal systems for sensory perception. These extremals carry classical em and Z^0 fields related to each other by a constant factor and this could explain the large parity breaking effects characterizing living matter. The assumption that at least some cell membranes are nearly vacuum extremals and that nuclei can feed their Z^0 charges to this kind of space-time sheets (not true for atomic electrons) in living matter leads to a modification of the model for the cell membrane as Josephson junction. Also a model of photoreceptors explaining the frequencies of peak sensitivity as ionic Josephson frequencies and allowing the dual identifications Josephson radiation as biophotons (energies) and EEG radiation (frequencies) emerge since the values of Planck constant can be very large. Contrary to the original believe, this model does not require non-standard value of Weinberg angle and this model and first model allow a hybrid.

2. DNA as topological quantum computer model plus certain simplifying assumption leads to the conclusion that the spectrum of net quantum numbers of quark antiquark pair define the primary qualia assignable to a nucleotide-lipid pair connected by a magnetic flux tube. The most general prediction is that the net quantum numbers of two quark pairs characterize the qualia. In the latter case the qualia would be assigned to a pair of receptor cells.

3. Composite qualia result when one allows the nucleotide-lipid pairs of the membrane to be characterized by a distribution of quark-antiquark pairs. Cell membrane -or at least the axonal parts of neurons- would define a sensory representation in which is a pair of this kind defines a pixel characterized by primary qualia. Cells would be sensory homunculi and DNA defines a sensory hologram of body of or of part of it. Among other things this would give a precise content to the notion of grandma cell.

4. Josephson frequencies of biologically important ions are in one-one correspondence with the qualia and Josephson radiation could re-generate the qualia or map them to different qualia in a one-one and synesthetic manner in the neurons of the sensory pathway. For large values of Planck constant Josephson frequencies are in EEG range so that a direct connection with EEG emerges and Josephson radiation indeed corresponds to both biophotons and EEG. This would realize the notion of sensory pathway which originally seemed to me a highly non-realistic notion and led to the vision that sensory qualia can be realized only at the level of sensory organs in TGD framework.

5. At the level of brain motor action and sensory perception look like reversals of each other. In zero energy ontology motor action can be indeed seen as a time reversed sensory perception so that the model of sensory representations implies also a model for motor action. Magnetic body serves as a sensory canvas where cyclotron transitions induced by Josephson frequencies induce conscious sensory map entangling the points of the magnetic body with brain and body.

The model for hearing follows as a special case from the general model for sensory receptor and representations.

1. Concerning hearing, the basic questions relate to the precise identification of the hearing quale, to the representation of pitch of the sound at the magnetic body, and to the representation of various geometric data about sound. The electromagnetic charge of the quark pair (or equivalently electroweak isospin) looks like an excellent candidate in this respect so that charge increment would define one fundamental hearing quale.

   This quale need not correspond to pitch. The vision about hearing as a frequency quale suggests that cyclotron transition frequency corresponds to the pitch. Sound frequency would be coded to an increment of cyclotron frequency and pitch would be a quale assignable to magnetic body rather than biological body. Hearing would in a well-defined sense represent a higher level sensory modality not understandable without the notion of magnetic body. The strength of the magnetic field would code for cyclotron frequency and therefore for the pitch.

One of the mysteries related to hearing is the ability to hear frequencies much higher than the maximum rate of nerve pulses which is below kHz. The coding by Josephson frequencies and representation of them as quale of the magnetic body resolves this mystery.

2. At the quantative level the first challenge is to understand the typical hearing ranges (humans, mice, bats, sea mammals) and here the time scales of CDs associated with quarks and leptons give intriguing hints. Also their cyclotron frequencies are involved and large values of Planck constant are unavoidable. Josephson frequencies are given by the effective membrane potential (Z^0 potential must be included) divided by Planck constant and it is possible to represent arbitrarily low frequencies in terms of membrane potential by allowing Planck constant to have high enough values.

3. The extreme rapidity of signalling from hair cells to brain is one of the mysteries of hearing and here Josephson radiation (biophotons) provides a direct neuronal window with practically instantaneous communication. Microtubules could be associated with the flux tubes along which Josephson radiation propagates and also microtubular conformational waves could be involved.

4. Hearing represent in many respects an exceptional quale: consider only music experience, language, internal speech, the understanding and production of speech, and right brain sings-left brain talks metaphor. This conforms with the assumption that magnetic body is involved in essential manner with hearing. Zero energy ontology leads to a vision explaining basic aspects of music experience and the notion of memetic code plus possible realization of genetic code as temporal patterns could provide first principle understanding of language.

What Music Could Teach about Consciousness?

Recently I have been reading the book by Oliver Sacks titled "Musicophilia" dealing with various aspects of music experience. Humans as a species indeed have a very special relation to music. But is it really genuine characteristic of human consciousness? One can even ask whether consciousness emerges only in higher species or whether it could be in some form a characteric of any living or even inanimate system? I am not the only quantum consciousness theorists forced to consider panpsychism in some form. In this framework one can ask whether music like aspects of conscious experience could be universal and only especially highly developed in humans?

In this chapter I restrict the consideration to those stories of *Musicophilia*, which I find of special interest from the point of view of TGD inspired theory of consciousness. The outcome isa more precise formulation for the general TGD inspired vision about brain based on basic ideas of quantum TGD.

Zero Energy Ontology (ZEO) implies a new view about the relation between geometric and experienced time and allowing to generalize quantum measurement theory to a theory of consciousness.

Strong form of holography implies the analog of AdS/CFT duality between 2-D representation of physics based on string world sheets and partonic 2-surfaces and 4-D space-time representations. This duality is not tautology and this inspires the idea that these two representations correspond to two modes for consciousness motivating "Left brain talks, right brain sings" metaphor.

1. Language and music could relate to two dual representations of conscious information - local and holistic, cognitive and sensory. Discretization of function/its Fourier transform as a collection of its values at discrete set values of time/frequencies would correspond local/holistic approximations of function. In principle any conscious entity - self- could utilize these two representational modes at appropriate quantum criticality.

2. The holistic "musical consciousness" is assignable to right brain hemisphere and according to the stories of Sacks seems to characterized by episodal sensory memories. TGD based view about memories relies on ZEO: the memories would be mental images with sensory input from geometric past, genuine sensory experiences of time reversed sub-selves! This picture simplifies considerably and one can see all memories - sensory, cognitive, or emotional - as analogs of phantom pain, which would be also a sensory memory and even more a genuine

sensory experience. It is even possible that our biological bodies are used by two selves: right brain hemisphere sleeps when we are awake and vice versa. Even the experiences of epileptics about having double consciousness could be understood.

3. A more concrete realization of "Left brain talks, right brain sings" metaphor relies on the assumption that "magneto-anatomy" is universal. Only the "magneto-physiology" characterized by the values of h_{eff} characterizing quantum criticality and defining a kind of intelligence quotient dictating the span of long term memory and planned action varies.

   h_{eff} would differ for the magnetic bodies of various brain areas, and the spectrum of h_{eff} for right and left brain would differ and characterize their specializations. For instance, the value of h_{eff} would be large (small) for the cognitive areas of left (right) brain and small (large) for some higher sensory areas of right (left) brain. Magnetic bodies form a fractal hierarchy and one can characterize even individual cells and neurons by the value of h_{eff} associated with them. The spectrum for h_{eff} allows also to distinguish between members of the same species since it defines the skill profile. This obviously goes far beyond the genetic determinism.

Geometric Theory of Bio-Harmony

For some years ago I developed a model of music harmony. As a surprising side product a model of genetic code predicting correctly the number of codons coding given amino-acid emerged. Since music expresses and creates emotions, one can ask whether genes could have "moods" characterized by these bio-harmonies. The fundamental realization could be in terms of dark photon triplets replacing phonon triplets for ordinary music.

1. The model relies on the geometries of icosahedron and tetrahedron and representation of 12-note scale as so called Hamiltonian cycle at icosahedron going through all 12 vertices of icosahedron. The 20 faces correspond to allowed 3-chords for harmony defined by given Hamiltonian cycle. This brings in mind 20 amino-acids (AAs).

2. One has three basic types of harmonies depending on whether the symmetries of icosahedron leaving the shape of the Hamiltonian cycle is Z_6, Z_4 or Z_2. For Z_2 there are two options: $Z_{2,rot}$ is generated by rotation of π and $Z_{2,refl}$ by reflection with respect to a median of equilateral triangle.

3. Combining together one harmony from each type one obtains union of 3 harmonies and if there are no common chords between the harmonies, one has 20+20+20 3-chords and a strong resemblance with the code table. To given AA one assigns the orbit of given face under icosahedral isometries so that codons correspond to the points of the orbit and orbit to the corresponding AA. 4 chords are however missing from 64. These one obtains by adding tetrahedron. One can glue it to icosahedron along chosen face or keep is disjoint.

4. The model in its original form predicts 256 different harmonies with 64 3-chords defining the harmony. DNA codon sequences would be analogous to sequences of chords, pieces of music. Same applies to mRNA. Music expresses and creates emotions and the natural proposal is that these bio-harmonies correlate with moods that would appear already at molecular level. They could be realized in terms of dark photon triplets realized in terms of light and perhaps even music (living matter is full of piezo-electrets). In fact, also the emotions generated by other art forms could be realized using music of dark light.

The model of music harmony is separate from the model of genetic code based on dark proton triplets and one of the challenges has been to demonstrate that they are equivalent. This inspires several questions.

1. Could the number of harmonies be actually larger than 256 as the original model predicts? One could rotate the 3 fused Hamilton's cycles with respect to each by icosahedral rotations other leaving the face shared by icosahedron and tetrahedron invariant. There are however conditions to be satisfied.

(a) There is a purely mathematical restriction. If the fused 3 harmonies have no common 3-chords the number of coded AAs is 20. Can one give up the condition of having no common 3-chords and only require that the number of coded AAs is 20?

(b) There is also the question about the chemical realizability of the harmony. Is it possible to have DNA and RNA molecules to which the 3-chords of several harmonies couple resonantly? This could leave only very few realizable harmonies.

2. The model predicts the representation of DNA and RNA codons as 3-chords. Melody is also an important aspect of music. Could AAs couple resonantly to the sums of the frequencies (modulo octave equivalence) of the 3-chords for codons coding for given AA? Could coding by the sum of frequencies appear in the coupling of tRNA with mRNA by codewords and coding by separate frequencies to the letterwise coupling of DNA and RNA nucleotides to DNA during replication and transcription?

3. What about tRNA. Could tRNA correspond to pairs of harmonies with 20+20+444 codons? What about single 20+4=24 codon representation as kind of pre-tRNA?

4. What is the origin of 12-note scale? Does genetic code force it? The affirmative answer to this question relies on the observation that 1-1 correspondence between codons and triplets of photons requires that the frequency assignable to the letter must depend on its position. This gives just 12 notes altogether. Simple symmetric arguments fix the correspondence between codons and 3-chords highly uniquely: only 4 alternatives are possible so that it would be possible to listen what DNA sequences sounds in given mood characterized by the harmony.

5. What disharmony could mean? A possible answer comes from 6 Hamiltonian cycles having no symmetries. These disharmonies could express "negative" emotions.

TGD View about Language

Human languages differ dramatically from their analogos for animals. Animal languages consist mainly of simple signals, warnings and threats for instance. The emotional expression dominates. There seems to be no grammar. Birds can have repertoire of different song patterns and monkeys have gesture language. There is a huge variety of human languages. One can also regard music as a kind language expressing emotions and creating them. Also pictures define linguistic representations. Children and animals learn speech by mimicry and the grammar and syntax without conscious efforts. Human language is also special in that it involves conceptualization, metaphors, and analogies representing abstract concepts in terms of objects and actions of the external world.

One might understand the semantic aspect of language in terms of association and conditioning. Language acquisition involves showing the object and saying the word describing it. This suggests conditioning and association so that a mere word generates an imagined percept of the object. Conditioning and formation of associations is a very general form of learning assumed to relate to the increase of synaptic strengths leading to a generation of association pathways. In computer science pattern recognition and completion models it mathematically.

Amazingly, only a few point mutations for relatively few genes seems so have led to human languages and transformed biological evolution to cultural evolution? What happened for these genes? In the biochemistry framework it is difficult to imagine an answer to this question. Here TGD could come in rescue.

Number theoretic physics is part of quantum TGD and essential for understanding evolution as an increase of algebraic complexity. Evolutionary hierarchies would correspond to hierarchies of algebraic extensions of rationals. The dimension n of extension defines effective Planck constant $h_{eff}/h_0 = n$. The larger the dimension, the larger the scale of quantum coherence at corresponding layer of magnetic body (MB) associated with the system: n would be analogous to IQ. One can assign a value of h_{eff} characterizing the evolutionary level also to genes. The genes with larger h_{eff} would serve as control genes and the increase of h_{eff} would mean an evolutionary step. Perhaps a dramatic increase of h_{eff} occurred to FOXP2 and some other genes as human language emerged.

Is Non-associative Physics and Language Possible only in Many-Sheeted Space-time?

Language is an essentially non-associative structure as the necessity to parse linguistic expressions essential also for computation using the hierarchy of brackets makes obvious. Hilbert space operators are associative so that non-associative quantum physics does not seem plausible without an extension of what one means with physics. Associativity of the classical physics at the level of *single* space-time sheet in the sense that tangent or normal spaces of space-time sheets are associative as sub-spaces of the octonionic tangent space of 8-D embedding space $M^4 \times CP_2$ is one of the key conjectures of TGD. But what about many-sheeted space-time? The sheets of the many-sheeted space-time form hierarchies labelled by p-adic primes and values of Planck constants $h_{eff} = n \times h$. Could these hierarchies provide space-time correlates for the parsing hierarchies of language and music, which in TGD framework can be seen as kind of dual for the spoken language? For instance, could the braided flux tubes inside larger braided flux tubes inside... realize the parsing hierarchies of language, in particular topological quantum computer programs? And could the great differences between organisms at very different levels of evolution but having very similar genomes be understood in terms of widely different numbers of levels in the parsing hierarchy of braided flux tubes- that is in terms of magnetic bodies as indeed proposed. If the intronic portions of DNA connected by magnetic flux tubes to the lipids of lipid layers of nuclear and cellular membranes make them topological quantum computers, the parsing hierarchy could be realized at the level of braided magnetic bodies of DNA. The mathematics needed to describe the breaking of associativity at fundamental level seems to exist. The hierarchy of braid group algebras forming an operad combined with the notions of quasi-bialgebra and quasi-Hopf algebra discovered by Drinfeld are highly suggestive concerning the realization of weak breaking of associativity.

1.3.2 PART II: ARROW OF TIME AND NEUROSCIENCE

Arrow of time and neuroscience: TGD based view

The question that inspired this article is whether memories about the future - precognitions - are possible in some sense. This requires retrocausality. The criticism of retrocausality relies on the assumption that time, in particular the thermo-dynamical time, has always the same arrow. TGD inspired theory of consciousness as quantum measurement theory based on zero energy ontology (ZEO) predicts that the arrow of time can vary and changes in ordinary - "big" -state function reductions (BSFRs): self dies (falls asleep) and re-incarnates with a opposite arrow of time. This leads to a generalisation of thermodynamics and allows to see self-organisation basically as a consequence of the generalised second law.

Precognition as a recall of future geometric memories would rely on sensory perception with an opposite arrow of time by some sub-selves assignable to the structures of the brain. The arrow of time would be reversed at some layer of the magnetic body in a master-slave relation with the biological body and induce an effective change of arrow at the level of ordinary biomatter in longer time scales than usual. The sensory perceptions with reversed arrow time would be communicated to the self as dreams meaning BSFR for the time reversed mental and its death and reincarnation with standard arrow of time. There are findings about Alzheimer patients supporting this hypothesis.

This proposal deviates from standard neuroscience in that ZEO and the notion of magnetic body carrying phases of ordinary matter with effective Planck constant $h_{eff} = nh_0 > h$ behaving like dark matter. Also a purely biochemistry based hypothesis that biochemical factors responsible for the buildup of memory traces select the arrow of time: perhaps their shortage could lead to the selection of the opposite arrow of time.

Sensory Perception and Motor Action as Time Reversals of Each Other: a Royal Road to the Understanding of Other Minds?

The notion of mirror neuron is extremely attractive because it could allow the understanding of the observed goal directed behaviors of living systems by inducing corresponding imagined or even real actions. The sensory input about behavior would automatically induce the neural activity representing intention about the behavior or imagined behavior. Mirror neuron hypothesis was derived originally for monkeys but has been considerably generalized. For instance, in the case of

humans mirro neurons could allow an almost automatic understanding of intentions and emotions of other people.

In TGD framework the objections against mirror neuron hypothesis motivate its replacement with what I call time mirror hypothesis inspired by zero energy ontology, and stating that motor action and sensory perception are in a well-defined sense time reversals of each other. This hypothesis could explain the time anomalies assignable to mirror neurons if they are indeed involved (reactions tend assigned to mirror neurons tend to be "too fast") and also Libet's findings. This inspires the notion of quantum monadology: parts of brain would be continually time mirroring each other. Also magnetic body would be involved. The time mirror relationship could correspond to directed attention having as space-time correlates magnetic flux tubes carrying dark photon signals in both time directions. Time mirror hypothesis is applied to the entrainment of the speech motor regions with auditory areas at the opposite side of brain occurring at resonance frequency 4.5 Hz as discovered by Poeppel and Assaneo.

This vision allows to build a model of sensory memories with motivation coming from the findings challenging the standard view about them. This model in turn inspires a very general model of motor action applying also to basic biochemical processes such as transcription, replication, and translation as being induced by topological quantum computer programs running in non-standard time direction.

Quantum Statistical Brain

This chapter was originally inspired by the findings of Li et al, which can be summarized as follows. Humans know the uncertainty of their working memory and use it to make decisions; the content and the uncertainty of working memory can be decoded from BOLD signals; decoding errors predict memory errors at the single-trial level; decoded uncertainty correlates with behavioral reports of working memory uncertainty.

Later I learned about the findings of Manassi and Whitney about the stability illusion of perceptions making the world look smoothly changing and effectively shifting the perception towards the past.

It is not too surprising that the states of feature detector neurons obey a statistical distribution. It is however not obvious that the reliability of the memory should correlate with the width of this distribution and that even the subjective estimate for the reliability should reflect this width.

If one accepts the notion of a quantum brain, the distribution of features could reflect the non-determinism of the outcome in the reduction of entanglement quantum measurements producing sensations.

Zero energy ontology (ZEO) leads to the notion of 4-D brain and suggests that the feature ensemble is not spatial, as it should be in standard quantum theory, but a temporal ensemble formed by the memory mental images of the feature. Quite generally, in ZEO sequences of "small" state function reductions (SSFRs) as counterparts of so called weak measurements would form temporal ensembles of memory mental images so that the connection with short term memory would be direct. This picture explains the findings of both Li et al and Manassi and Whitney.

Taos hum, stochastic resonance, and sensory perception

Taos hum is an experimentally well-established anomalous phenomenon which has escaped rational explanations. Very concisely, taos hum seems is apparently a subjective experience without identifiable objective counterpart and could thus provide an application for the sensory canvas hypothesis.

The TGD based model for EEG is based on dark Josephson radiation generated by cell membrane Josephson junctions in the energy range of visible and UV light and covering a wide frequency range. The model explains bio-photons and EEG photons as manifestations of one and same thing. Taos hum might be perhaps understood in terms of this kind of Josephson radiation at microwave frequencies generated by living matter during night-time and possibly providing some organisms with an active vision. The emission of negative energy dark photons could also make it possible for plants to suck metabolic energy from environment in the absence of solar radiation.

Also other interpretations might be considered and the most recent idea suggests a connection with quantum gravitation which plays a key role in TGD inspired quantum biology. The proposed generalization of the notion of stochastic resonance inspired by the zero energy ontology of TGD could also serve as a mechanism of Taos hum. The bistable state would be replaced by a pair of states with an opposite arrow of time so that the mechanism would be universal. Zero energy ontology would explain the thermodynamically questionable ability of the system to extract energy from white noise assumed in the standard model of stochastic resonance. Stochastic resonance also allows to construct a more precise model of sensory perception.

Part I

QUANTUM MODEL FOR HEARING AND LANGUAGE

Chapter 2

Quantum Model for Hearing

2.1 Introduction

The quantum model of hearing has evolved through several twists and turns. For years this model seemed to be one of the stable portions of TGD inspired theory of qualia and, what was remarkable, allowed rather precise quantitative predictions. The model relied crucially on TGD based new physics: in particular, the roles of long ranged dark weak force and of neutrinos was central. Long ranged weak force predicted by TGD explains nicely the parity breaking effects in living matter but the idea that neutrinos could be central for cognition looks outlandish in the context provided by the text book myth about elusive neutrino travelling light years through condensed matter without any interactions.

The emergence of zero energy ontology, the explanation of dark matter in terms of a hierarchy of Planck constants requiring a generalization of the notion of embedding space, the view about life as something in the intersection of real and p-adic worlds, and the notion of number theoretic entanglement negentropy lead to the breakthrough in TGD inspired quantum biology and also to the recent view of qualia and sensory representations including hearing allowing a precise quantitative model at the level of cell membrane. This also modified dramatically the speculative ideas about the role of neutrinos in hearing.

Also in the recent view long range weak forces play a key role. They are made possible by the exotic ground state represented as almost vacuum extremal of Kähler action for which classical em and Z^0 fields are proportional to each other wheras for standard ground state classical Z^0 fields are very weak. Neutrinos are present but it seems that they do not define cognitive representations in the time scales characterizing neural activity. Electrons and quarks for which the time scales of causal diamonds correspond to fundamental biorhythms - one of the key observations during last years- take this role.

2.1.1 General Model For Qualia And Sensory Receptor

The identification of quantum number increments in quantum jump for a subsystem representing sub-self and the capacitor model of sensory receptor are already more than decade old ideas.

The concrete realization of this vision is based on several ideas that I have developed during last five years.

1. The vision about dark matter as a hierarchy of phases partially labeled by the value of Planck constant led to the model of DNA as topological quantum computer [K3]. In this model magnetic flux tubes connecting DNA nucleotides with the lipids of the cell membrane define strands of the braids defining topological quantum computations. The braid strand corresponds to so called wormhole flux tube and has quark and antiquark at its ends. u and d quarks and their antiquarks code for four DNA nucleotides in this model.

2. Zero energy ontology assigns to elementary particles so called causal diamonds (CDs). For u and d quarks and electron these time scales are (6.5,.78, 100) ms respectively, and correspond to fundamental biorhythms. Electron time scale corresponds to 10 Hz fundamental biorhythm

defining also the fundamental frequency of speech organs,.78 ms to kHz cortical synchrony [J40]. and 160 Hz to cerebellar synchrony [J39]. Elementary particles therefore seem to be directly associated with neural activity, language, and presumably also hearing. One outcome was the modification of the earlier model of memetic code involving the notion of cognitive neutrino pair by replacing the sequence of cognitive neutrino pairs with that of quark sub-CDs within electron CD. Nerve pulses could induce the magnetization direction of quark coding for bit but there are also other possibilities. The detailed implications for the model of nerve pulse [K59] remain to be disentangled.

3. The understanding of the Negentropy Maximization Principle [K41] and the role of negentropic entanglement in living matter together with the vision about life as something in the intersection of real and p-adic worlds was a dramatic step forward. In particular, space-like and time-like negentropic entanglement become basic aspects of conscious intelligence and are expected to be especially important for understanding the difference between speech and music.

4. The most important implication concerning the model of sensory receptors however relate to the vacuum degeneracy of Kähler action. It has been clear from the beginning that the nearly vacuum extremals of Kähler action could play key role key role in living systems. The reason is their criticality making them ideal systems for sensory perception. These extremals carry classical em and Z^0 fields related to each other by a constant factor and this could explain the large parity breaking effects characterizing living matter. The assumption that cell membranes are nearly vacuum extremals and that nuclei can feed their Z^0 charges to this kind of space-time sheets (not true for atomic electrons) in living matter leads to a modification of the model for the cell membrane as Josephson junction [K59]. Also a model of photoreceptors explaining the frequencies of peak sensitivity as ionic Josephson frequencies and allowing the dual identifications Josephson radiation as bio-photons (energies) [I13] and EEG radiation (frequencies) emerge since the values of Planck constant can be very large. The value of the Weinberg angle in this phase is fixed to $sin^2(\theta_W) = .0295$, whereas in standard phase the value is given by $sin^2(\theta_W) = .23$. The significance of this quantitative success for TGD and TGD inspired quantum biology cannot be over-estimated.

2.1.2 Some Implications Of The Model Of Cell Membrane As Sensory Receptor

The ensuing general model of how cell membrane acts as a sensory receptor has unexpected implications for the entire TGD inspired view about biology.

1. DNA as topological quantum computer model plus certain simplifying assumption leads to the conclusion that the spectrum of net quantum numbers of quark antiquark pair define the primary qualia assignable to a nucleotide-lipid pair connected by a magnetic flux tube. The most general prediction is that the net quantum numbers of two quark pairs characterize the qualia. In the latter case the qualia would be assigned to a pair of receptor cells.

2. Composite qualia result when one allows the nucleotide-lipid pairs of the membrane to be characterized by a distribution of quark-antiquark pairs. Cell membrane -or at least the axonal parts of neurons- would define a sensory representation in which is a pair of this kind defines a pixel characterized by primary qualia. Cells would be sensory homunculi and DNA defines a sensory hologram of body of or of part of it. Among other things this would give a precise content to the notion of grandma cell.

3. Josephson frequencies of biologically important ions are in one-one correspondence with the qualia and Josephson radiation could re-generate the qualia or map them to different qualia in a one-one and synesthetic way in the neurons of the sensory pathway. For large values of Planck constant Josephson frequencies are in EEG range so that a direct connection with EEG emerges and Josephson radiation indeed corresponds to both bio-photons and EEG. This would realize the notion of sensory pathway which originally seemed to me a highly non-realistic notion and led to the vision that sensory qualia can be realized only at the level of sensory organs in TGD framework.

4. At the level of brain motor action and sensory perception look like reversals of each other. In zero energy ontology motor action can be indeed seen as a time reversed sensory perception so that the model of sensory representations implies also a model for motor action. Magnetic body serves as a sensory canvas where cyclotron transitions induced by Josephson frequencies induce conscious sensory map entangling the points of the magnetic body with brain and body.

2.1.3 Model For Hearing

The model for hearing follows as a special case from the general model for sensory receptor and representations.

1. Concerning hearing, the basic questions relate to the precise identification of the hearing quale, to the representation of pitch of the sound at the magnetic body, and to the representation of various geometric data about sound. The electromagnetic charge of the quark pair (or equivalently electroweak isospin) looks like an excellent candidate in this respect so that charge increment would define one fundamental hearing quale.

   This quale need not correspond to pitch. The vision about hearing as a frequency quale suggests that cyclotron transition frequency corresponds to the pitch. Sound frequency would be coded to an increment of cyclotron frequency and pitch would be a quale assignable to the magnetic body rather than biological body. Hearing would be in a well-defined sense represent a higher level sensory modality not understandable without the notion of magnetic body. The strength of the magnetic field would code for cyclotron frequency and therefore for the pitch. One of the mysteries related to hearing is the ability to hear frequencies much higher than the maximum rate of nerve pulses which is below kHz. The coding by Josephson frequencies and representation of them as a quale of the magnetic body resolves this mystery.

2. Equilibrioception (perception of the position and orientation of head) is very closely related to hearing as far as sensory receptors are considered: the basic difference is that the motion of hair cells is periodic for the sound perception and constant shift for equilibrioception. In this case the most important sensory data is geometric and the challenge is to build a model for magnetic body and for how the sensory data is communicated to the magnetic body.

3. At the quantative level the first challenge is to understand the typical hearing ranges (humans, mice, bats, sea mammals) and here the time scales of CDs associated with quarks and leptons give intriguing hints. Also their cyclotron frequencies are involved and large values of Planck constant are unavoidable. Josephson frequencies are given by the effective membrane potential (Z^0 potential must be included) divided by Planck constant and it is possible to represent arbitrarily low frequencies in terms of membrane potential by allowing Planck constant to have high enough values.

4. The frequency 2 kHz scale represents the lower bound for the frequencies representable in terms of cyclotron frequencies assignable to the CD of d quark. The CD of u quark allows to reduce the lower cutoff to 320 Hz and the CD of electron reduces the lower scale to 20 Hz representing the lower bound for the range of audible frequencies. The coding by the rate of nerve pulses can also resolve this problem as long as the rate of pulses is so high that the pulses sequences is experienced as a sound with a well-define pitch (the lower bound is about 28 Hz and higher than 20 Hz). The ultimate representation of the pitch would be always at the magnetic body.

5. The extreme rapidity of signalling from hair cells to brain is one of the mysteries of hearing and here Josephson radiation (bio-photons) provides a direct neuronal window with practically instantaneous communication. Microtubules could be associated with the flux tubes along which Josephson radiation propagates and also microtubular conformational waves could be involved.

6. Hearing represent in many respects an exceptional quale: consider only music experience, language, internal speech, the understanding and production of speech, and right brain sings-left brain talks metaphor. This conforms with the assumption that magnetic body is involved

in essential way with hearing. Zero energy ontology leads to a vision explaining basic aspects of music experience and the notion of memetic code plus possible realization of genetic code as temporal patterns could provide first principle understanding of language.

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` [L8].

2.2 TGD Based Model For Qualia And Sensory Receptors

The identification of quantum number increments in quantum jump for a subsystem representing sub-self and the capacitor model of sensory receptor are already more than decade old ideas.

The concrete realization of this vision is based on several ideas that I have developed during last five years.

1. The vision about dark matter as a hierarchy of phases partially labeled by the value of Planck constant led to the model of DNA as topological quantum computer [K3]. In this model magnetic flux tubes connecting DNA nucleotides with the lipids of the cell membrane define strands of the braids defining topological quantum computations. The braid strand corresponds to so called wormhole flux tube and has quark and antiquark at its ends. u and d quarks and their antiquarks code for four DNA nucleotides in this model.

2. Zero energy ontology assigns to elementary particles so called causal diamonds (CDs). For u and d quarks and electron these time scales are (6.5, .78, 100) ms respectively, and correspond to fundamental biorhythms. Electron time scale corresponds to 10 Hz fundamental biorhythm defining also the fundamental frequency of speech organs, .78 ms to kHz cortical synchrony [J40], and 160 Hz to cerebellar synchrony [J39]. Elementary particles therefore seem to be directly associated with neural activity, language, and presumably also hearing. One outcome was the modification of the earlier model of memetic code involving the notion of cognitive neutrino pair by replacing the sequence of cognitive neutrino pairs with that of quark sub-CDs within electron CD. Nerve pulses could induce the magnetization direction of quark coding for bit but there are also other possibilities. The detailed implications for the model of nerve pulse [K59] remain to be disentangled.

3. The understanding of the Negentropy Maximization Principle [K41] and the role of negentropic entanglement in living matter together with the vision about life as something in the intersection of real and p-adic worlds was a dramatic step forward. In particular, space-like and time-like negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) become basic aspects of conscious intelligence and are expected to be especially important for understanding the difference between speech and music.

4. One of the basic challenge has been to construct a quantitative model for cell membrane.

   (a) The first model was based on the assumption that long range weak forces however play a key role [K8]. They are made possible by the exotic ground state represented as almost vacuum extremal of Kähler action for which classical em and Z^0 fields are proportional to each other whereas for the standard ground state classical Z^0 fields are very weak. Neutrinos are present but it seems that they do not define cognitive or Boolean representations in the time scales characterizing neural activity. Electrons and quarks for which the time scales of causal diamonds correspond to fundamental biorhythms - one of the key observations during last years- take this role. The essential element is that the energies of the Josephson photons are in visible range. This would explain bio-photons and even why the frequencies assignable to visual receptors. The problem is that Weinberg angle must be assumed to be much smaller in the near vacuum extremal phase than in standard model.

(b) Second model is based on Gerald Pollack's findings about fourth phase of water and exclusion zones [I4]. These zones inspire a model for pre-biotic cells. The outcome is a modification of the simplest model of Josephson junction. Besides resting potential also the difference between cyclotron energies between the two sides of the membrane plays a key role. This model allows to understand what happens in metabolism in terms of a quantum model replacing the thermodynamical model for cell membrane with its quantal "square root" inspired by Zero Energy Ontology. The model allows also to understand bio-photons as decay products of dark photons.

(c) The success of the latter model does not of course mean that the weak forces could not be important in cell membrane scale and the realistic model could be a hybrid of these two models. The inclusion of Z^0 contribution to the effective magnetic field could also to the fact that the endogenous magnetic field deduced from Blackman's experiments is $B_{end} = 2B_E/5$ rather than B_E (Earth's magnetic field).

2.2.1 A General Model Of Qualia And Sensory Receptor

The identification of sensory qualia in terms of quantum number increments and geometric qualia representing geometric and kinematic information in terms of moduli of CD, the assignment of sensory qualia with the membrane of sensory receptor, and capacitor model of qualia are basic ideas behind the model. The communication of sensory data to magnetic body using Josephson photons is also a key aspect of the model.

A general model of qualia

It is good to start by summarizing the general vision about sensory qualia and geometric qualia in TGD Universe.

1. The basic assumption is that sensory qualia correspond to increments of various quantum numbers in quantum jump. Standard model quantum numbers- color quantum numbers, electromagnetic charge and weak isospin, and spin are the most obvious candidates. Also cyclotron transitions changing the integer characterizing cyclotron state could corresponds to some kind of quale- perhaps "a feeling of existence". This could make sense for the qualia of the magnetic body.

2. Geometric qualia could correspond to the increments of zero modes characterizing the induced CP_2 Käjhler form of the partonic 2-surface and of the moduli characterizing the causal diamonds serving as geometric correlates of selves. This moduli space involves the position of CD and the relative position of tips as well as position in CP_2 and relative position of two CP_2 points assigned to the future and past boundaries of CD. There are good motivations for proposing that the relative positions are quantized. This gives as a special case the quantization of the scale of CD in powers of two. Position and orientation sense could would represent this kind of qualia. Also kinematical qualia like sensation of acceleration could correspond to geometric qualia in generalized 4-D sense. For instance, the sensation about motion could be coded by Lorentz boots of sub-CD representing mental image about the object.

3. One can in principle distinguish between qualia assignable to the biological body (sensory receptors in particular) and magnetic body. The basic question is whether sensory qualia can be assigned only with the sensory receptors or with sensory pathways or with both. Geometric qualia might be assignable to the magnetic body and could provide third person perspective as a geometric and kinematical map of the body and its state of motion represented using the moduli space assignable to causal diamonds (CD). This map could be provided also by the body in which case the magnetic body would only share various mental images. The simplest starting assumption consistent with neuro-science is that sensory qualia are assigned with the cell membrane of sensory receptor and perhaps also with the neurons receiving data from it carried by Josephson radiation coding for the qualia and possibly partially regenerating them if the receiving neuron has same value of membrane potential as the sensory receptor when active. Note that during nerve pulse also this values of membrane potential is achieved for some time.

Could some sensory qualia correspond to the sensory qualia of the magnetic body?

Concerning the understanding of a detailed model for how sensory qualia are generated, the basic guideline comes from the notion of magnetic body and the idea that sensory data are communicated to the magnetic body as Josephson radiation associated with the cell membrane. This leaves two options: either the primary a sensory qualia are generated at the level of sensory receptor and the resulting mental images negentropically entangle with the "feeling of existence" type mental images at the magnetic body or they can be also generated at the level of the magnetic body by Josephson radiation -possibly as cyclotron transitions. The following arguments are to-be-or-not-to-be questions about whether the primary qualia must reside at the level of sensory receptors.

1. Cyclotron transitions for various cyclotron condensates of bosonic ions or Cooper pairs of fermionic ions or elementary particles are assigned with the motor actions of the magnetic body and Josephson frequencies with the communication of the sensory data. Therefore it would not be natural to assign qualia with cyclotron transitions. One the other hand, in zero energy ontology motor action can be regarded formally as a time reversed sensory perception, which suggests that cyclotron transitions correlated with the "feeling of existence" at magnetic body entangled with the sensory mental images. They could also code for the pitch of sound as will be found but this quale is strictly speaking also a geometric quale in the 4-D framework.

2. If Josephson radiation induces cyclotron transitions, the energy of Josephson radiation must correspond to that of cyclotron transition. This means very strong additional constraint not easy to satisfy except during nerve pulse when frequencies varying from about 10^{14} Hz down to kHz range are emitted the system remains Josephson contact. Cyclotron frequencies are also rather low in general, which requires that the value of $\hbar$ must be large in order to have cyclotron energy above the thermal threshold. This would however conform with the very beautiful dual interpretation of Josephson photons in terms of bio-photons and EEG. One expects that only high level qualia can correspond to a very large values of $\hbar$ needed.

   For the sake of completeness it should be noticed that one might do without large values of $\hbar$ if the carrier wave with frequency defined by the metabolic energy quantum assignable to the kicking and that the small modulation frequency corresponds to the cyclotron frequency. This would require that Josephson frequency corresponds to the frequency defined by the metabolic quantum. This is not consistent with the fact that very primitive organisms possess sensory systems.

3. If all primary qualia are assigned to the magnetic body, Josephson radiation must include also gluons and light counterparts of weak bosons are involved besides photons. This is quite a strong additional assumption and it will be found that the identification of sensory qualia in terms of quantum numbers of quark pair restricts them to the cell membrane. The coding of qualia by Josephson frequencies is however possible and makes it possible to regenerate them in nervous system. The successful model explaining the peak frequencies of photoreceptors in terms of ionic cyclotron frequencies supports this view and provides a realization for an old idea about spectroscopy of consciousness which I had already been ready to give up.

Capacitor model of sensory qualia

In capacitor model of sensory receptor the increments of quantum numbers are amplified as particles with given quantum numbers flow between the plates of capacitor like system and the second plate defines the sub-self responsible for the mental image. The generation of complementary qualia assignable to the two plates and bringing in mind complementary colors is predicted. The capacitor is at the verge of di-electric breakdown. The interior and exterior of the receptor cell are the most plausible candidates for the capacitor plates with lipid layers defining the analog of di-electric able to changes its properties. Josephson currents generating Josephson radiation could communicate the sensory percept to the magnetic body but would not generate genuine sensory qualia there (the pitch of sound would be interpreted as a geometric quale). The coding is possible if the basic qualia correspond in one-one manner to ionic Josephson currents. There are sensory receptors which themselves do not fire (this is the case for hair cells for hearing and tactile receptor cells)

and in this case the neuron next to the receptor in the sensory pathway would take the role of the quantum critical system.

The notion of sensory capacitor can be generalized. In zero energy ontology the plates could be effectively replaced with positive and negative energy parts of zero energy state or with cyclotron Bose-Einstein condensates corresponding to two different energies. Plates could also correspond to a pair of space-time sheets labeled by different p-adic primes and the generation of quale would correspond in this case to a flow of particles between the space-time sheets or magnetic flux tubes connected by contacts defining Josephson junctions.

The TGD inspired model for photoreceptors [K59] relies crucially on the assumption that sensory neurons at least and probably all cell membranes correspond to nearly vacuum extremals with the value of Weinberg angle equal to $sin^2(\theta_W) = .0295$ and weak bosons having Compton length of order cell size and ordinary value of Planck constant. This also explains the large parity breaking effects in living matter. The almost vacuum extremal property conforms with the vision about cell membrane as a quantum critical system ideal for acting as a sensory receptor.

2.2.2 Detailed Model For The Qualia

The proposed vision about qualia requires a lot of new physics provided by TGD. What leads to a highly unique proposal is the intriguing coincidence of fundamental elementary particle time scales with basic time scales of biology and neuro science and the model of DNA as topological quantum computer [K3].

1. Zero energy ontology brings in the size scale of CD assignable to the field body of the elementary particle. Zero energy states with negentropic time-like entanglement between positive and negative energy parts of the state might provide a key piece of the puzzle. The negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) beween positive energy parts of the states associated with the sub-CD assignable to the cell membrane and sub-CD at the magnetic body is expected to be an important factor.

2. For the standard value of $\hbar$ the basic prediction would be 1 ms second time scale of d quark, 6.5 ms time scale of u quark, and.1 second time scale of electron as basic characterizes of sensory experience if one accept the most recent estimates $m(u) = 2$ MeV and $m(d) = 5$ MeV for the quark masses [C1]. These time scales correspond to 10 Hz, 160 Hz, and 1280 Hz frequencies, which all characterize neural activity (for the identification of 160 Hz frequency as cerebellar resonance frequency see [J39]). Hence quarks could be the most interesting particles as far as qualia are considered and the first working hypothesis would be that the fundamental quantum number increments correspond to those for quark-anti-quark pair. The identification in terms of quantum numbers of single quark is inconsistent with the model of color qualia.

3. The model of DNA as topological quantum computer led to the proposal that DNA nucleotides are connected to the lipids of the cell membrane by magnetic flux tubes having quark and antiquark at its ends such that the u and d quarks and their antiquarks code for the four nucleotides. The outer lipid layer was also assumed to be connected by flux tubes to the nucleotide in some other cell or in cell itself.

4. The model for DNA as topological quantum computer did not completely specify whether the flux tubes are ordinary flux tubes or wormhole flux tubes with possibly opposite signs of energy assigned with the members of the flux tube pair. Although it is not necessary, one could assume that the quantum numbers of the two parallel flux tubes cancel each other so that wormhole flux tube would be characterized by quantum numbers of quark pairs at its ends. It is not even necessary to assume that the net quantum numbers of the flux tubes vanish. Color confinement however suggests that the color quantum at the opposite ends of the flux tube are of opposite sign.

   (a) The absence of a flux tube between lipid layers was interpreted as an isolation from external world during the topological quantum computation. The emergence of the

flux tube connection means halting of topological quantum computation. The flux tube connection with the external world corresponds to sensory perception at the level of DNA nucleotide in consistency with the idea that DNA plays the role of the brain of cell [K64]. The total color quantum numbers at the ends of the flux tubes were assumed to sum up to zero. This means that the fusion of the flux tubes ending to the interior and exterior cell membrane to single one creates a flux tube state not localized inside cell and that the interior of cell carries net quantum numbers. The attractive interpretation is that this process represents the generation of quale of single nucleotide.

(b) The formation of the flux tube connection between lipid layers would involve the transformation of both quark-antiquark pairs to an intermediate state. There would be no kinematic constraints on the process nor to the mass scales of quarks. A possible mechanism for the separation of the two quark-antiquark pairs associated with the lipids from the system is double reconnection of flux tubes which leads to a situation in which the quark-antiquark pairs associated with the lipid layers are connected by short flux loops and separated to a disjoint state and there is a long wormhole flux tube connecting the nucleotides possibly belonging to different cells.

(c) The state of two quark pairs need not have vanishing quantum numbers and one possibility is that the quantum numbers of this state code for qualia. If the total numbers of flux tubes are vanishing also the net quantum numbers of the resulting long flux tube connecting two different cells provide equivalent coding. A stronger condition is that this state has vanishing net quantum numbers and in this case the ends of the long flux tube would carry opposite quantum numbers. The end of flux tube at DNA nucleotide would characterize the quale.

5. Two identification of primary qualia are therefore possible.

   (a) If the flux tubes have vanishing net quantum numbers, the primary sensory quale can be assigned to single receptor cell and the flow of the quantum numbers corresponds to the extension of the system with vanishing net quantum numbers in two-cell system.

   (b) If the net quantum numbers of the flux tube need not vanish, the resulting two cell system carries non-vanishing quantum numbers as the pair of quark-antiquark pairs removes net quantum numbers out of the system.

6. If the net quantum numbers for the flux tubes vanish always, the specialization of the sensory receptor membrane to produce a specific quale would correspond to an assignment of specific quantum numbers at the DNA ends of the wormhole flux tubes attached to the lipid layers of the cell membrane. The simplest possibility that one can imagine is that the outer lipid layer is connected to the conjugate DNA nucleotide inside same cell nucleus. This option would however assign vanishing net quantum number increments to the cell as whole and is therefore unacceptable.

7. The formation of a temporary flux tube connection with another cell is necessary during the generation of quale and the question is what kind of cell is in question. The connection of the receptor to cells along the sensory pathway are expected to be present along the entire sensory pathway from DNA nucleotide to a nucleotide in the conjugate strand of second neuron to DNA nucleotide of the third neutron.... If Josephson photons are able to regenerate the quale in second neuron this would make it possible to replicate the quale along entire sensory pathway. The problem is that Josephson radiation has polarization orthogonal to axons and must propagate along the axon whereas the flux tube connection must be orthogonal to axon. Hence the temporary flux tube connection is most naturally between receptor cells and would mean horizontal integration of receptor cells to a larger structure. A holistic process in directions parallel and orthogonal to the sensory pathway would be in question. Of course, the flux tube could be also curved and connect the receptor to the next neuron along the sensory pathway.

8. The specialization of the neuron to sensory receptor would require in the framework of positive energy ontology that -as far as qualia assignable to the electro-weak quantum numbers are considered - all DNA nucleotides are identical by the corresponds of nucleotides with quarks and antiquarks. This cannot be the case. In zero energy ontology and for wormhole flux tubes it is however enough to assume that the net electroweak quantum numbers for the quark antiquark pairs assignable to the DNA wormhole contact are same for all nucleotides. This condition is easy to satisfy. It must be however emphasized that there is no reason to require that all nucleotides involved generate same quale and at the level of neurons sensory maps assigning different qualia to different nucleotides and lipids allowing DNA to sensorily perceive the external world are possible.

The model should be consistent with the assignment of the fundamental bio-rhythms with the CDs of electron and quarks.

1. Quark color should be free in long enough scales and cellular length scales are required at least. The QCD in question should therefore have long enough confinement length scales. The first possibility is provided by almost vacuum extremals with a long confinement scale also at the flux tubes. Large $\hbar$ for the cell membrane space-time sheet seems to be unavoidable and suggests that color is free in much longer length scale than cell length scale.

2. Since the length of the flux tubes connecting DNA and cell membrane is roughly 1 micrometer and by a factor of order 10^7 longer than the d quark Compton length, it seems that the value of Planck constant must be of this order for the flux tubes. This however scales up the time scale of d quark CD by a factor of 10^{14} to about 10^4 years! The millisecond and 160 ms time scales are much more attractive. This forces to ask what happens to the quark-anti-quark pairs at the ends of the tubes.

3. The only possibility seems to be that the reconnection process involves a phase transition in which the closed flux tube structure containing the two quark pairs assignable to the wormhole contacts at lipid layers is formed and leaks to the page of the Big Book with pages partially labeled by the values of Planck constant. This page would correspond to the standard value of Planck constant so that the corresponding d quark CDs would have a duration of millisecond. The reconnection leading to the ordinary situation would take place after millisecond time scale. The standard physics interpretation would be as a quantum fluctuation having this duration. This sequence of quark sub-CDs could define what might be called memetic codon representation of the nerve pulse sequence.

4. One can also consider the possibility is that near vacuum extremals give rise to a copy of hadron physics for which the quarks associated with the flux tubes are light. The Gaussian Mersennes corresponding to $k = 151, 157, 163, 167$ define excellent p-adic time scales for quarks and light variants of weak gauge bosons. Quark mass 5 MeV would with $k = 120$ would be replaced with $k = 163$ (167) one would have mass 1.77 eV (.44 eV). Small scaling of both masses gives 2 eV and.5 eV which correspond to basic metabolic quanta in TGD framework. For quark mass of 2 MeV with $k = 123$ $k = 163$ (167) one would give masses.8 eV (.05 eV). The latter scale correspond to Josephson energy assignable with the membrane potential in the ordinary phase.

   In this case a phase transition transforming almost vacuum extremal to ordinary one takes place. What this would mean that the vacuum extremal property would hold true below much shorter p-adic length scale. In zero energy ontology the scaling up of quark masses is in principle possible. This option looks however too artificial.

2.2.3 Overall View About Qualia

This picture leads to the following overall view about qualia. There are two options depending on whether single quark-antiquark pair or two of them labels the qualia. In the following only the simpler option with single quark-antiquark pair is discussed.

1. All possible pairings of spin and electroweak isospin (or em charge) define 16 basic combinations if one assumes color singletness. If arbitrary color is allowed, there is a nine-fold

increase of quantum numbers decomposable to color singlet and octet qualia and further into 3×15 qualia with vanishing increments of color quantum numbers and 6×16 qualia with non-vanishing increments of color quantum numbers. The qualia with vanishing increments for electroweak quantum numbers could correspond to visual colors. If electroweak quantum numbers of the quark-anti-quark pair vanish, one has 3×7 *resp.* 6×8 combinations of colorless *resp.* colored qualia.

2. There is a huge number of various combinations of these fundamental qualia if one assumes that each nucleotide defines its own quale and fundamental qualia would be analogous to constant functions and more general qualia to general functions having values in the space with $9 \times 16 - 1$ points. Only a very small fraction of all possible qualia could be realized in living matter unless the neurons in brain provide representations of body parts or of external world in terms of qualia assignable to lipid-nucleotide pairs. The passive DNA strand would be ideal in this respect.

3. The basic classification of qualia is as color qualia, electro-weak quale, and spin quale and products of these qualia. Also combinations of color qualiaandelectroweak and spin quale are possible and could define exotic sensory qualia perhaps not yet realized in the evolution. Synesthesia is usually explained in terms of sensory leakage between sensory pathways and this explanation makes sense also in TGD framework if there exists a feedback from the brain to the sensory organ. Synesthesia cannot however correspond to the product qualia: for "quantum synesthesia" cross association works in both directions and this distinguishes it from the ordinary synesthesia.

4. The idea about brain and genome as holograms encourages to ask whether neurons or equivalently DNA could correspond to sensory maps with individual lipids representing qualia combinations assignable to the points of the perceptive field. In this framework quantum synesthesia would correspond to the binding of qualia of single nucleotide (or lipid) of neuron cell membrane as a sensory representation of the external world. DNA is indeed a holographic representation of the body (gene expression of course restricts the representation to a part of organism). Perhaps it is this kind of representation also at the level of sensory experience so that all neurons could be little sensory copies of body parts as holographic quantum homunculi. In particular, in the associative areas of the cortex neurons would be quantum synesthetes experiencing the world in terms of composite qualia.

5. The number of flux tube connections generated by sensory input would code for the intensity of the quale. Josephson radiation would do the same at the level of communications to the magnetic body. Also the temporal pattern of the sequence of quale mental images matters. In the case of hearing this would code for the rhythmic aspects and pitch of the sound.

2.2.4 About Detailed Identification Of The Qualia

One can make also guesses about detailed correspondence between qualia and quantum number increments.

1. Visual colors would correspond to the increments of only color quantum numbers. Each biologically important ion would correspond to its own color increment in one-one correspondence with the three pairs of color-charged gluons and these would correspond to blue-yellow, red-green, and black white [K59]. Black-white vision would mean a restriction to the $SU(2)$ subgroup of color group. The model for the cell membrane as a nearly vacuum extremal assigns the peak frequencies corresponding to fundamental colors with biologically important ions. Josephson radiation could induce artificially the same color qualia in other neurons and this might provide an manner to communicate the qualia to the brain where they could be re-experienced at neuronal level. Some organisms are able to perceive also the polarization of light. This requires receptors sensitive to polarization. The spin of quark pair would naturally code for polarization quale.

2. Also tastes and odours define qualia with "colors". Certainly the increments of electroweak numbers are involved but since these qualia do not have any directional flavor, spin is probably

not involved. This would give c 3×4 basic combinations are possible and can certainly explain the 5 or 6 basic tastes (counted as the number of different receptors). Whether there is a finite number of odours or not has been a subject of a continual debate and it might be that odours already correspond to a distribution of primary qualia for the receptor cell. That odours are coded by nerve pulse patterns for a group of neurons [J65] would conform with this picture.

3. Hearing seems to represent a rather colorless quale so that electroweak isospin suggests again itself. If we had a need to hear transversely polarized sound also spin would be involved. Cilia are involved also with hair cells acting as sensory receptors in the auditory system and vestibular system. In the case of hearing the receptor itself does not fire but induces a firing of the higher level neuron. The temporal pattern of qualia mental images could define the pitch of the sound whereas the intensity would correspond to the number of flux tube connections generated.

   The modulation of Josephson frequencies -rather than Josephson frequencies as such- would code for the pitch and the total intensity of the Josephson radiation for the intensity of the sound and in fact any quale. Pitch represents non-local information and the qualia sub-selves should be negentropically entangled in time direction. If not, the experience corresponds to a sequence of sound pulses with no well-defined pitch and responsible for the rhythmic aspects of music. Right brain sings-left brain talks metaphor would suggests that right and left brain have different kind of specializations already at the level of sensory receptors.

4. Somato-sensory system gives rise to tactile qualia like pain, touch, temperature, proprioception (body position). There are several kinds of receptors: nocireceptors, mechanoreceptors, thermoreceptors, etc... Many of these qualia have also emotional coloring and it might be that the character of entanglement involved (negentropic/entropic defines the emotional color of the quale. If this is the case, one might consider a pure quale of touch as something analogous to hearing quale. One can argue that directionality is basic aspect of some of these qualia -say sense of touch- so that spin could be involved besides electroweak quantum numbers. The distribution of these qualia for the receptor neuron might distinguish between different tactile qualia.

2.2.5 Recent TGD based view about qualia

The TGD inspired theory of qualia [K27] has evolved gradually and the recent view differs from the above described picture in some aspects.

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 [K41] 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.

2.3 The Roles Of Josephson Radiation, Cyclotron Radiation, And Of Magnetic Body

Before representing any detailed model for hearing, it is good to summarize the vision about the roles of Josephson radiation, cyclotron radiation, and of magnetic body on basis of the proposed general view about qualia and sensory receptors. The representation below is somewhat out of date and the updated and considerably more detailed view can be found in [K6].

2.3.1 The Role Of Josephson Currents

The general vision is that Josephson currents of various ions generate Josephson photons having dual interpretations as bio-photons and EEG photons. Josephson photons can in principle regenerate the quale in the neurons of the sensory pathway. In the case of motor pathways the function would be different and the transfer of metabolic energy by quantum credit card mechanism using phase conjugate photons is suggested by the observation that basic metabolic quanta 2 eV *resp.* 4 eV are associated with smooth muscle cells *resp.* skeletal muscle cells.

As already found in the previous section, the energies of Josephson photons associated with the biologically important ions are in general in visible or UV range except when resting potential has the value of -40 mV which it has for photoreceptors. In this case also IR photons are present. Also the turning point value of membrane potential is +40 mV so that one expects the emission of IR photons.

Josephson photons could be used to communicate the qualia to the magnetic body.

1. If Josephson currents are present during the entire action potential, the entire range of Josephson photons down to frequencies of order 2 kHz range is emitted for the standard value of $\hbar$. The reason is that lower frequencies corresponds to cycles longer than the duration of the action potential. The continuum of Josephson frequencies during nerve pulse makes it possible to induce cyclotron transitions at the magnetic body of neuron or large structure. This would make possible to communicate information about spatial and temporal behavior of the nerve pulse pattern to the magnetic body and build by quantum entanglement a sensory map.

2. The frequencies below 2 kHz could be communicated as nerve pulse patterns. When the pulse rate is above $f = 28.57$ Hz the sequence of pulses is experienced as a continuous sound with pitch f. f defines the minimum frequency for which nerve pulses could represent the pitch and there remains a 9 Hz long range to be covered by some other communication method.

3. The cyclotron frequencies of quarks and possibly also of electron would make possible a selective reception of the frequencies emitted during nerve pulse. Same applies also to the Josephson frequencies of hair cell (, which does not fire). If the value of Planck constant is large this makes possible to communicate the entire range of audible frequencies to the magnetic body. Frequency would be coded by the magnetic field strength of the flux tube. Two options are available corresponding to the standard ground state for which Z^0 field is very weak and to almost vacuum extremals. For the first option one as ordinary cyclotron frequencies. The cyclotron frequency scales for them differ by a factor

$$r(q) = \frac{Q_{eff}(q)}{Q_{em}(q)} = \frac{\epsilon(q)}{2pQ_{em}(q)} + 1 \; per, \;\; \epsilon(u) = -1 \;\; , \epsilon(d) = 1$$

from the standard one. For $p = .0295$ one obtains $(r(u), r(d), r(e) = (24.42, 49.85, 15.95)$. The cyclotron frequencies for quarks and electron with masses m(u)=2 MeV, m(d)=5 MeV,

fermion	$f_c(e)/MHz$	$f_c(u)/MHz$	$f_c(d)/MHz$
standard	.564	.094	.019
nearly vacuum extremal	8.996	2.275	.947

Table 2.1: Cyclotron frequencies of quarks and electron in magnetic field $B_{end} = .2$ Gauss for standard vacuum with very small Z^0 field and nearly vacuum extremal.

and m(e)=.5 MeV are given by **Table 2.1** for the two options. If one assumes that B_{end} defines the upper bound for field strength then he standard option would require both d quark and electron. Gor $d$quark with kHz CD the upper bound for cyclotron frequencies would be 20 kHz which corresponds to the upper limit of audible frequencies.

4. Besides cyclotron frequencies also the harmonics of the fundamental frequencies assignable to quark and electron CDs could be used and in case of musical sounds this looks a highly attractive option. In this case it is now however possible to select single harmonics as in the case of cyclotron transitions so that only the rate of nerve pulses can communicate single frequency. Lorentz transform sub-CD scales up the frequency scale from the secondary p-adic time scale coming as octave of 10 Hz frequency. Also the scaling of $\hbar$ scales this frequency scale.

2.3.2 What Is The Role Of The Magnetic Body?

The basic vision is that magnetic body receives sensory data from the biological body- basically from cell membranes and possibly via genome - and controls biological body via genome. This leaves a huge amount of details open and the almost impossible challenge of theoretician is to guess the correct realization practically without any experimental input. The following considerations try to clarify what is involved.

Is magnetic body really needed?

Libet's findings and the model of memory based on time mirror hypothesis suggests that magnetic body is indeed needed. What is the real function of magnetic body? Is it just a sensory canvas? The previous considerations suggest that it is also the seat of geometric qualia, in particular the pitch of sound should be coded by it. It would be relatively easy to understand magnetic body as a relatively passive sensory perceiver defining sensory map. If one assumes that motor action is like time reversed sensory perception then sensory and motor pathways would be just sensory pathways proceeding in opposite time directions from receptors to the various layers of the magnetic body. Brain would perform the information processing.

Certainly there must exist a region in which the motor and sensory parts of the magnetic body interact. What comes in mind is that these space-time sheets (or actually pairs of space-time sheets) are parallel and generate wormhole contacts between them. This interaction would be assignable to the region of the magnetic body could receive positive energy signals from associative sensory areas and send negative energy signals to motor motor neurons at the ends of motor pathways wherefrom they would propagate to premotor cortex, supplementary motor cortex and to frontal lobes where the abstract plans about motor actions are generated.

Is motor action time reversal of sensory perception in zero energy ontology?

One could argue that the free will aspect of motor actions does not conform with the interpretation as sensory perception in reversed direction of time. On the other hand, also percepts are selected -say in binocular rivalry [J40]. Only single alternative percept need to be realized in a given branch of the multiverse. This makes possible metabolic economy: for instance, the synchronous firing at kHz frequency serving as a correlate for the conscious percept requires a lot of energy since dark photons at kHz frequency have energies above thermal threshold. Similar selection of percepts could occur also at the level of sensory receptors but quantum statistical determinism

would guarantee reliable perception. The passivity of sensory perception and activity of motor activity would reflect the breaking of the arrow of time if this interpretation is correct.

What magnetic body looks like?

What magnetic body looks like has been a question that I have intentionally avoided as a question making sense only when more general questions have been answered. This question seems however unavoidable now. Some of the related questions are following. The magnetic flux lines along various parts of magnetic body must close: how does this happen? Magnetic body must have parts of size at least that defined by EEG wavelengths: how do these parts form closed structures? How the magnetic bodies assignable to biomolecules relate to the Earth sized parts of the magnetic body? How the personal magnetic body relates to the magnetic body of Earth?

1. The vision about genome as the brain of cell would suggest that active and passive DNA strands are analogous to motor and sensor areas of brain. This would suggests that sensory data should be communicated from the cell membrane along the passive DNA strand. The simplest hypotesis is that there is a pair of flux sheet going through the DNA strands. The flux sheet through the passive strand would be specialized to communicate sensory information to the magnetic body and the flux sheet through the active strand would generate motor action as DNA expression with transcription of RNA defining only one particular aspect of gene expression. Topological quantum computation assignable to introns and also electromagnetic gene expression would be possible.

2. The model for sensory receptor in terms of Josephson radiation suggests however that flux tubes assignable to axonal membranes carry Josephson radiation. Maybe the flux tube structures assigned to DNA define the magnetic analog of motor areas and flux tubes assigned with the axons that of sensory areas.

3. A complex structure of flux tubes and sheets is suggestive at the cellular level. The flux tubes assignable to the axons would be parallel to the sensory and motor pathways. Also microtubules would be accompanied by magnetic flux tubes. DNA as topological quantum computer model assumes and the proposed model of sensory perception and cell membrane level suggests transversal flux tubes between lipids and nucleotides. The general vision about DNA as brain of cell suggest flux sheets through DNA strands.

   During sensory perception of cell and nerve pulse the wormhole flux tube connecting the passive DNA strand of the first cell to the inner lipid layer would recombine with the flux tube connecting outer lipid layer to some other cell to form single flux tube connecting two cells. In the case of sensory organs these other cells would be naturally other sensory receptors. This would give rise to a dynamical network of flux tubes and sheets and axonal sequences of genomes would be like lines of text at the page of book. This structure could have a fractal generalization and would give rise to an integration of genome to super-genome at the level of organelles, organs and organism and even hypergenome at the level of population. This would make possible a coherent gene expression.

4. This vision gives some idea about magnetic body in the scale of cell but does not say much about it in longer scales. The CDs of electrons and quarks could provide insights about the size scale for the most relevant parts of the magnetic body. Certainly the flux tubes should close even when they have the length scale defined by the size of Earth.

Additional ideas about the structure follow follow if one assumes that magnetic body acts a sensory canvas and that motor action can be regarded as time reversed sensory perception.

1. If the external world is represented at part of the magnetic body which is stationary, the rotation of head or body would not affect the sensory representation. This part of the magnetic body would be obviously analogous to the outer magnetosphere, which does not rotate with Earth.

2. The part of the magnetic body at which the sensory data about body (posture, head orientations and position, positions of body parts) is represented, should be fixed to body and

change its orientation with it so that bodily motions would be represented as motions of the magnetic , which would be therefore analogous to the inner magnetosphere of rotating Earth.

3. The outer part of the personal magnetic body is fixed to the inner magnetosphere, which defines the reference frame. The outer part might be even identifiable as the inner magnetosphere receiving sensory input from the biosphere. This magnetic super-organism would have various life forms as its sensory receptors and muscle neurons. This would give quantitative ideas about cyclotron frequencies involved. The wavelengths assignable to the frequencies above 10 Hz would correspond to the size scale of the inner magnetosphere and those below to the outer magnetosphere. During sleep only the EEG communications with outer magnetic body would remain intact.

4. Flux quantization for large value of $\hbar$ poses an additional constraint on the model.

   (a) If Josephson photons are transformed to a bunch of ordinary small $\hbar$ photons magnetic flux tubes can correspond to the ordinary value of Planck constant. If one assumes the quantization of the magnetic flux in the form

   $$\int BdA = n\hbar$$

   used in super-conductivity, the radius of the flux tube must increase as $\sqrt{\hbar}$ and if the Josephson frequency is reduced to the sound frequency, the value of $\hbar$ codes for the sound frequency. This leads to problems since the transversal thickness of flux tubes becomes too large. This does not however mean that the condition might not make sense: for instance, in the case of flux sheets going through DNA strands the condition might apply.

   (b) The quantization of magnetic flux could be replaced by a more general condition

   $$\oint (p - ZeA)dl = n\hbar \ , \tag{2.3.1}$$

   where p represents momentum of particle of super-conducting phase at the boundary of flux tube. In this case also $n = 0$ is possible and poses no conditions on the thickness of the flux tube as a function of $\hbar$. This option looks reasonable since the charged particles at the boundary of flux tube would act as sources of the magnetic field.

   (c) Together with the Maxwell's equation giving $B = ZeNv$ in the case that there is only one kind of charge carrier this gives the expression

   $$N = \frac{2m}{RZ^2e^2} \tag{2.3.2}$$

   for the surface density N of charge carrier with charge Z. R denotes the radius of the flux tube. If several charge carriers are present one has $B = \sum_k N_k Z_k e v_k$, and the condition generalizes to

   $$N_i = \frac{2m_i v_i}{RZ_i \sum_k Z_k v_k e^2} \ . \tag{2.3.3}$$

   It seems that this condition is the most realistic one for the large $\hbar$ flux sheets at which Josephson radiation induces cyclotron transitions.

What are the roles of Josephson and cyclotron photons?

The dual interpretation of Josephson radiation in terms of bio-photons and EEG photons seems to be very natural and also the role of Josephson radiation seems now relatively clear. The role of cyclotron radiation and its interaction with Josephson radiation are not so well understood.

1. At least cell membrane defines a Josephson junction (actually a collection of them idealizable as single junctions). DNA double strand could define a series of Josephson junctions possibly assignable with hydrogen bonds. This however requires that the strands carry some non-standard charge densities and currents- I do not know whether this possibility is excluded experimentally. Quarks and antiquarks assignable to the nucleotide and its conjugate have opposite charges at the two sheets of the wormhole flux tube connective nucleotide to a lipid. Hence one could consider the possibility that a connection generated between them by reconnection mechanism could create Josephson junction.

2. The model for the photoreceptors leads to the identification of bio-photons as Josephson radiation and suggests that Josephson radiation propagates along flux tubes assignable to the cell membranes along sensory pathways up to sensory cortex and from there to motor cortex and back to the muscles and regenerates induced neuronal sensory experiences.

3. Josephson radiation could be used quite generally to communicate sensory data to/along the magnetic body: this would occur in the case of cell membrane magnetic body at least. The different resting voltages for various kinds of cells would select specific Josephson frequencies as communication channels.

4. If motor action indeed involves negative energy signals backwards in geometric time as Libet's findings suggest, then motor action would be very much like sensory perception in time reversed direction. The membrane resting potentials are different for various types of neurons and cells so that one could speak about pathways characterized by Josephson frequencies determined by the membrane potential. Each ion would have its own Josephson frequency characterizing the sensory or motor pathway.

The basic questions concern the function of cyclotron radiation and whether Josephson radiation induces resonantly cyclotron radiation or vice versa.

1. Cyclotron radiation would be naturally associated with the flux sheets and flux tubes. The simplest hypothesis is that at least the magnetic field $B_{end} = .2$ Gauss can be assigned with the some magnetic flux quanta at least. The model for hearing suggests that B_{end} is in this case quantized so that cyclotron frequencies provide a magnetic representation for audible frequencies. Flux quantization does not pose any conditions on the magnetic field strength if the above discussed general flux quantization condition involving charged currents at the boundary of the flux quantum are assumed. If these currents are not present, $1/\hbar$ scaling of B_{end} for flux tubes follows.

2. The assumption that cyclotron radiation is associated with the motor control via genome is not consistent with the vision that motor action is time reversed sensory perception. It would also create the unpleasant question about information processing of the magnetic body performed between the receival of sensory data and motor action.

3. The notion of magnetic sensory canvas suggests a different picture. Josephson radiation induces resonant cyclotron transitions at the magnetic body and induces entanglement of the mental images in brain with the points of the magnetic body and in this manner creates sensory maps giving a third person perspective about the biological body. There would be two kind of sensory maps. Those assignable to the external world and those assignable to the body itself. The Josephson radiation would propagate along the flux tubes to the magnetic body.

4. There could be also flux tube connections to the outer magnetosphere of Earth. It would seem that the reconnections could be flux tubes traversing through inner magnetosphere to poles and from there to the outer magnetosphere. These could correspond to rather low cyclotron frequencies. Especially interesting structure in this respect is the magnetic flux sheet at the Equator.

2.3.3 Magnetic Homeostasis And Magnetic Circulation?

The possible importance of the precise value of the local magnetic field for say memetic code [K29] suggests that living matter has learned to control local magnetic field inside magnetic flux tubes just as it controls salt level of biological water.

Variation of the local strength of B_{end}

B_{end} -which is assigned to the magnetic body of particular body part- should scale as $1/\hbar$ to maintain the constant ratio of Josephson and cyclotron frequencies. This predicts hierarchy of cyclotron frequency scales coming in octaves if one accepts that the preferred levels of dark matter hierarchy come as $r = \hbar/\hbar_0 = 2^{k_d}$ with values of k_d fixed by Mersenne hypothesis introduced in introduction and discussed in detail in [K24]. Cell differentiation could lead to the differentiation of the local value of k_d and the value could vary even inside single cell nucleus.

Also a slight variation of the strength of B_{end} for a given value of r is possible. The condition that the ratios of Josephson frequencies and cyclotron frequencies remain constant means that the scalings of B_{end} and membrane resting potential are identical. Also the relative variation of EEG frequency scale would be same as that of the resting potential. The variation of resting potential is 10 per cent as is also that of EEG frequency scale so that this prediction is correct. Since the resting potential is characteristic of cell type [K24], also the value of B_{end} for corresponding part of magnetic body would be such. In the model of hearing the variation of both k_d decomposing the frequencies into octaves and smaller variations of B_{end} allowing to decompose octaves into smaller intervals would make possible to sense the pitch of the sound [K58]. This sense would be essentially a sensory quale assignable to magnetic body.

Magnetic circulation

There is a rather precise analogy with blood flow since both incompressible velocity field of blood and magnetic field are divergenceless: one can imagine magnetic flux to flow along "B-veins" (magnetic flux tubes) along organism or at least CNS. Variation of the magnetic field strength would be forced by the variation of the thickness of the flux tube since magnetic flux is conserved just as the variation of the thickness of blood veins affects blood flow. Artificial small alteration of local magnetic from outside would only interfere with this control.

For instance, alpha peak drifts in Hz range and this could be due the variation of the value of local magnetic field varies as much as 10 per cent. If this variation is due to the homeostatic variation of the local magnetic field, absolute variation should increase for higher frequencies: at the upper end of gamma band it would be 9 Hz. An alternative explanation for drifting is in terms of amplitude modulation: amplitude modulation of frequency f_1 by frequency f implies that original frequency is split to frequencies $f_1 \pm f$. In this case the amplitude of drifting does not depend on frequency.

The analogy with blood flow suggests that one could speak about B-circulation completely analogous to blood circulation: B-circulation could be crucial for bio-system to act as macroscopic quantum system. B-circulation would naturally accompany neural circuitry. It could be also accompany ordinary blood circulation physically or could form an independent system. The association with blood circulation would provide prerequisites for quantum control of also blood circulation and metabolism. The control could be based on MW frequency Josephson currents associated with ELF em fields inducing conformational changes of proteins coherently in large regions in turn giving rise to needed synchronous biochemical self-organization processes.

Temperature dependence of the local magnetic field strength

EEG frequencies are known to change with [I32] [J93] in the sense that the increase of the temperature raises the peak frequency of the power spectrum. This need not mean that the individual EEG frequencies are affected since the distribution of these frequencies could be affected due to the effects on the ionic conductances.

On the other hand, the equilibrium potentials for various ions are proportional to the temperature. In TGD framework this would predict that also EEG frequency scale is proportional to T so that the effect of temperature could be understood at least partially. Of course, very large

drop of temperature known to induce sleep EEG involves dropping of higher EEG bands from the spectrum. The maximal reduction of body temperature have been to about 1 degree C and correspond to 10 per cent reduction of absolute temperature. 10 per cent variation is also characteristic variation of EEG band positions.

As far as nerve pulse generation is considered small reduction of temperature should lead to reduced membrane potential and if the value of the potential inducing nerve pulse does not follow, this would lead to a level of arousal. Maybe this could explain the stimulating effect of cold.

The question is whether cyclotron frequency scale follows the scale of the resting potential. If this is not the case, the communications to the magnetic body suffer from temperature changes since resonance conditions are lost. This could partially explain why a serious hibernation leads to a lower level of arousal. Cyclotron frequency scale can follow the change of the temperature as long as the transversal size scale of the magnetic flux quanta can react on the changes of the temperature and by flux conservation induce a change of the magnetic field strength. It is however highly questionable whether this is possible at distant parts of the magnetic body if it indeed can have the size scale of Earth.

The results of Blackman [J20] suggesting that ELF effects with given frequency disappear when body temperature is not in the range $36-37$ C inspires the hypothesis that quantum critical high T_c superconductivity and almost vacuum extremal property of the cell membrane space-time sheet are possible only in the range 36-37 C. This obviously provides a more plausible explanation for the effect of hibernation. In this picture the extreme importance of temperature regulation for the functioning of organism could be seen as a prerequisite for continual quantum control by magnetic transition frequencies.

Circadial temperature variation can be something like 20 Kelvins, which means relative variation about 10 per cent for poikilotherms, which is of same order as alpha frequency drifting. The relative width of the cyclotron resonance would be from this about 7 per cent ($\Delta f/f = \Delta B/B \propto \Delta T/T$). The relative variation of the membrane resting potential as a function of temperature is predicted to be sam.

Why the increase of the local magnetic field strength by factor of ten does not raise alpha band to heaven?

The increase of the local magnetic field strength by a factor $10-20$ is known to induce stress [J28] and confuse biological timekeeper mechanisms but it certainly cannot raise alpha band above 100 Hz as as a very naïve standard physics based application of the cyclotron frequency hypothesis would suggest.

In standard physics picture one could indeed argue that the increase of the strength of the local magnetic field interferes directly with bio-control and has catastrophic consequences. This is not the case of B_{end} corresponds to so large value of Planck constant that cyclotron energy corresponds to the energy of visible or UV photon and if the local magnetic field corresponds to the ordinary (or just different) value of Planck constant. That the variation local magnetic field has effect can be understood if the flux tubes of the dark magnetic field B_{end} are in contact with the those of the local magnetic field presumably having standard value of Planck constant. This would be classical interaction between visible and dark sectors of "world of classical worlds". One can of course imagine also other interaction mechanisms.

2.3.4 Some Remarks And Questions

Synchronizing effect of Earth's magnetic field

Earth's magnetic field could act as grand synchronizer of biorhythms of even separate organisms. Magnetic homeostasis does not prevent the effects due to the variation of Earth's magnetic field on human consciousness.

The close correlation of various cycles of biological and brain activity, in particular sleep-wake cycle, with periodic circadial variations of the geomagnetic field [J28], is consistent with this. Magnetic storms change temporarily the value of the local magnetic field and also this should have effects on consciousness. The statistics about mental hospitals supports this view [J28]. Also Persinger has proposed that the modulations of Earth's magnetic field caused by geomagnetic perturbations have effect on human consciousness [J28, J75]. Michael Persinger has

studied extensively the effects of Schumann resonances on brain and has even explained religious and UFO experiences as correlates of this interaction [J75].

Also the diurnal changes of magnetic field caused by Moon having period of 25 hours are known and this variation seems to provide fundamental biological clock which sets on in absence of the normal 24 rhythm regulated by sunlight. The diurnal variations of the geomagnetic field are also responsible for sleep-awake rhythm: the increased melatonin secretion during dark hours correlate with the variation of Earth's magnetic field.

It is also known that the exposure to magnetic fields 10-20 times geomagnetic field induces stress in rabbits and slowed reaction time in humans; that the absence of geomagnetic field leads to a complete de-synchronization of biorhythms and that the synchronization of ELF biorhythms is coupled to ELF geomagnetic pulsations [J28]. In particular, pineal gland serves as biological timekeeper with cyclotron frequency of Co^{2+} ion defining the basic time unit of .1 seconds.

Dr. Phil Callahan [I1] claims on basis of intensive experimental work that there is a tendency of political strifes and wars to concentrate on regions where Schumann resonances are weak. This would not be surprising since Schumann resonances act as collective bio-rhythms if vertebrate brains are connected to the magnetic body of Earth.

3. What happens to astronaut's magnetic body

There is an old objection against the notion of magnetic body. If the local value of Earth's magnetic field is crucial for the brain functioning, astronauts should experience grave difficulties or at least dramatic changes in the character of consciousness. A possible estimate for the weakening of the local magnetic field is based on the scaling law $B \propto 1/r^3$ for dipole field. In this case a rough estimate for the relative change of the EEG frequency scale is $\Delta f/f = 3\Delta R/R \sim 6$ per cent for satellites moving below the ionosphere. This should affect the state of consciousness.

As a matter fact, there is reported evidence [J33, J92] that cosmonauts spending months in MIR had strange altered states of consciousness involving among other things precognition of the difficulties to be countered by MIR and receiving advices and identification experiences with other people and life forms, even dinosaurs of ancient Earth!

In the many-sheeted space-time the situation looks like following.

1. Only the levels k_d for which the size scale is between the size scale of personal magnetic body and the distance travelled could have been affected.

2. Astronauts could have drawn the magnetic flux sheets connecting them to the magnetic body of Earth and higher level magnetic bodies with them but long period could have led to a loss of the connections to the magnetic body of Earth.

3. At the level of cell nuclei nothing dramatic need happen. Energetically the stretching magnetic flux sheets associated with DNA is not a problem since the energy densities involved are rather tiny. Furthermore, if the flux sheets carry homological monopole flux, they could highly stable against increase of length since they would have magnetic monopole wormhole contacts at their ends.

4. A long period in space without contact with magnetic Mother Gaia might relate to the strange experiences reported by astronauts. One might imagine that the magnetic body of say solar system or even galactic magnetic body replaces Earth's magnetic body as a kind of fundamental reference frame. For instance, the third person perspective could rely on the inner magnetosphere which is at rest with respect to rotating Earth and the outer magnetosphere which does not rotate with Earth would provide even higher level reference system which begins to dominate in this kind of situation.

5. The experiences are consistent with TGD based view about geometric time and possibility of geometric memories extending beyond the duration of individual life cycle. There is also a consistency with Mersenne hypothesis summarized in the introduction and with the vision about long term memory inspired by this hypothesis [K24]. If one takes seriously the report about dinosaurs, which lived for $\sim 10^8$ years ago, the level $k_{eff} = 163 + k_d = 257$, which corresponds to Josephson period of about 10^8 years could have contributed to the conscious experience of astronauts. Therefore $k_d = 94$ characterizes the value of Planck

constant as $r = \hbar/\hbar_0 = 2^{k_d}$. $k_{eff} = 257$ is consistent with Mersenne hypothesis. One has $257 = 239 + 18$, where $k_{eff} = 239$ is member of the twin pair $(239, 241)$ of Gaussian Mersennes suggested to be responsible for long term memory. $257 - 239 = 18$ in turn equals to the difference $107 - 89 = 18$ corresponds to the ratio of hadronic p-adic length scale $k = 107$ and intermediate boson length scale $k = 89$ defined by Mersenne primes. One cannot of course take the individual numbers deadly seriously: what is important the general view about memory based on hierarchy of weak physics assigned to Mersennes and their Gaussian counterparts suggests an explanation for the reported transpersonal memories.

5. What the reduction of Earth's magnetic field means?

The strength of Earth's magnetic field has reduced 50 per cent during last 1.000 years. The fact that an exponential evolution of civilization has occurred during this period, is perhaps not an accident. Surprisingly many magnetic transition frequencies happen to be near to Schumann resonance frequencies which do not depend on the strength of the magnetic field. If the scale of dark magnetic field B_{end} has followed the scale of B_E the the weakening of B_E furing this period has reduced cyclotron frequency spectrum of heavy ions from $3-8$ Hz range to the range $1.5-4$ Hz but leaving the spectrum of Schuman resonances unchanged. Rather remarkably, delta frequencies near 3 Hz correspond to a peak in the frequency spectrum of so called sferics associated with lightning activity [J55].

These observations suggest the emergence of strong interaction between brain and higher levels of the self hierarchy based on spherics and Schumann resonances. Assuming temporal linearity, the reduction of Earth's magnetic field has been 25 per cent after Newton and 5 per cent during last 100 years. Perhaps an exponential development of mathematical consciousness made possible by the activation of cyclotron frequencies of heavy ions with high nuclear and electronic angular momenta and allowing large number of conscious-to-us magnetic transitions, and possibly also involving some kind of fine tuning is taking place.

The weakening of Earth's magnetic field probably relates to a forthcoming change in the polarity of Earth's magnetic field. One might guess that the personal magnetic bodies are not affected appreciably during this period but that the violent change of Earth's magnetic field induces dramatic effects on collective aspects of consciousness at $k_d = 44$ level as the findings of Callahan suggest.

What about spin flips?

The natural question is whether also spin flips to which Larmor frequencies are associated could be important. If anomalous magnetic moment vanishes Larmor frequency differs by a factor $1/2$ from cyclotron frequency: $f_L = f_c/2$ so that spin flip frequency is same as cyclotron frequency. For atomic nuclei the Larmor frequency tends to be larger than cyclotron frequency as the table of Appendix demonstrates. The effects of em fields in living matter at Larmor frequencies have not been however reported.

The natural expectation is that Larmor frequency behaves in the same manner as cyclotron frequency in the scaling of Planck constant and this is indeed the case since spin scales as $\hbar_{eff}$. This allows to consider the possibility that also spin flip transitions are of interest and perhaps define correlates for sensory qualia.

Spin flip frequencies are in general of order few hundred Hz for $B = .2$ Gauss. The eight ions listed in **Table 2.2** have however exceptionally low Larmor frequencies and, very importantly, the singly ionized states have vanishing electronic spin for all ions except Rh and IR for which electronic configuration corresponds to $J - e = 2/2$ (non-vanishing electronic spin implies that the Larmor frequency of ion is of order $f_L = f_c(e)/2 \simeq 3 \times 10^5$ Hz). This suggests that electromagnetic spin flip transitions for these ions at least could be related to our consciousness. Note that K, Ag and Au have spin flip frequencies near to the harmonics of the fundamental frequencies of exotic supersymplectic representations important in EEG frequency range. Note that the spin flip frequency of K is 39.1 Hz which is in 40 Hz thalamocortical resonance band. The spin flip frequency 82.2 Hz for Cl might relate to the resonance frequency 80 Hz associated with retina.

Ion	(Z, A, S)	f_1/Hz	f_{flip}/Hz	J
Cl	(17, 35, F)	8.5	82.2	3/2
K	(19, 39, F)	7.5	39.1	3/2
Rb	(37, 85, F)	3.5	81.0	5/2
Y	(39, 89, F)	3.4	41.2	1/2
Rh	(45, 103, F)	2.9	26.6	1/2
Ag	(47, 107, F)	2.8	34.2 (39.2)	1/2
Ir	(77, 193, F)	1.6	17.0	3/2
Au	(79, 197, F)	1.5	14.0	3/2

Table 2.2: The ions for which electronic spin vanishes in ground state and minimum spin flip frequency f_{flip} is below 90 Hz. f_{flip} is defined as $f_{min} = 2f_L/J$m, where J is nuclear spin. Ag allows two stable isotopes with almost same abundances and the values of f_{flip} are given for both.

2.4 Quantum Model For Hearing

It is very difficult to understand how neural processing could cope with the fast temporal gradients of the auditory input: the rate of nerve pulse transmission is simply too slow for this. The basic difficulty is that the time scale of nerve pulses is below millisecond whereas the highest audible sounds correspond to frequencies of about 200 kHz for some sea mammals [J2]. Also bats hear very high frequencies. The frequencies below kHz seem to be coded to spike interval distributions [J81] but for higher frequencies this is not possible. The mystery is how brain -or whatever is the ultimate perceiver- receives the information about higher frequencies. There is also the mystery of missing fundamenta [J8], which suggests a feedback from brain to ear, which is indeed known to exist and can sometimes be even heard directly as oto-acoustic sounds.

2.4.1 Basic Facts About Hearing And Their Interpretation In TGD Framework

It is good to start by a summary of the basic facts about hearing before applying the already summarized general model.

Inner and outer hair cells

Cochlea [J4] is the basic structure responsible for the transformation of sound to nerve pulse patterns and conscious experience. It is located in the inner ear together with the vestibular system [J11] responsible for equilibrioception- sense of balance requiring coding of information about the position and orientation of head. Both these systems utilize hair cells [J6] to detect the motion of the fluid and the only basic difference is that in the case of hair cells related to hearing the motion is oscillatory inducing oscillation of membrane potential whereas for vestibular system the motion is non-periodic inducing a shift of the membrane potential.

The ear of mammals involves outer and inner hair cells [J2, J6]. Outer hair cells have no axons to brain but there are efferents from cortex to them. The interpretation is that outer hair cells act as pre-amplifiers. They also make possible feedback from cortex allowing to build sensory percepts already at the level of ear. This makes reasonable the idea that sensory representations are indeed constructed at the level of sensory organs.

Hair cells act as filters selecting only one particular frequency. For cochlea piano keyboard is a good but not complete metaphor. The input at a given frequency presses various keys with a maximum activation at a key characterized by this frequency. Stereo cilia are nanotubes emerging from the surface of hair cell and participate the motion of the oscillation cochlear fluid. In inner cells this mechanism induces evoked potential varying in the rhythm of the filtered frequency. In outer cells the hair cell feeds actively energy to the sound wave and amplifies it. Outer hair cells as a dancer is a good metaphor.

The coupling of hair cells with neurons

The coupling of hair cells with neurons mediating neuronal signals to brain is poorly understood [J2, J6].

1. The transmission of neurotransmitters to postsynaptic neuron from the hair cell should be uncannily fast. The existence of unidentified very fast neurotransmitter is postulated.

2. Hair cell contains near presynaptic cleft a mysterious structure with ring like shape known as presynaptic dense body. The function of this structure is not known but is believed to be crucial for the transfer of the neural transmitter.

3. There is chronical Ca^{2+} leakage to the hair cell. This is also believed to be crucial for the transmission of the mystery transmitter.

Hearing range

The hearing ranges [J7] are the basic quantitative facts that the model of hearing should be able to explain.

1. For humans the hearing range is between 20 Hz and 20 kHz. For dogs the hearing range is from 40 Hz to 60 kHz. For bats the hearing range is between 20 Hz and 120 kHz. This suggests the existence of two different mechanisms of hearing. For mice the hearing range is from 1 kHz to 70 kHz, which suggests that the ranges $20 - 10^3$ Hz and the range above it are fundamentally different as far hearing is considered. One explanation is that rate coding is lacking.

   Sea mammals have also wide hearing ranges. Harbour porpoise emits sounds at two bands: one at 2 kHz and one above 110 kHz and the cochlear of these dolphins are specialized to accommodate extremely high frequencies. Bottlenose dolphin produces sound in a range varying from 250 Hz to 150 kHz. Marine mammals are also known to possess language and whales are known to sing.

2. Outer hair cells -possessed only by mammals- are known to be crucial for the expansion of the hearing range besides pre-amplification increasing the sensitivity and it might be that the two hearing ranges relate to the presence of two kinds of hair cells. Mechanoreception is based on vibrations of stereocialia in the cochlear fluid mediating the sound vibrations.

Hearing range involves several poorly understood aspects. Frequencies above kHz do not allow rate coding by nerve pulses and one mystery of neuroscience is how these sounds give rise to a conscious experience. One should also understand why 20 Hz defines the lower bound of audible frequencies and why the fundamental frequency of speech organs is 10 Hz, which by the way suggests that harmonics of 10 Hz could provide a fundamental representation of frequencies. One should identify the mechanism giving rise to the two audible ranges suggested by the hearing of bats and sea mammals.

Pitch

Pitch corresponds to the subjective sensation created by the sound and is determined by the fundamental frequency and its harmonics which are its integer multiples. If the distribution of frequencies is even (non-harmonicy) there is no distinguishable pitch. The sounds produced by music instruments to represent melodies have well-defined pitch.

The phenomenon of missing fundamental means that fundamental is experienced although it is not present. This can be understood in terms of the feedback from brain artificially generating the missing harmonic in outer hair cells. The higher harmonics of the fundamental determine the character of the pitch and define the recognizable character of music instrument and human voice (timbre).

The relative resolution of pitch is $\Delta f/f = 4.3$ per cent so that octave could be divided to 86 notes distinguishable from each other to be compared with 12 notes in the well-tempered scale. If the two frequencies are heard simultaneously the resolution increases since beat frequencies can

be perceived. According to [J80] even subjects with absolute pitch require a context in order to recognize the pitch of the sound. There are several acoustic illusions related to pitch. For instance, a continues or discrete sequence of specially formed tones can be made to sound as if the sequence would continue to ascend or descend indefinitely.

Other aspects of hearing

Hearing involves also many other aspects discussed in [J80] and is clearly an exceptional sensory modality.

1. One key aspect of hearing relates to the determination of the direction of the sound source. This is known to involve the comparison of timing of the signals coming to ears and involves neuronal activity.

2. Hearing can be selective and auditory system is able to recognize the voice of a familiar person from the crowd. This suggests that the feedback generating artificial percept is especially important for hearing. I have a personal experience about conference held in Finland, where I listened english for a week. As I returned from the conference I heard to my surprise the finnish language as english for some time. Obviously, my brain manipulated the auditory input very actively.

3. Music experience involves several poorly understood phenomena serving as guidelines for anyone trying to understand sensory experience at deeper level. Mention only octave phenomenon and harmony and rhythm and pitch are dual aspects of the music.

4. Speech and language relate also to hearing. Why just hearing? Does this reflect that fact that pitch is a quale of magnetic body? And how internal speech relates to speech and hearing? The interpretation of internal speech as imagined speech would look natural but the challenge is to understand what imagination is. Could internal speech be based to a cortical projection to outer hair cells generating a weak auditory stimulus? Or could neurons generate internal speech in terms of neuronal quale distributions analogous to hearing quale but without the signalling to the magnetic body? Also sign languages are possible but sign language might express internal speech. Right brain sings-left brain talks metaphor has also something in it and the theory should provide insights about this specialization.

Cochlea and its magnetic body could give rise not only to auditory qualia but also define low level cognitive and emotional representations of auditory input realized already at the magnetic body of cochlea and realized in terms of cyclotron phase transitions. The right brain signs-left brain talks metaphor suggests an identification of cognitive *resp.* emotional representations as sequences of "phonemes" *resp.* "notes". The construction of the sensory representations involves in an essential manner back projection from brain to outer hair cells. Astrocytes regarded earlier as mere metabolic energy reservoirs are in this model carriers of higher level cognitive and emotional representations: this applies to all qualia. Microtubuli are responsible for mediating auditory input to brain as acoustic/electric signals (also propagating conformational patterns could be involved) and this resolves the mystery of how frequencies above kHz frequency are heard.

2.4.2 How Pitch Is Represented?

The proposed vision about sensory perception would suggests that pitch is directly experienced at the magnetic body of the cochlea or some higher level magnetic body. This would solve the problem posed by high pitches for the model based on rate coding. The frequency modulated Josephson radiation generated by the hair cells would define the experienced pitch. Given hair cell would correspond to a specific position of the magnetic body and Josephson radiation from the hair cell could induce cyclotron transition at it.

The frequencies assignable to CDs seem to be involved

The frequency coding by cyclotron frequencies or by harmonics assignable to various kinds of CDs is highly suggestive.

1. This coding need not be same as the coding by cyclotron frequencies. Indeed, since the time scale of CD scales as $\hbar$, the CDs in question must correspond to the standard value of Planck constant. This would require that Josephson photons leak to these CDs and are transformed to bunches of ordinary photons. The proposed model for the generation of quale involves a leakage of two quark-antiquark pairs to a space-time sheet with ordinary value of $\hbar$ for a time interval defined by the corresponding CD scale. This CD could be interpreted as the embedding space region in which attention is directed when mental image is created. For low frequencies electron CD would be involved also.

2. Quark sub-CD correspond to time span of 1 ms (d quark) or 6.5 ms (u quark) and electronic sub-CD to the time scale.1 s. The restriction to harmonics of the fundamental frequency would mean frequency cutoff $f_{low} = (2 \times 10^3, 320, 20)$ Hz for (d, u, e) respectively. For frequencies below the 320 Hz electronic sub-CD should be used and this gives IR cutoff frequency of 20 Hz, which is indeed the cutoff for audible frequencies.

3. The Josephson radiation with frequencies above $f_{low} = (2 \times 10^3, 320, 20)$ Hz could be generated during the nerve pulse and induce (d, u, e) cyclotron transition at the flux tube assignable to the sensory pathway corresponding to a given frequency. Rate coding by nerve pulse patterns could apply below frequencies sufficiently below kHz. These frequencies would correspond most naturally to harmonics of the fundamental frequency (10, 160, 1280) Hz, which suggests that this coding relates to music experience.

4. The frequencies could be coded by the local value of the magnetic field at magnetic body and the pitch of the sound could be represented in this manner as a quale of the magnetic body. Similar coding is possible for other qualia. One can of course ask whether cyclotron frequencies are involved with this coding at all. The idea about resonance at the level of CD is suggestive but a proper formulation for this idea is lacking.

Codings based on cyclotron frequencies

The cyclotron frequencies of electron and quarks would define three different frequency ranges. For the standard vacuum (classical Z^0 field is very small) electron, u, and d quarks would define for $B_{end} = .2$ Gauss the basic cyclotron frequencies as $f_{up} = (564, 94, 19)$ kHz. The lower bound for the cyclotron frequency would be above $f_{low} = (2 \times 10^3, 320, 20)$ Hz for B_{end}. For electron this would give $B_{end,min} = 2$ nT, which represents an alarmingly weak magnetic field but could make sense if the value of Planck constant is large.

One can imagine several kinds of codings even if one assumes that the ultimate representation of the pitch is based a cyclotron transitions and that Josephson frequencies or their modulation codes for qualia. It is not completely clear what the correct option could be. Two basic classes of codings can be considered depending on whether the magnetic flux quanta correspond to the ordinary value of $\hbar$ or not.

1. If one assumes generalized flux quantization posing no conditions on the thickness of the flux quanta, the frequency can be coded by $B_{end} \propto 1/\hbar$, and one can assume that they correspond to flux tubes assignable to cell membranes. It seems that this option is the only reasonable one if flux tubes correspond to large $\hbar$. This in turn is supported by the dual interpretation of Josephson radiation in terms of bio-photons and EEG.

2. If one assumes that flux tube correspond to the ordinary value of $\hbar$ and that the geometric data about percept -say the direction of the sound source- are coded by Josephson radiation, one must assume that the quanta of Josephson radiation are transformed to bundles of ordinary photons with cyclotron frequency in a phase transition changing the value of $\hbar$.

Two mechanisms for the coding of the pitch using cyclotron frequencies

The basic idea is that magnetic body responds by cyclotron transitions to the incoming radiation representing the frequencies of sound. The Josephson frequency of the cell membrane proportional to $1/\hbar$ is a natural first guess for the representative of the sound frequency. Also its frequency

modulation with sound frequency could be a natural manner to represent the sound frequency: this would require amplitude modulation of the membrane potential by sound frequency.

One can imagine several mechanisms for the coding of the pitch.

1. The sound is directly converted to electromagnetic oscillations so that Josephson frequencies would not be involved at all. This requires piezoelectricity. Biomolecules are typically electrets and often also piezeoelectrics. The interaction of the electric field most naturally represented as MEs with the magnetic field body would induce cyclotron transitions.

2. Second mechanism relies on the coding of sound frequency by Josephson frequency. Large values of $\hbar$ are unavoidable since for ordinary value of $\hbar$ Josephson frequency would be of order 10^{14} Hz. In this case place coding is possible in the sense that different sound frequencies would stimulate different positions at the magnetic body with flux tubes of varying thickness but same magnetic flux.

3. Third mechanism relies on the modulation of Josephson frequency by sound frequency. In this case the carrier frequency could be rather high. Piezo-electric effect would code sound waves to amplitude modulations of the membrane voltage. The resonance mechanism implies that the pitch is represented by the time interval between absorption peaks. Note that sound is analyzed already in the cochlea to frequencies and resonance mechanism allows response only in a limited region of magnetic body if the magnetic field at magnetic body varies (say flux tubes do not have constant thickness). Therefore place coding is natural also now. Quite generally, FM is very natural for place coding for coding of all kinds of geometric information such as positions of objects of perceptive field.

The latter option allows several alternatives.

1. If the modulation frequency is much lower than Josephson frequency (proportional to $1/\hbar$), the periodic variation of the Josephson frequency defining cyclotron frequency f_c for the receiving end induces a sequence of peaks as the Josephson frequency passes through f_c and this sequence would generate the sensation of pitch.

   For frequencies below kHz the same mechanism could realize rate coding. A sequence of nerve pulses would generate sequence of pulses of Josephson radiation generating the cyclotron transition. Since the Josephson frequency of cell membrane can be quite high -varying up to about 10^{14} Hz, also high frequencies can be coded using FM.

2. In principle the cyclotron frequency need not depend on the frequency detected by the hair cell. It can be also a piecewise constant functions of it. If sound wave generates a perturbation of membrane potential, linear coding in the entire range communicating different frequencies to different positions of the magnetic body is natural. Josephson radiation with given frequency should be guided by magnetic flux tubes -most naturally the flux tubes assignable to cell membranes or microtuli- to a larger area of the magnetic body. Only the spots of the magnetic body for which the cyclotron frequency corresponds to Josephson frequency would respond to the Josephson radiation.

3. Josephson frequency cannot be too large since the cyclotron frequencies at the magnetic body are bounded by the value of magnetic field. For high audible frequencies electron's cyclotron frequency is natural at the receiving end: for $B_{end} = .2$ Gauss it equals to 6×10^5 Hz and poses upper bound for audible frequencies unless one allows stronger magnetic fields. Certainly a rather large value of $\hbar$ is needed for Josephson radiation and also for the flux tubes unless Josephson radiation is transformed to a energy radiation radiation with ordinary value of Planck constant before the interaction with the cyclotron condensate. The amplitude of the modulation of the membrane potential would define the maximum deviation from the cyclotron resonance.

4. Cyclotron frequency could be proportional to the audible frequency so that the modulation frequency would be a constant proportion of modulated frequency- most naturally identical with it. In this case, place coding by position at magnetic body would result even when only massless extremals propagating in arbitrary directions are used (mass communication

and tuning at the receiving end). This would require that the field strength at the magnetic body varies. The magnetic body of the entire cochlea would experience the sounds as spatial patterns of cyclotron transitions.

5. Each hair cell could represent its special frequency at the magnetic body of the group of hair cells coding for the same frequency. If Josephson frequency equals to the modulating frequency, one cannot speak about frequency modulation anymore. The resulting Josephson radiation would be at the harmonics of the audible frequency. If the cyclotron frequencies are identical to Josephson frequencies, one would have a coding of audible frequencies by magnetic field strength. $B_{end} = .2$ Gauss is a good guess for the order of magnitude. This option is attractive since the modulation can be said to be in resonance.

   This option is problematic if one assumes flux quantization in the form $\int BdA = n\hbar$. As explained, there are two ways to avoid the problems. The first one relies on currents at the boundaries flux tubes generating the magnetic flux. Second one assumes ordinary value of Planck constant and that Josephson photons are first transformed to bunches of ordinary cyclotron photons. For both options magnetic field strength is proportional to $1/\hbar$ which therefore codes for the frequency. For the first option the transversal scale of the flux tube can be independent of $\hbar$ constant and most naturally corresponds to that for the axonal membrane.

The cyclotron frequencies of electron and quarks define three different frequency ranges and all these might be involved with frequency coding.

1. For the standard vacuum (classical Z^0 field is very small) and for $B_{end} = .2$ Gauss the cyclotron frequencies would be $(f_e, f_u, f_d) = (564, 94, 19)$ kHz. For $f = 20$ Hz frequency the ratio $f/f_d \sim 10^{-3}$ would be obtained for d quark. These choices would allow to understand all hearing ranges. 150 kHz is the highest upper bound for the hearing range and should corresponds to electron's cyclotron frequency. The coding of 20 Hz frequency for d quark would require $B_{end,min}/B_{end,max} = 10^{-3}$ in the case of human auditory range containing 10 octaves. The same ratio would predict hearing range 94 Hz-94 kHz for u quark and hearing range 564 Hz-564 kHz for electron. For $B_{end,max} = .2$ Gauss one would have $B_{end,min} = .2$ μT. Magnetic fields of strength of order.05 μT have effects on living matter [J15] so that the proposal is consistent with experimental findings.

2. The flux tubes could also correspond to almost vacuum extremals. In this case the values of cyclotron frequencies would be considerable higher. This option does not seem to bring anything essentially new to the picture but cannot be excluded. It might even forced by the fact that cell membrane space-time sheet corresponds to almost vacuum extremal. In this case the frequencies corresponding to $B_{end} = .2$ Gauss are $(f_e, f_u, f_d) = (8.996, 2.275, .947)$ MHz. This option would give $B_{end,min}/B_{end,max} \simeq 10^{-5}$ and $B_{end,min} \sim .4$ nT if d quark is required to code for 20 Hz.

3. Fractality encourages to consider a fractal consisting of flux tubes inside flux tubes with flux tubes associated with the low frequencies containing those assigned to high frequencies. The quantization of magnetic flux is consistent with this mechanism. For B_{end} the flux tube thickness from the quantization of the magnetic flux would be about cell size, which looks natural. For larger values of $\hbar$ the natural quantization condition at the axonal level involves the currents at the boundaries of the flux tube generating the magnetic field. The flux tubes assignable to axons and other structures could fuse outside the body to larger flux tubes satisfying the standard quantization condition of magnetic flux and form flux tubes inside flux tubes.

4. If the magnetic field of Earth is used for place coding the distance to the flux tube would code for the frequency. This would however induce frequency dependent phase shift and distortion of spectrum. This suggests that endogenous magnetic field -that is magnetic field assignable to personal magnetic body must be used. The most natural quanta are the flux tubes assignable to teh cell membranes.

2.4.3 The Mystery Of The Fast Transmitter

The extreme rapidity of the transfer of the postulated unidentified nerve transmitter from the hair cells to the nerve axons is a mystery.

1. The transmitter is not needed at all if Josephson radiation mediates the signal along the auditory pathways and possibly also re-generates the quale at neuronal level. This is certainly the most elegant solution of the mystery since Josephson radiation has also interpretation in terms of EEG and EEG correlates strongly with the contents of conscious experience. The chronic leakage of Ca^{++} wave would relate to the Josephson current and the related Josephson radiation would provides EEG representation of the quale.

2. Also microtubuli could mediate the information about evoked potentials at hair cell membrane to brain as microtubular conformal patterns and/or acoustic/electric waves. Acoustic and electric waves would be both present since microtubuli are electrets.

   (a) The transfer of auditory information from hair cells to postsynaptic neuron could occur also via acoustic transmission meaning that the time lag spent in this step would be of order $\sim .1$ ns only. The reported extreme sensitivity of of the axonal signal to the evoked potential (the resolution is about $\Delta V \sim .1$ mV) [J2] conforms with the view that evoked potential provides a representation of the sensory input.

   (b) The representation and communication of acoustic signals at microtubular level could induce the coding of frequencies sufficiently below 1 kHz to spike interval distributions [J81]. The obvious critical question is how badly nerve pulse disturbs microtubular communications. One might argue that these perturbations do not affect conformational waves. As proposed earlier, the microtubular conformational wave patterns could be responsible for long term memories for instance. Acoustic waves could fulfill the same function.

   (c) For this option the presynaptic dense body would be involved with the transformation of the temporal pattern represented by the time pattern of Ca^{2+} leakage to a signal propagating along the microtubule. Coupling to the microtubular conformational waves/acoustic signals could be also mechanical and the dense body could generate acoustic oscillations representing the temporal pattern of Ca^{2+} waves.

2.5 Music And Consciousness

Music experience provides an interesting testing ground for several assumptions of quantum TGD and TGD inspired theory of consciousness. The notion of self is especially interesting in this respect.

2.5.1 Some Aspects Of Music Experience

It is good to list first some elementary characteristics of music experience that the model should be able to explain. Both rhythmic aspects and pitch of the sound are important. Rhythmic aspects correspond to time domain representation for the intentsity of sound carrying local information about sound wave whereas pitch carries global information. The relationship between these two elements of music is like that of function and its Fourier transform. Harmony enters the game when several frequencies are present.

Rhythm

There are two basic types of views about rhythm, additive and divisive, and they correspond to the multiplication and sum as basic arithmetic operations.

1. In western music rhythm corresponds to a division of longer periods of time divived into smaller rhythmic units. Rhythm is basically a clock and rhythm is essentially a decomposition

of integer to a product of integers defining the rhythmic unit and their number. Classical western music is relatively simple rhythmically (consider only the music of Bach). In the music of Chopin tempo rubato makes the duration of the basic rhythmic unit and of its basic structural elements dynamical but rhythms are still relatively simple although simultaneous 3/4 and 3/8+3/8 appears often. In jazz and various forms of popular music rhythms tend to be highly clocklike but are very complex.

2. In Indian music for instance, rhythms are additive and larger periods of time are constructed from smaller rhythmic unis added to the end of the previous unit. This division corresponds to addition rather than multiplication algebraically. Also intermediate forms can appear and do so often in folk music (say folk music of Greece, Balkan, and Spain). For instance, one can have the sum of 3/4+3/8+3/8 as a repeating rhythmic unit. In flamenco form known as Bulerias [J3] the basic rhythmic unit consists of 12 beats and the collective performance creates a very complex and emotionally catching rhythm, which is almost impossible to analyze to pieces. It is easy to believe the claim that artists often fall in trance during the flamenco sessions.

Pitch

Pitch can be identified as the fundamental frequency of note. Pure sine wave is aesthetically unpleasing and harmonics are always present and characterize the music instrument. Not only frequencies but also phase relationships between them are important. For instance, they distinguish between the phonemes of spoken language and in the case of singing this brings in an important additional element not so important for non-electronic instrumental music. Furthermore, melody is never a mere sequence of precisely defined frequencies. For instance, slow modulations of the pitch reducing mathematically to a superposition of closely separated frequencies and glissandos have emotional affect.

The model of music experience should explain also the following aspects related to pitch understand as fundamental frequency.

1. Octaves of the fundamental are experienced as equivalent. The presence of higher harmonics is needed to make pure sinus wave a musical note. Higher harmonics determine the character of the pitch chracterizing the music instrument.

2. There exists a large number of different scales to which one assigns attributes like diatonic, minor, chromatic, whole tone, pentatonic, diminished... All these scales have quite specific emotional coloring and they characterize different music styles. The minimum frequency interval corresponds to a minimal scaling of the frequency and depends on music style. Western classical music uses semitone as the basic unit corresponding to the scaling $2^{1/12}$ in equally tempered scale but also microintervals are used and the only limitation comes the from ability to discriminate between different frequencies. The scales have special notes such as tonic, supertonic, mediant, subdominant, dominant, submediant, subtonic with special roles in harmony. For instance, listener is often able to remember the basic scales even if the tonic of the scale has suffered several modulations during the music piece. Deviations from basic scale have important emotional effects (say in the case of minor scale).

3. Ancient mathematicians believed that the presence of rational multiples of fundamental frequencies are essential for harmony. It is possible to construct the basic scales involving only rational multiples of the fundamental in terms of selected harmonics. For instance, Pythagorean construction uses only powers of 3/2 and octaves to construct the basic scale (C, G, D, A, E, H, ...). Although the pitch is distinguished only within a finite resolution and equally tempered 12-note scale uses only powers of $2^{1/12}$ of the fundamental, rational multiples of the fundamental might relate deeply to the basic physics of cognition and to the frequencies generated in brain as opposed to those used to produce the music.

4. The expectation of an engineer is that the transposition of the scale should not effect on the music experience and one could think that it could be done in a continuous manner. Many composers, for instances Sibelius, experienced different modes differently and as synesthetes assigned to them different visual associations. Many people are able to recognize the ratios

of notes but there is also the much rare phenomenon of absolute ear meaning that subject person is able to tell the pitch of the note directly. A synesthesia like phenomenon is probably in question.

5. An interesting question the notion of absolute scale could make sense to some degree? The fundamental frequency of sound producing organs is 10 Hz and the region of audible frequencies begins at 20 Hz and consists of approximately 10 octaves. kHz frequency is the resonance frequency of head sized object and at this frequency the mechanism allowing to deduce the direction of sound source changes. The biological basis for this would be that 10 Hz and 1 kHz define fundamental biorhythms. The quantum physical basis for this could relate to the p-adic length scale hypothesis predicting that 10 Hz and 1280 Hz could correspond CDs of electron and quarks. To get a contact with concretia note that soprano C corresponds to 1046.50 Hz. Also the cyclotron frequencies assignable to various biologically important ions in endogenic magnetic fields could defined preferred scales. The A above middle C corresponds by convention to 440 Hz, which is integer multiple of 10 Hz but by pure convention and fifth octave of 8.175 Hz which is not too far from the lowest Schumann resonance. An interesting question is whether the transposition to a scale for which the fundamental is simple rational multiple of 10 Hz or lowest Schumann resonance might have some specific emotional effect.

Harmony and other collective aspects of music

Harmony relates closely to the interaction of different frequencies and is therefore one particular collective aspect of music experience.

In the terminology of physicists, harmony is a phenomenon of many particle physics with particles replaced notes of the scale and many-particle states with chords. Depending on the ratios of the frequencies certain chords are aesthetically pleasing and emotionally significant and there are also principles governing aesthetically pleasing chord progressions. Harmony might be seen as the vertical aspect of the music whereas melody would correspond to horizontal one. Dissonance is the opposite of harmony and tritonus was forbidden in the early western music but is nowadays used to create tension. Polyphony -say in Bach's music- and simple chords used to accompany singing represent two opposite views about harmony. Chopin's music has especially rich harmonies and emotional expressive power.

While listening music one typically selects some instrument as figure and the rest as a background. In romantic piano concertos the competition between the solist and orchestra about the attention of the listener creates the basic tension. In polyphonic music one must also select the tone progression to which attention is directed and it is difficult -perhaps even impossible- to simultaneously grasp the separate tone progressions. Same applies to other elements of music.

2.5.2 Zero Energy Ontology, Hierarchy Of Planck Constants, And Number Theoretic Physics

The number theoretic vision brings interesting new physics elements which might help to understand music experience.

1. The hierarchy of selves has as an embedding space correlate the hierarchy of CD is basic prediction. p-Adic length scale hypothesis suggests that quantization of size scales of CDs as octaves and the question is whether this relates directly to the preferred role of octaves in music experience. The time scales of CDs define preferred fundamental frequencies coming as octaves and the hierarchy of Planck constants defines scaled variants of these as rational or integer multiples (depending on generalization of the embedding space).

2. The question is whether these fundamental frequencies also define fundamental keys so that music experience would depend on absolute frequency scale. Even if CDs define fundamental keys, the frequency scale associated with sub-CD as experienced in the rest system of CD can be scaled continuously by performing a Lorentz boost for CD. Even glissando could be achieved for CD by performing to the sub-CD a Lorentz boost continuously and leaving the other tip of CD invariant. The boost would be the hyperbolic analog of an ordinary rotation and act like acceleration from rest to constant velocity inside sub-CD. If one takes

this picture seriously also Lorentz boosts would be important part of the representation of music at the level of magnetic body (presumably using MEs). Quantum TGD proper suggests the quantization of these boosts.

3. Number theoretic vision predicts an infinite number of algebraic extensions of p-adic numbers -in particular those corresponding to roots of unity. In the p-adic context the proper representation of sine waves requires the introduction of these algebraic extensions and the prediction is that rational multiples of the fundamental frequencies assignable to p-adic length scales should have a special role from the point of view of cognition.

   This might justify the belief that the notes of the scale should be expressible in the optimal situation as rational multiples of the fundamental note. The cognitive representation of the music in the intersection of real and p-adic worlds should map the physical frequencies or rather the sine waves at a discrete set of time values to their p-adic counterparts. One has to deal with phase factors defined by plane waves $exp(ift_n)$ at discrete set of points t_n such that the exponent equals to $exp(i2\pi m/N)$ and belongs to the algebraic extension. The harmonics of f obviously satisfy the same condition. The representation of pitch in terms of algebraic extensions of rationals requires that the corresponding partonic 2-surfaces correspond to complex enough algebraic extensions of rationals containing high enough roots of unity. The modulation of the pitch as superposition of two nearby rational frequencies could is possible without leaving this framework.

4. One can consider also different but not exclusive explanation for why scales define preferred collections of frequencies. Pythagorean scale involves rational multiples of fundamental obtained as powers of 3/2 and 2 so that the frequencies involved correspond to rationals of form $3^m 2^n$ for which only 3-adic and 2-adic norms differ from one. Small-p p-adicity associated with $p = 2$ and $p = 3$ could select the preferred frequencies.

2.5.3 Why Octaves Are Experienced Similarly?

The model should explain the basic features of music experience. There are many interesting questions related to this. One of the most important is why frequencies which are 2^k- multiples of the fundamental frequency, notes differing by octaves, are experienced as identical notes.

1. p-Adic length scale hypothesis, zero energy ontology, and octaves

Thus the phenomenon of octaves could relate to the p-adic length scale hypothesis, which implies that physically preferred p-adic primes correspond to primes near prime power powers of two. For instance, this implies that the massless extremals (MEs) associated with physically important p-adic primes have fundamental frequencies which are octaves of each other. Therefore a classical resonance via the formation of flux tubes becomes possible and real space-time sheets corresponding to preferred p-adic primes can form larger resonant structures. This universal resonance could explain why octaves are experienced similarly. The problem of this argument was that primary p-adic time scales would come as half octaves instead of octaves.

Octaves seem to have much deeper significance than I thought originally and seem to emerge at the level of fundamental formulation of quantum TGD rather than characterizing only a very special kind of sensory experience. In the recent formulation of quantum TGD using zero energy ontology [K17, K16] one uses zero energy states which have their positive and negative energy parts at the light-like boundaries of causal diamonds consisting of future and past directed light-cones.

Physics as a generalized number theory vision, in particular the assumption that real physics and various p-adic physics result as algebraic completions of rational physics, motivates the hypothesis that the temporal distance T between the tips of the causal diamond is quantized and corresponds to powers of 2 using time scale defined by CP_2 size as a basic unit. This assumption allows to deduce p-adic length scale hypothesis ($p \simeq 2^k$, k integer), and to identify T as a secondary p-adic time scale. For electron this time scale is .1 seconds and corresponds to the fundamental 10 Hz biorhythm. For non-standard values of Planck constant T is scaled by a factor $\hbar/\hbar_0$. Thus octaves become a key element of fundamental physics. One can say that causal diamonds as space-time correlates of self appear naturally as octaves. Also rational multiples of fundamental frequency emerge via the hierarchy of Planck constants: in principle all rational scalings of the basic hierarchy are allowed.

2. Is sensory experience 2-adic in some sense?

A stronger hypothesis for the phenomenon of octaves is that cognitive music selves are 2-adic or that real music selves can transform easily to 2-adic selves. One might even consider the possibility that the phenomenon is much more general. Music metaphor has indeed turned out to be of crucial importance for the theory of qualia. Thus music metaphor could reflect the underlying 2-adicity of the sensory experience (at some level of self hierarchy). Perhaps at least some aspects of our experience result from a mimicry of the lowest level of the p-adic self-hierarchy. Taking 2-adicity seriously, one is forced to ask for the possible consequences of 2-adicity. For instance, could it be that at the level of primary qualia the intensity of sensation as function of stimulus depends on the 2-adic norm of the 2-adic counterpart of the stimulus and is thus a piecewise constant function if sensory input?

An observation supporting this speculation is following. When over-learning occurs in tasks involving temporal discrimination, the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [J62] such that the plateaus, where response remains constant are octaves of each other.

This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has a multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jump-wise replacement of the n: th harmonic by $n+1$: th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of over-learning or neurons involved act unisono and the underlying 2-adicity is not masked anymore.

At the level of MEs this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier. This certainly would mean that cognition is an important part of music experience. The strongest assumption is that the real note selves are able to transform to 2-adic selves by a phase transition changing local topology from real to 2-adic. Note however that p-adic length scale hypothesis might be enough.

2.5.4 Does Harmonic Complexity Reduce To 3-Adicity?

An interesting question relates to the conditions guaranteeing that a chord is experienced as harmonious in the Pythagorean sense [J9]. Pythagorean tuning is based on the notion of perfect fifths identified as scalings by 3/2 producing the sequence C, G, D, A, E, .. In this tuning major-C scale corresponds to ratios $C = 1/1, D = 9/8, E = 81/64, F = 4/3$, $G = 3/2, A = 27/16, B = 243/128, C = 2/1$. E_b and $F_\#$ correspond to ratios $2^5/3^3$ and $3^6/2^9$. All notes are expressible as powers of two and three. Since the multiplication of any note by a power of two does not affect the harmony it should be to drop the powers of two from the integers characterizing the notes in the ratio of three notes. For instance, C-E-G reduces $3 : 3^4 : 1$, $C - E_b - G$ to $3^4 : 1 : 3^3$, and tritonus $C - E_b - F_\#$ to $3^9 : 1 : 3^3$. The problem of Pythagorean tuning is that one cannot represent 2 as an exact integer power of 3/2 and the scalings give infinite number of tones. If the construction starts from G_b then $F_\#$ and G_b correspond to frequencies, which are not quite identical in Pythagorean tuning. One could make compromize by introducing the geometric mean of $F_\#$ and G_b but this would bring in $\sqrt{3}$ and would force to leave the world of pure rationals. For string instruments and electronic instruments the Pythagorean tuning is practical but for instruments like piano the transposition of the scale is impossible.

One should be able to characterize a given chord harmonically by a function $F(a, b, c)$, which is symmetric under the permutations of the reduced pitches a, b and c obtained by dropping powers of two and is invariant under over all scaling of the reduce frequencies. The elementary symmetric functions $F(a, b, c) = [a^2(b + c) + b^2(a + c) + c^2(a + b)]/abc$ and $G(a, b, c) = [a^3 + b^3 + c^3]/abc$ are the simplest functions of this kind. Either of these functions or their product or ratio could be considered as a measure for the harmonic complexity. The value of the denominator abc equals to 3^n, $n = 3, 7, 12$ in the cases considered. The numerator has in all cases 3-adic norm equal to one for both F and G. This suggests that the 3-based logarithm of the 3-adic norm $1/|abc|_3 = |F|_3 = |G|_3$ having the values 3, 7, and 12 for C-major, C-minor, and tritonus could serve as the measure

for the complexity. It is indeed smallest for major and largest for tritonus. 3-adic norm for the product $1/a_1a_2...a_n$ of n notes of the chord defines a measure of complexity in more general case. A good guess is that the 3-adic norms of the elementary symmetric functions give rise to the same measure.

For the chords C-E-G, F-A-C, and G-H-D appearing as basic chords in C- major scale the values of the harmonic measure are 3, 2, and 8. This means that the basic chords are not harmonically equivalent in Pythagorean system whereas in equally tempered system they would be. One might think that this explains why the tonic is remembered. The anomalously low value for F-A-C relates to the fact that it is only tone for which the power of 3 is negative. Situation changes of F is identified as a minimal power of 3 giving F equivalent with Pythagorean F within the resolution of ear to pitch which is about $|\Delta f/f| = 4.3$ per cent. $F = 3^5/2^8$ gives $|\Delta f/f| = 4.8$ per cent. This F would give for F-A-C the harmonic measure 8 which equals to that for G. This looks more reasonable than the purely Pythagorean value. This definition would also allow to find a unique choice of powers of three for 12-chord system. For instance, $F_\#$ is favored over G_b since it corresponds to a positive power of 3.

2.5.5 The Notion Of Self And Music

The music experience allows also to test the ideas related to the notion of self.

1. Summation hypothesis states that self is a sum of abstracted experiences of sub-selves and thus representing kind of averages about the experiences of sub-sub-selves.

   (a) The conscious experience induced by music decomposes in a clear manner to basic elements identifiable as sub-selves. For instance, melody and more generally various tone progressions could define such sub-selves and the experiences of these sub-selves would sum up to music experience. In the same manner rhythmic patterns define their own sub-selves. Therefore it might make sense to speak about "frequency sub-selves" and "rhythm sub-selves".

   (b) At space-time level the magnetic body and massless extremals (MEs) are the natural candidate for the representation of "frequency sub-selves". One can say that MEs provide a universal music instrument at the level of magnetic body since they allow arbitrary superposition of collinear waves proceeding in the same direction which is non-dispersive (shape of the pulse is preserved) so that arbitrary harmonics are possible for a ME with fixed length. Maybe the temporal duration of sub-selves assignable to MEs is what distinguishes between these representations.

   (c) A collection of sub-selves associated with ME at precisely defined periodically appearing positions could define rhythm whereas frequency selves would correspond to MEs with relatively long temporal duration. Interpreting MEs in terms of communications to the magnetic body, one expects that the rhythm automatically generates short-lasting MEs communication the pulses defining the rhythm to the magnetic body whereas pitch corresponds to long lasting MEs.

   (d) This picture challenges the assumption that the mental images created during music experience are localized to brain. Rather, MEs and magnetic body would be the carriers of the mental images. Maybe one could say that nerve pulse patterns induce these MEs. In left hemisphere nerve pulse patterns induced by the beats of rhythm and having a total duration considerably below.1 second would send single ME to the magnetic body. In right hemisphere the pulse patterns would integrate to single ME having duration of the note.

2. The hypothesis that entanglement creates wholes from parts and that there are three cognitive modes corresponding to reductionistic and holistic cognition and their hybrid based on negentropic entanglement is of special interest in the context of music experience.

(a) Even admitting the dangers of naïve right-left thinking it would seem natural to assign the rhythmic aspects of the music to the reductionistic regions of brain and various aspects related to pitch to the right brain hemisphere. At least in the latter case MEs are highly suggestive as a fundamental representation of music at the level of magnetic body. Perhaps music experience actually involves in a very essential manner also magnetic body. That "eastern" music favors additive instead of divisive rhythm could be understood as higher right brain dominance. The extremely mechanical rhythms characterizing the popular music today, the lack of melodic aspects, and the use of the volume of music as the basic means to induce emotional effect, could in turn interpreted in terms of extreme left brain dominance.

(b) Music can have a strong emotional effects and this allows to test the hypothesis that the character of entanglement correlates with the emotional color. Maybe just the fact that these emotions are enjoyable irrespective of whether they are sad or joyful and have an undeniable healing effect can be interpreted in terms of the presence of the negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). For instance, the ability of good music to generate vibrations in spine could relate to this negentropic aspects. Music as purely intellectual experience could induce essentially an analysis of what was heard based on the use of holistic-reductionistic dichotomy. Chopin's music has especially strong healing effect. Tempo rubato might reflect the profound integration of rhythmic aspects, melodic, and harmonic to single organic whole both at the level of representation and music experience.

3. The model of subjective memory and the new view about time might be relevant for the understanding of how the basic key of the music piece can be remembered. If conscious experience for a given self is about the space-time region defined by corresponding CD, one could understand how Mozart was able to experience the entire composition as a single whole. If the music piece defines in the ideal case the fundamental CD inside which the sub-selves representing the elements of the music oiece reside, this CD could also define the fundamental "key" and would be more or less sensorily experienced and need not even to be remembered. This would explain why the return to the original key in classical is so important to relieve the tension created by modulations.

2.5.6 Harmony And Self-Organization

The phenomenon of harmony should be somehow related to quantum self-organization: perhaps the often used metaphor of harmonious co-existence could be turned around. Various notes correspond to sub-selves in the population of sub-selves and it might be that self-organization favours simultaneous conscious existence of sub-selves corresponding to subsets of frequencies defining basic chords. One could even consider some kind of co-operation between the frequency selves belonging to same basic chord.

The simplest model for the phenomenon of harmony relies on the identification of the chords as "chord selves" formed by entangled "note selves" consisting of negentropically entangled "frequency selves". The listener is self having as sub-selves (mental images) note selves and chord selves which correspond to the same level of the self hierarchy. The entanglement between note selves could occur even at the level of ear between the mind-like space-time sheets sensitive to various frequencies. Topologically it would correspond to the formation of magnetic flux tubes between corresponding partonic 2-surfaces. The ability of the "note selves" of the chord to have stable flux tube bonds between themselves should depend crucially on the fact that the frequencies of the notes of the basic chords have simple rational ratios so that the oscillations involved are commensurate and match together. Hence a resonance phenomenon ins spirit of classical physics involving rational ratios of frequencies would be in question. During listening the chord self continually decomposes into sub-selves when listener consciously concentrates attention to some notes in the chord.

The ability of the music to occasionally create thrills in spine could correspond to whole-body consciousness in unusually large length scale. Note the this scale could correspond also to

the secondary time length scale assignable to CD. It presumably involves a resonant fusion of also other than note sub-selves to larger negentropic sub-selves by the formation of stable flux tubes identifiable as magnetic flux tubes. The ability of certain sounds ("Om") to promote the emergence of whole-body consciousness could be due to the ability to very effectively generate negentropic entanglement direction. Perhaps the frequency spectrum of "Om" contains resonant frequencies of several sub-selves and induces large sub-selves. Also the healing effect of music and sounds could rely on this mechanism.

Focusing attention to some instrument producing melody creates kind of figure-background relationship. This requires that entire instrument playing the melody is represented by "instrument self". An interesting possibility is that various instruments give rise to their own ensembles of frequency-selves. Note that the model makes it easy to understand why experienced performance is not simply the sum of indidividual performances. Music experience is a complicated self-organization process in which parts compose to wholes by quantum entanglement and vice versa according to how the listener directs his/her attention.

2.5.7 Absolute Ear

Absolute ear means the existence of a preferred hardwired scale and ability to associate to the heard notes their names. Transposing an instrument is painful for an instrumentalist with perfect pitch since the notes she's playing are not the ones she's hearing.

Musicians with absolute ear can even decompose sounds that are usually regarded as a noise to a collection of notes with well-defined pitches. Obviously absolute ear means a well-developed ability of some part of brain to perform a Fourier analysis for the incoming sounds. It is known that the temporal planum part of the cortex is much more developed on the left side than on the right side for people with absolute ear [J58]. The larger size of left temporal planum correlates also with right-handedness so that "absolutists" might be more strongly right-handed than usual. The increased size of the left temporal planum is also involved with reading: people with dyslexia tend to lack temporal planum asymmetry [J77].

Perhaps the left temporal planum of the "absolutist" automatically assigns to the heard notes a symbolic representation as written notes. If only right brain hemisphere performs the Fourier analysis, this would require right-left communication which could be also carried out via the magnetic body inducing generalized motor action associating to the pitch pattern heard by right magnetic body their names in left temporal planum.

One can however imagine much simpler mechanism. During the recognition task the left temporal planum could simply send Josephson radiation from the points representing the names of notes to the right magnetic body at the frequency of the note in question. The recognition of the note would be based on resonance with the Josephson signal coming from the signal representing the music percept. This would also allow to detect dissonance. The inability to adapt to a new scale would be due to the fact that the Josephson frequencies in the left temporal planum are hard wired.

2.6 Pythagoras, Music, Sacred Geometry, And Genetic Code

The conscious experiences generated by music demonstrate a fascinating connection between algebra and emotions. How can major and minor scale using different frequency ratios generate so different emotional experiences. This strongly suggests the we experience music as entire time interval, 4-D patterns - rather than time=constant snapshots. Also the ability remember the key and the tension lasting as long as the return to the basic key has not taken place, is example of this. One of the key questions is why octaves - that is powers of 2 of the basic note of the scale - are experienced as equivalent? One can also wonder what is behind consonance and dissonance.

I have already earlier tried to understand music experience and considered some ideas inspired by p-adic numbers fields - such as the idea that Pythagorean scale coming as powers of 3 for the basic note modulo octave equivalence might relate to 3-adicity. Reading of a book titled "Interference: A Grand Scientific Musical Theory" by Richard Merrick [J86] freely available in web (`http://tinyurl.com/8d2hfka`) re-stimulated my interest. In particular, I found the idea

about a connection between music scale and harmonies with Platonic solids (3-D "sacred geometry") as highly inspiring. The basic question was whether the 12-tone scale could be mapped to a curve going once through each point of icosahedron having 12 vertices and whether the 20 faces of icosahedron, which are triangles could define the basic chords in 12-tone scale. These curves are known as Hamiltonian cycles and in the case of icosahedron there are 2^{10} of them: those obtained from each other by rotation leaving icosahedron invariant are however equivalent.

A given triangle of icosahedron can contain 0, 1 or 2 edges of the cycle and the numbers of the triangles corresponding to these triangle types classify partially the notion of harmony characterized by the cycle. Quint cycle suggests the identification for the single edge of curve as quint interval so that triangles would represent basic 3-chords of the harmony with 0, 1, or 2 quints.

One can make same questions also for other Platonic solids- tetrahedron (4 vertices), octahedron and cube which are duals of each other and have (6 and 8 vertices respectively, and dodecahedron which is dual of icosahedron having 20 vertices and 12 faces. Arabic music uses half intervals and scales with 19 and 24 notes are used. Could 20-note scale with harmony defined by 5-chords assigned to the pentagons of dodecahedron have some aesthetic appeal? Nowadays it is possible to develop electronically music based on this kind of scale and this kind of experimentation might be a fascinating intellectual and artistic adventure for a young composer.

I have also played with the idea that the 20 amino-acids could somehow correspond to the 20 triangles of icosahedron. The combination of this idea with the idea of mapping 12-tone scale to a Hamiltonian cycle at icosahedron leads to the question whether amino-acids could be assigned with the equivalence class of Hamiltonian cycles under icosahedral group and whether the geometric shape of cycle could correspond to physical properties of amino-acids [I3]. The identification of 3 basic polar amino-acids with triangles containing no edges of the scale path, 7 polar and acidic polar amino-acids with those containing 2 edges of the scale path, and 10 non-polar amino-acids with triangles containing 1 edge on the scale path is what comes first in mind.

The number of DNAs coding for a given amino-acid [I2] could be also seen as such a physical property. The model for dark nucleons leads to the vertebrate genetic code with correct numbers of DNAs coding for amino-acids. It is not however clear how to interpret DNA codons geometrically.

It however turns out that one can understand only the role of 60 codons in the icosahedral framework. The treatment of the remaining 4 codons and of the well-known 21st and 22nd amino-acids requires the fusion of icosahedral code with tetrahedral code represented geometrically as fusion of icosahedron and tetrahedron along common face which has empty interior and is interpreted as punct coded by stopping codons. In this manner one can satisfy the constraints on the Hamiltonian cycles, and construct explicitly the icosahedral Hamiltonian cycle as (4, 8, 8) cycle whose unique modification gives (4, 11, 7) icosa-tetrahedral cycle. Remarkably, two months after writing the first version of the article I learned that the data needed to calculate the Hamiltonian cycles can be found from web and that (4, 8, 8) cycle allows at least two realizations whereas the original candidate (3, 10, 7) allows no realization with symmetries but could do so with no symmetries.

2.6.1 Could Pythagoras Have Something To Give For The Modern Musicology?

The ideas of Pythagorean school about music were strongly based on the number theory of that time. So called modern approaches tend to seem music scales as cultural phenomena. There are however many reasons to suspect that Pythagorean school might have been much nearer to truth.

Pythagoras and transition from rational numbers to algebraic numbers

Pythagoras was one the greatest ancient mathematicians. The prevailing belief at that was that the world can be described solely in terms rational numbers. During the times of Pythagoras the ancient mathematical consciousness had entered at the verge of a profound revolution: the time had become ripe for the discovery of algebraic numbers expanding rational numbers to an infinite series of algebraic extensions of rationals containing also rational multiples for finite number of algebraic numbers emerging as roots of polynomials with rational coefficients. Euclid introduces square root geometrically as length of the diagonal of square. In ancient India it was discover 800-500 BC, possibly much earlier. Unfortunately, the emergence of Christianity stopped the evolution

of mathematics and new progress began at times of Newton when also reformation took place.

The well-known but story (good story but probably not true) tells that a pupil of Pythagoras demonstrated that the diagonal of unit square ($\sqrt{2}$) cannot be rational number and had to pay with his life for the discovery. Pythagoras himself encountered $\sqrt{2}$ through music theory. He asked what is the note exactly in the middle of the of the scale. Modern mathematician would answer half of octave corresponding to the frequency ratio $2^{1/2}$. Algebraic numbers did not however belong to the world of order of Pythagoras and he obtained to a non-satisfactory rational approximation of this number. This was very natural since only rational approximations of algebrais are possible in the experimental approach using only strings with rational number valued lengths. $\sqrt{2}$ represents the interval $C - F_{\#}$ known as tritone and this this interval was associated with devil and its use was denied also by church. Only after reformation $\sqrt{2}$ was accepted and this interval appears repeatedly in the compositions of Bach.

The amazing connections between evolution of mathematics and evolution of the religious beliefs inspires the question whether the evolution of consciousness could at basic level correspond to th evolution of the complexity of the number field behind the dynamics underlying consciousness. For instance, in TGD framework the vision about physics as generalized number theory allows one can to ask whether the mathematical evolution could have meant quite concretely the emergence of increasingly algebraic extensions of rationals for the coefficients of polynomials describing space-time surfaces serving as space-time correlates of consciousness.

Pythagoras and music

Pythagoras was both mathematician and experimentalist studying the world of musical experience experimentally. String instruments were his tool. The notion of frequency was not know at the time and length of vibrating part of string was the notion used. The experienced equivalence of notes differing by octave was known at that time and octave equivalence was understood as a fundamental symmetry of music manifesting itself as a scaling-by-2 symmetry for the length of a vibrating string.

Pythagoras developed 8 note scale CDEFGAHC (as a matter fact, 7 notes by octave equivalence) as we know as a combination of two scales EFGA and HCDE using octave equivalence and it was established as the official music scale. Pythagorean scale is expressed solely in terms of rational number valued ratios of the string length to that for the basic note of the scale (ratio of frequency to the fundamental).

Pythagorean scale (`http://tinyurl.com/28cu6j`, `http://tinyurl.com/7mc4ut`) is expressed solely in terms of powers of the ratio 3/2 for lengths of vibrating strings correspond to an interval known and complete fifth (C-G). The series of complete fifths (C-G-D-A...) known as progression by fifths gives very nearly 7 octaves but not quite: $(3/2)^{12} \simeq 128+1.75 = 2^7+1.745$. It would have been very natural to build 12-note scale as powers of rational (3/2) or by octave equivalence as powers of 3. The failure to close is very small but people with absolute ear experience the transponation of a melody to different key as dissonant since the frequency ratios do not remain quite same. At the time of Bach (Well tempered Klavier) the equal tempered scale obtained by diving the logarithmic scale to 12 equally long parts emerged and replacing powers of 3/2 with the 12 powers of algebraic number $2^{1/12}$ inside same octave even without octave equivalence emerged.

By octave equivalence Pythagorean scale means that all notes of the scale come in powers of 3 which strongly brings in mind 3-adicity. If one does not use octave equivalence when generalization of p-adicity to q-adicity with $q = 3/2$ is highly suggestive. q-adic numbers do not in general form number field, only an algebra.

Later more complex rational number based representations of scale using octave equivalence have been developed. The expression of the frequency ratios of the notes of the scale in terms of harmonic of fundamental modulo octave equivalence and involving only integers consisting of primes 2, 3, 5 is known as just intonation (`http://tinyurl.com/7mc4ut`).

1. Music and Platonic solids

Pythagoras was also aware of a possible connection between music scales and Platonic solids. Pythagoras is claimed to have discovered tetrahedron, hexahedron (cube) and dodecahedron while octahedron and icosahedron would have been documented by greek mathematician Thaletus two hundred years later. The tetrachord and was assigned with tetrahedron and one and imagined that

Pythagorean scale could have been assigned with pair of tetrahedra somehow - cube or octahedron which comes in mind. Note that this would require that basic note and its octave should be regarded as different notes.

These attempts inspire the question whether the mapping music scales to the vertices of Platonic solids could provide insights about music experience. One can also ask whether there might be a mapping of music understood as melodies and chords in some scale to the geometries defined by Platonic solids.

1. Since 12-note scale is used in practically all classical western music and even in atonal music based on 12-note scale, the natural question is whether 12-note scale could be mapped to a connected, closed, non-self-intersecting path on icosahedron going through all 12 vertices and consisting of edges only. Closedness would mean that base note and its octave are identified by octave equivalence.

2. This mathematical problem is well-known and curves of this kind are known as Hamilton cycles and can be defined for any combinatorial structure defined by vertices and faces. Hamilton proved that Hamiltonian cycles (possibly identifiable as 20-note scale) at dodecahedron is unique module rotations and reflection leaving dodecahedron invariant. Also in the case of tetrahedron and cube the Hamiltonian cycle is unique.

3. For octahedron and icosahedron this is not the case [A7] and there are both cycles containing only faces with at least 1 edge of the path and also cycles containing no faces containing no edges of the path. Numerical experimentation is rather straightforward manner to determine Hamiltonian cycles and $H = 2^{10} = 1024$ cycles can be found. The number of topologically non-equivalent cycles (not transformable to each other by the isometries of icosahedron) is factor of this number. The group of orientation preserving isometries of icosahedron is the alternating group A_5 of 60 even permutations of five letters. The full group of isometries is $G = A_5 \times Z_2$ containing $N = 120$ elements.

4. Some subgroup of G leaves given path invariant and its order must be factor M of N so that topological equivalence class of cycles contains $R = N/M$ elements. The number of topologically non-equivalent cycles in given class with $H(top)$ elements is $N_{tot} = H(top)/R$ so that R must be a factor of $H(top)$.

Before continuing it is good so summarize the geometry of icosahedron shortly. There are 20 faces which are triangles, 12 vertices, and 30 edges. From each vertex 5 edges. Therefore the construction of Hamiltonian cycles means that at each vertex on path one must select between four options edges since one cannot return back. This gives $4^{12} = 2^{24} \sim 1.6 \times 10^7$ alternatives to be considered. Therefore the numerical search should be relatively easy. Keeping account of the points already traversed and not allowing self intersections, the actual number of choices is reduced. The construction requires labeling of the vertices of the icosahedron by integers 1, ..., 12 in some manner and defining 12×12 matrix $A(i, j)$ whose element equals to 1 if vertices are neighbours and 0 if not. Only the edges for with $A(i, j) = 1$ holds true are allowed on the path. A concrete representation of icosahedron as a collection of triangles in plane with suitable identifications of certain edges is needed. This helps also to visualize the classification of triangles to three types discussed below. This can be found in the Wikipedia article (see `http://tinyurl.com/ns9aa`).

2. Numbers of different triangles as characterizers of harmony

A possible interpretation for topologically non-equivalent paths is as different notions of harmony.

1. Proceeding in Pythagorean spirit, the neighboring points would naturally correspond to progression by fifths - that is scalings by powers of 3/2 or in equal temperated scale by powers of $2^{7/12}$. This would mean that two subsequent vertices would correspond to quint.

2. The twenty triangles of the icosahedron would naturally correspond to 3-chords. Triangles can contain either 0, 1, or 1 edges of the 12-edge scale path. The triangle containing 3 edges is not possible since it would reside on a self-intersecting path. A triangle containing one edge of path the chord would contain quint which suggest a chord containing basic note, quint and

minor or major third. The triangle containing two edges would contain subsequent quints - CDG is one possible example by octave equivalence. If the triangle contains no edges of the path one can say that the chord contains no quints.

The numbers of triangles classified according to the number of path edges contained by them serves as the first classification criterion for a given harmony characterized by the Hamiltonian cycle (note that one cannot exclude the possibly of non-closed paths since Pythagorean construction of the scale by quints does not yield quite precisely octave as outcome).

Fig 1. There are 3 different types of triangles characterized by the number of edges contained by them. This predicts chords with 0, 1 or 2 quints.
`http://tgdtheory.fi/appfigures/kolmiot.jpg`

Consider now the situation in more detail.

1. The topologically equivalent cycles must have same numbers of faces containing 0, 1, or 2 edges of the Hamiltonian path since isometries do not change these numbers. Let us denotes these numbers by n_0, n_1 and n_2. The total number of faces is 20 so that one has

$$n_0 + n_1 + n_2 = 20 \ .$$

Furthermore, each of the 12 edges on the path is contained by two faces so that by summing over the numbers of edges associated with the faces one obtains twice the number of edges:

$$0 \times n_0 + 1 \times n_1 + 2 \times n_2 = 2 \times 12 = 24 \ .$$

From these constraints one can solve n_0 and n_1 as function of n_2:

$$\begin{aligned} n_0 &= n_2 - 4 \ , \quad n_2 \geq 4 \ , \\ n_1 &= 24 - 2n_2 \ , \quad n_2 \leq 12 \ . \end{aligned}$$

If these integers characterize the topological equivalence completely and if the allowed combinations are realized, one would have 12-4=8 topologically nonequivalent paths. The actual number is $N_{tot} = 2^k$, $k \geq 7$, so that the integers cannot characterize the topology of the path completely.

2. The number of Hamiltonian cycles on icosahedron is known to be 2560 [A3]. Numerical calculations [A4] (`http://tinyurl.com/pmghcwd`) shows that the number of Hamiltonian cyclesw with one edge fixed is $2^{10} = 1024$. Here one regards cycles with different internal orientation as different. This would mean that the sum over the numbers $N(n_2)$ if cycles associated with differ values of n_2 satisfies

$$\sum_{n_2=4}^{12} \sum_i N(n_2, i)) = 2^{10} \ .$$

$N(n_2, i)$ is the number of paths of given topology with fixed n_2. The numbers $N(n_2, i)$ are integers which are factors of $N = 120$ of the order of the isometry group of the icosahedron. The average of $N(n_2, i)$ is $2^7 = 128$.

3. Additional topological invariants characterizing the notion of harmony

The interpretation of amino-acids in terms of 20 triangles of icosahedron interpreted as allowed chords for a given notion of harmony leads to a unique identification of the integers n_i as $(n_0, n_1, n_2) = (3, 10, 7)$. The attempt to interpret this "biological harmony" leads to the identification of additional topological invariants characterizing the notion of harmony. It will be assumed that edges correspond to quints. If they would correspond to half-step the chords would contains 0, 1, or 2 subsequent half-intervals which does not conform with the usual views about harmony.

In Pythagorean scale quint corresponds to 3/2 and in equal tempered scale quint corresponds to the algebraic number number $2^{7/12}$.

Above the attention was paid to the properties of the triangles in relation to the Hamiltonian cycle. One can consider also the properties of the edges of the cycle in relation to the two neighboring triangles containing it. Restrict first the attention to the biological harmony characterized by $(n_0, n_1, n_2) = (3, 10, 7)$.

Fig. 2. The edge of the cycle belongs to 2 triangles, which as chords can correspond to 1 resp.2, 1 resp. 1 and 2 resp. 2 quints.
`http://tgdtheory.fi/appfigures/sivut.jpg`

1. Everyone of the 12 quints $C-G$, $C_\#-G_\#$, ... would be contained to neighboring triangles tht is 3-chords containing at least one quint. Denote by p_{12}, p_{11} resp. p_{22} denote the number of edges shared by 1-quint triangle and 2-quint triangle, by 2 1-quint triangles, resp. 2 2-quint triangles. Besides $p_{ij} \geq 0$ one has

   $$\sum p_{ij} = 12 \ .$$

   since the cycle contains 12 edges. There are $p_{12} + 2p_{11} = n_1$ 1-quint triangles and $(p_{12} + 2p_{22})/2 = n_2$ 2-quint triangles (note double counting responsible for division by two). Altogether this gives

   $$\begin{aligned} p_{22} &= 12 - p_{11} - p_{22} \ , \\ p_{22} &= p_{11} + n_2 - \tfrac{n_1}{2} \ , \\ p_{22} &= n_2 - \tfrac{p_{12}}{2} \ . \end{aligned}$$

2. These three Diophantine equations are for integers and would allow for real numbers only single solution and for integers it in the generic case there are no solutions at all. Situation changes if the equations are not independent which can happen if the integers n_i satisfy additional conditions. By subtracting first and second and second and third equation from each other one obtains the consistency condition

   $$n_1 = 24 - 2n_2 \ .$$

   This condition is however second of the conditions derived earlier so that only two equations, say the first two ones, are independent.

   $$\begin{aligned} p_{22} &= p_{11} + n_2 - \tfrac{n_1}{2} \ , \\ p_{22} &= n_2 - \tfrac{p_{12}}{2} \ . \end{aligned}$$

   giving

   $$\begin{aligned} p_{11} &= (n_1 - p_{12})/2 \ , \\ p_{22} &= p_{11} + n_2 - \tfrac{n_1}{2} = n_2 - \tfrac{p_{12}}{2} \ . \end{aligned}$$

   One must have $0 \leq p_{ij} \leq 12$ and $p_{12} \leq n_1$ from $p_{11} = (n_1 - p_{12})/2$. Here one has $p_{12} \in \{0, 2, ...Min\{12, 2n_2, n_1\}$ so that $Min\{7, n_2 + 1, [n_1/2] + 1\}$ solutions are possible. The condition that the cycle has no self-intersections can forbid some of the solutions.

3. The first guess for the "biological harmony" possibly associated with amino-acids would be $(n_0, n_1, n_2) = (3, 10, 7)$: this if one neglects the presence of 21st and 22th amino-acid also appearing in proteins. It turns out that a more feasible solution fuses tetrahedral code and icosahedral codes with $(n_0, n_1, n_2) = (4, 8, 8)$ giving $(n_0, n_1, n_2) = (4, 11, 7)$ for icosatetrahedral code.

   For instance, $(n_0, n_1, n_2) = (3, 10, 7)$ would give $p_{12} \in \{0, 2, 4, 6, 8, 10\}$, $p_{11} \in \{5, 4, 3, 2, 1, 0\}$, $p_{22} \in \{7, 6, 5, 4, 3, 2\}$ so that one has 6 alternative solutions to these conditions labelled by p_{12}. The number of neighboring triangles containing single quint is even number in the

range $[0, 10]$: this brings in mind the possibility that the neighboring single quint triangles correspond to major-minor pairs. Clearly, the integer p_{12} is second topological invariant characterizing harmony.

4. Distribution of different types of edges

Also the distribution of the 12 edges to these 3-types is an invariant characterizing the shape of the curve and thus harmony as isometric invariant.

Fig. 3. There are different distributions of edge types characterized by the neighboring triangles of the edge.
`http://tgdtheory.fi/appfigures/jakauma.jpg`

1. p_{12} 1-1 edges can be chosen in

$$N(1-1, p_{12}) = \begin{pmatrix} 12 \\ p_{12} \end{pmatrix}$$

ways and 1-2 edges in

$$N(1-2, p_{12}) = \begin{pmatrix} 12 - p_{12} \\ p_{12} \end{pmatrix}$$

ways. The remaining 2-2 edges can be chosen only in one manner. This gives altogether

$$N(p_{12}) = N(1-1, p_{12}) \times N(1-2, p_{12})$$

ways for given value of p_{12}.

To summarize, one obtains large number of notions of harmony are possible although one cannot expect that the absence of self-intersections does not allow all topologies for the cycle.

Would you come with me to icosadisco?

This map would allow one-to-one map of the notes of any music piece using icosahedral geometry. If octave equivalence is assumed, a given note would be mapped to a fixed vertex of icosahedron at which lamp is turned on and also to the wavelength of the light in question since visible light spans an octave. Chords would correspond to the turning on of lights for a group of icosahedral points. Icosahedrons with size scaled up by two could correspond to octave hierarchy: for practical purposes logarithmic scale implying that icosahedrons have same distance would be natural as in the case of music experience since piano spans 7 octaves and human ear can hear 10 octaves. Church would nowadays allow icosadiscos to use also half octaves to amplify further the audiovisual inferno effect so characteristic for discos. One could also try to realize special effects like glissandos, vibratos and tremolos.

2.6.2 Connection Between Music Molecular Biology?

Music affects directly emotions, and consciousness is one aspect of being living. This raises the question whether the Platonic geometries might have something to do with basic building bricks of life and with genetic code.

Could amino-acids correspond to 3-chords of icosahedral harmony?

The number of amino-acids is 20 and same as the number of triangular faces of icosahedron and the vertices of dodecahedron. I have considered the possibility that the faces of icosahedron could correspond to amino-acids [K3]. Combined with the idea about connection between music scale and icosahedron this inspires the following consideration.

1. For a proper choice of the mapping of the 12-note scale to the surface of icosahedron the 20 triangles could correspond to 20 amino-acids analogous to 3-chords and that the 3 types of 3-chords could correspond to 3 different classes of amino-acids. One can of course consider also the mapping of amino-acids to a unique sequence of 20 vertices of dodecahedron representing 20-note scale or 20-chord scale and replacement of the 3-chords defining the harmony with 12 5-chords.

2. Amino-acids are characterized by the non-constant side chain and these can be classified to three categories: basic polar, non-polar, and polar (`http://tinyurl.com/ycvm6yjs`). The numbers of amino-acids in these classes are $a_0 = 3$, $a_1 = 10$, $a_2 = 7$. Could these classes correspond to the numbers n_i characterizing partially some topological equivalence classes of Hamiltonian paths in icosahedron? There is indeed a candidate: $a_0 = n_0 = 3$, $a_1 = n_1 = 10$, $a_2 = n_2 = 7$ satisfies the conditions discussed above. 3 basic polar amino-acids would correspond to the triangles with no edges on the Hamiltonian cycle, 10 non-polar amino-acids to triangles containing one edge, and 7 acidic polar and polar amino-acids to those containing two edges. One can criticize the combination of polar and acidic polar amino-acids in the same class. One can also classify amino-acids to positively charged (3), negatively charged (2) and neutral (15) ones. In this case the condition is however not satisfied. Thus the proposal survives the first test - assuming of a course that these Hamiltonian cycles exist! This has not been proven and would require numerical calculations.

3. As found Hamiltonian paths have also other topological characteristics and they could correspond to physical characteristics and it would be interesting to see what theyh are. To proceed further one should find the total number of the Hamiltonian paths with $n_2 = 7$ and identify the isometries of different topological equivalence class having $n_2 = 7$.

Amino-acid sequences would correspond to sequences of 3-chords. The translation of mRNA of gene to amino-acid sequence would be analogous to the playing of a record. The ribosome complex would be the record player, the amino-acid sequence would be the music, and mRNA would be the record. Hence genes would define a collection of records characterizing the organism.

Can one understand genetic code?

What remains open is the interpretation of genetic code [I2]. DNA triplets would correspond naturally to triangles but why their number is 64 instead of 20. They would be obviously the analogs of written notes: why several notes would correspond to the same chord?

1. Could different DNA triplets coding for the same amino-acid correspond to various octaves of the chord? The most natural expectation would be that the number of octaves so that one would have 3 DNAs would code single amino-acid and stopping codon would correspond to 4 DNAs. It is difficult to understand why some 3-chords could correspond to 6 octaves and one of them only one.

2. Could the degeneracy correspond to the ordering of the notes of the 3-chord? For the 3-chords there are 6 general orderings and 3 cyclic orderings modulo octave equivalence and characterizing by the choice of the lowest note. The simplest assumption would be that the allowed orderings - degeneracies - are characterized by a subgroup of the cyclic group S_3 yielding the allowed permutations of the notes of the chord. The subgroup orders for S_3 are 1, 2, 3, and 6. The allowed degeneracies are 6, 4, 3, 2, and 1 so that this identification fails for $D = 4$.

3. Could the different correspondences between DNA codons and amino-acids correspond to the different topological equivalence classes of $n_2 = 7$ Hamiltonian cycles. This does not seem to be the case. The number of different DNA-amino-acid correspondences obtained by choosing one representative from the set of DNAs coding for a given amino-acid (and not stopping sign) is the product of the numbers $D(a_i)$ coding amino-acid a_i. From **Table 2.3** this number is given by $6^3 \times 4^5 \times 3^1 \times 2^9 \times 1^2 = 3^4 \times 2^{21}$ and clearly much larger than $N = 2^{10}$.

d	6	4	3	2	1
N	3	5	2	9	2

Table 2.3: The number of amino acids N associated with a given degeneracy d telling the number of DNA triplets mapped to the amino acid in the genetic code. The degeneracies are always smaller than 7 as predicted by the proposed explanation of the Genetic Code.

4. Could the different codons coding for codon code for some additional information so that amino-acids would in some aspect differ from each other although they are chemically identical? Here the magnetic body of amino-acid is a natural candidate. This would suggest that the folding pattern of the protein depends on what DNA sequence codes it. This information might be analogous to the information contained by notes besides the frequencies. Durations of notes corresponds is the most important information of this kind: the only candidate for this kind of information is the value of $h_{eff} = n \times h$ associated with the amino-acid magnetic body determining its size scale. Magnetic fields strength could be also code by DNA codon besides amino-acid.

Second question concerns genetic code itself. Could the DNA degeneracies $D(a_i)$ (number of DNAs coding for amino-acid a_i) be understood group theoretically in terms of icosahedral geometry? The triangles of the icosahedron are mapped the triangles under the isometries.

1. One can start by looking the **Table 2.3** for the genetic code telling the number $N(d)$ of amino-acids coded by d DNA codons. One finds that one can divide DNAs to three groups containing $n = 20$, $n = 20$, resp. $n = 21$ codons.

   (a) There are 3 amino-acids codes by 6 codons and 2 amino-acids coded by 1 DNA: $3 \times 6 + 2 \times 1 = 20$ codons altogether.
   Note: One could also consider 1 amino-acid coded by 2 codons instead of 2 coded by 1 codon $3 \times 6 + 1 \times 2 = 20$.

   (b) There are 5 amino-acids coded by 4 codons making $5 \times 4 = 20$ codons altogether.

   (c) There are 9 amino-acids coded by 2 codons and 1 by 3 codons making $9 \times 2 + 1 \times 3 = 21$ codons.
   Note: One could also consider the decomposition $8 \times 2 + 2 \times 1 + 1 \times 3 = 21$ codons implied if 1 amino-acid is coded by 2 codons in the first group.

This makes 61 codons. There are however 64 codons and 3 codons code for stopping of the translation counted as punct in the table.

1. This would suggest the division to 60 + 4 codons. The identification of additional 4 codons and corresponding amino-acids is not so straightforward as one might first think. 3 of the 4 additional codons could code for punct (Ile) and 1 of them to Ile (empty amino-acid).

2. What suggests itself strongly is a decomposition of codons in 3 different ways. 3 groups of 6 codons plus 2 groups of 1 codon (1 group of 2 codons), 5 groups of 4 codons, and 10 groups of 2 codons (9 groups of 2 codons plus plus 2 groups of 1 codon).

This kind of decompositions are induced by the action on the triangles of icosahedron by three subgroups of the isometry group $A_5 \times Z_2$ of the icosahedron having $120 = 2 \times 2 \times 2 \times 2 \times 3 \times 5$ elements and subgroups for which number of elements can be any divisor of the order. The orbit associated with a subgroup with n elements has at most n triangles at its orbit. This allows immediately to deduce the values of n possibly explaining the genetic code in the proposed manner.

1. The 3 amino-acids coded by 6 codons must correspond to $n = 6$. This subgroup must have also two 1-element orbits (1 2-element orbit): in other words, 2 triangles must be its fixed points (form its orbit).

(a) The non-abelian group S_3 permuting the vertices of is the first candidate for the subgroup in question. The triangles at the opposite sides of the icosahedron remain invariant under these permutations. S_3 however has two orbit consisting of 3 triangles which are "wall neighbours" of the triangles which remains fixed.

(b) Second candidate is the abelian group $\tilde{Z}_2 \times Z_3$. Here Z_3 permutes the vertices of triangle and $\tilde{Z}_2$ is generated by a reflection of the triangle to opposite side of icosahedron followed by a rotation by π. This group has 3 orbits consisting of 6 triangles and 1 orbit consisting of 2 triangles (the triangles at opposite side of icosahedron). This group seems to be the only working candidate for the subgroup in question.

2. The 5 amino-acids coded by 4 codons must correspond to $n = 4$ and therefore to $\tilde{Z}_2 \times Z_2$. This is indeed subgroup of icosahedral group which permutes triangles at the vertices of inscribed tetrahedron. Now all orbits contain 4 triangles and one must have 5 orbits, which are obtained by acting on the 5 triangles emanating from a given vertex. Note that also Z_5 is subgroup of icosahedral group: this would give a variant of code with 4 amino-acids coded by 5 codons if it were possible to satisfy additional consistency conditions.

3. Consider next the group consisting of 9 amino-acids coded by 2 codons and Ile ("empty" amino-acid) coded by 3 codons. Since only the $\tilde{Z}_2 \times Z_3$ option works, this leaves 9 amino-acids coded by 2 codons and 2 amino-acids coded by 1 codon. The subgroup must correspond to $n = 2$ and thus Z_2 acting on fixed triangle and leaving it and its $\tilde{Z}_2$ image invariant. One has 9 2-triangle orbits and two single triangle orbits corresponding to the triangles at opposite sides of the icosahedron. The 9 amino-acids coded by 2 codons are all real or 8 of them are real and 1 corresponds to "empty amino-acid" coded by two codons.

3-element orbits are lacking and this forces to consider a fusion of of icosahedral code with tetrahedral code having common "empty-acid" - common triangle of icosahedron and tetrahedron) coded by 2 icosahedral codons and 1 tetrahedral codon. Ile would be coded by 3 codons assignable to the orbit of Z_3 subgroup of tetrahedral symmetry group S_3 and would be associated with the tetrahedron. This would predict 2 additional amino-acids which could be understood by taking into account 21st and 22nd amino-acid (Sec and Pyl [I3]).

The Hamiltonian cycle is not explicitly involved with the proposed argument. Some property of the cycle respected by the allowed isometries might bring in this dependence. In Pythagorean spirit one might ask whether the allowed isometries could leave the Hamiltonian cycle invariant but move the vertices along it and induce a mapping of faces to each other.

The amino-acid triangle at given orbit cannot be chosen freely. The choices of amino-acid triangles associated with the three groups of 20 DNAs must be different and this gives geometric conditions for the choices of the three subgroups and one can hope that the assignment of amino-acid toa given triangle is fixed about from rotational symmetries.

Does the understanding of stopping codons and 21st and 22nd amino-acids require fusion of tetrahedral and icosahedral codes?

Several questions remain. Could one also understand the additional 4 DNA codons? Could one understand also how one of them codes amino-acid (Ile) instead of stopping codon? Can one related additional codons to music?

1. Attachment of tetrahedron to icosahedron as extension if icosahedral code

The attachment of tetrahedron to icosahedron allows to understand both stopping codons and punct as well as the 21st and 22nd amino-acids geometrically.

1. Something is clearly added to the geometric structure, when at least 4 additional DNA codons and 2 amino-acids are brought in. The new codons could represent orbits of faces of Platonic solid with 4 faces representing punct and 3 real amino-acids: say Ile, Pyl, and Sec. The 4 faces should be triangles and actually must be so since tetrahedron is the only Platonic solid having 4 faces and its faces are indeed triangles. Tetrahedron has symmetry group S_3 containing Z_3 and Z_2 as subgroups. Z_3 leaves one of the tetrahedral triangles invariant so that one has two orbits consisting of 1 and 3 triangles respectively.

2. One amino-acid is coded by 3 rather than only 2 codons. One can indeed understand this symmetry breaking geometrically. Suppose that the tetrahedron is attached on icosahedron along one of its triangular faces and that this icosahedral face corresponds either Ile or punct coded by 2 icosahedral codons. This face remains also fixed by the action of Z_3 and S_3 subgroups of tetrahedron so that 1 tetrahedral codon codes also for the amino-acid in question.

3. The three other faces of tetrahedron r should bring in three additional amino-acids. punct could correspond to either one of them or to the common base triangle which is indeed geometrically in unique position. One could even demand that this triangle is "empty" so that tetra-icosahedron would be non-singular continuous manifold. The 3-triangle orbit outside the icosahedron would correspond to Ile and base triangle to empty amino-acid. Base triangle would be coded by 1 tetrahedral codon plus 2 icosahedral codons.

4. One of the outsider triangles would thus corresponds to Ile but two other triangles to two new exotic amino-acids. In some species there indeed are 21st and 22nd amino-acids (selenocysteine (Sec) and pyrrolysine (Pyl), `http://tinyurl.com/2byr2b`) with sulphur replaced with selene. This modification does not change the polarity properties of cys and lys: cys and thus Sec is non-polar and lys and thus Pyl is basic polar implying $(n_0, n_1, n_2) = (3, 10, 7) \to (4, 11, 7)$.

5. The two other outsider tetrahedral triangles could correspond to the orbits of Z_2 subgroup of S_3 acting as reflection with respect to median of the base triangle. Outside faces form orbits consisting of 1 triangle and 2-triangles. Could these orbits correspond to 21st and 22nd amino-acids coded by 1 and 2 exotic codons?

   Since Ile and Sec are non-polar, they can correspond to 1-quint triangles at tetrahedron. 2-quint triangle cannot however correspond to Pyl which should correspond 0-quint triangle. Hence the 0-quint triangle must be at the isosahedron and the 2-quint triangle must correspond to basic polar amino-acid coded by single codon: Tyr is the only possible option). Hence the tetrahedral amino-acids are fixed to be Ile, Sec, and Tyr and Pyl must correspond to some icosahedral amino-acid.

   The second implication is that the icosahedral Hamiltonian cycle from which the icosatetrahedral cycle is obtained as deformation must correspond to (4, 8, 8) since one cannot deform (3, 7, 10) in such a manner that one would obtain one additional 0-quint triangle.

   It should be noticed that the 2 exotic amino-acids are coded by codons which are usually interpreted as stopping codons. Something must however distinguish between standard and exotic codings. Is it "context" giving different meaning for codons and perhaps characterized by different magnetic bodies of codons [K55] ?

Fig. 4. tetra-icosahedron is obtained by attaching tetrahedron along one of its faces to icosahedron. The resulting structure is topological manifold if the common face is replaced with empty set and it is natural to identify it as punct.
`http://tgdtheory.fi/appfigures/tetra-icosahedron.jpg`

2. How the icosahedral Hamiltonian cycle is modified?

The properties of exotic amino-acids give constraints on how the modification of the Hamiltonian cycle should be carried out. The naïve expectation that the outer triangles of added tetrahedron correspond to punct and 2 exotic amino-acids is not correct. A more appropriate interpretation is as a fusion of icosahedral and tetrahedral codes having common "empty amino-acid" coded 2 icosahedral and 1 tetrahedral 1 stopping codons respectively and obtained by gluing these Platonic solids together along the triangle representing the "empty" amino-acid. That the common triangle corresponds to punct means geometrically that its interior is not included so that the resulting structure is continuous manifold having topology of sphere.

Consider now the detailed construction.

1. One should be able to modify the icosahedral Hamiltonian cycle so that the numbers (n_0, n_1, n_2) charactering icosahedral cycle change so that they conform with the properties of the two

exotic amino-acids. Selenocystein (Sec) is nonpolar like cys and pyrrolysine (Pyl) basic polar like Lys so that $(4, 11, 7)$ seems to be the correct characterization for the extended system. One must have $(n_0, n_1, n_2) \to (4, 11, 7)$.

2. One must visit the additional vertex, which means the replacement of one edge from the base triangle with wedge visiting the additional vertex. There are several cases to be considered depending on whether the base triangle is 1-quint triangle or 2-quint triangle, and what is the type of the edge replaced with wedge. One can even consider the possibility that the modified cycle does not remain closed.

   If the icosahedral cycle has $(n_0, n_1, n_2) = (3, 10, 7)$, the value of n_2 is not changed in the construction. For a closed cycle edge is replaced with wedge and the only manner to preserve the value of n_2 is that the process producing 1 tetrahedral 2-quint triangle transforms 1 icosahedral 2-quint triangle identified as base triangle to 1-quint triangle. If the replaced edge of base triangle is of type 2-1, one has $n_1 \to n_1 + 1$ since one icosahedral 1-quint triangle disappears and 2 tetrahedral ones appear. Icosahedral n_0 increases by 1 units. Hence the condition $(3, 10, 7) \to (4, 11, 7)$ would be met. It however seems that $(4, 8, 8)$ is more promising starting cycle as the argument below shows.

3. The number options is at most the number n_2 of 2-quint triangles serving as candidates for punct. An additional condition comes from the requirement that replaced edge is of type 2-1.

Fig. 4. tetra-icosahedron is obtained by attaching tetrahedron along one of its faces to icosahedron. The resulting structure is topological manifold if the common face is replaced with empty set and it is natural to identify it as punct.

Fig. 5. The modification of $(4, 4, 8)$ icosahedral Hamiltonian cycle consistent with the constraints that icosatetrahedral cycle corresponds to $(4, 11, 7)$ consistent the classification of amino-acids in three classes.
`http://tgdtheory.fi/appfigures/tetraikosahedroni.jpg`

3. Direct construction of Hamiltonian cycle corresponding to bio-harmony

Consider bio-harmony as an example about Hamiltonian cycle taking seriously the extension of the genetic code. I have made very many unsuccessful triangles starting from the assumption that icosahedral cycle satisfies $(n_0, n_1, n_2) = (3, 10, 7)$, and the following proposal starts from different icosahedral cycle. The following is just a trial, which should be checked by a direct calculation.

1. The most obvious guess for the cycle to be modified to cycle at tetra-icosahedron having $(n_0, n_1, n_2) = (4, 11, 7)$ (the triangle corresponding to "empty" amino-acid (to be called punct) is not counted) is $(n_1, n_2, n_3) = (3, 10, 7)$. I have not found cycle with these characteristics.

2. It seems however possible to find cycle with $(n_1, n_2, n_3) = (4, 8, 8)$. From this can obtain the desired kind of extended cycle if the "empty" triangle is 2-quint triangle and the edge replaced with the wedge is of type 2-2. The replacement of icosahedral edge eliminates two icosahedral 2-quint triangles and generates 1 tetrahedral 2-quint triangle giving $n_2 \to n_2 - 2 + 1 = n_2 - 1 = 7$. The disappearance of the icosahedral edge generates two icosahedral 1-quint triangles of which second one corresponds to empty amino-acid and is not counted and 2 tetrahedral 1-quint triangles giving $n_1 \to n_1 + 3 = 11$.

The figure below represents the construction of cycle $(4, 8, 8,)$. The icosahedron is constructed from regions $P(I)$ glued to the triangle t along one edge each. The arrows indicate that the one pair of edges of type 1 and 2, 1 and 3 and 3 and 2 are identified. Also the long edges I of T are identified with pairs of subsequent edges of $P(I)$ as the arrows indicate.

Fig. 6. A proposal for a Hamilton cycle realizing bio-harmony $(n_1, n_2, n_3) = (4, 8, 8)$ allowing extension to cycle $(3, 11, 7)$ on tetra-icosahedron. Circled "0", "1" and "2" indicates

whether a given small triangle is 0-, 1-, or 2-quint triangle. It is relatively easy to verify that the condition $(n_1, n_2, n_3) = (4, 8, 8)$ for bio-harmony is satisfied.
http://tgdtheory.fi/appfigures/aikosahedroni.jpg

4. Stopping codons and music

What could be the interpretation of the attached tetrahedron in terms of music harmony?

The attachment of tetrahedron means addition of an additional note to the 12-note scale. The scale constructed in Pythagorean spirit identifying quint as scaling by 3/2 contains the 12th note as scaling by $(3/2)^{12}$ of the basic frequency modulo octave equivalence. This is slightly more than scaling by 2^7 so that exact octave is not obtained. The attempt to solve this problem has lead to scales in which one allows a pair of notes with a very small interval between them - say $G_\#$ and A_b being regarded as different notes.

This suggests that the outsider vertex of the attached tetrahedron corresponds to a note very near to some note of the 12-note scale. Which note is in question depends on which of the 10 1-quint triangles is chosen as the base triangle. This is expected to imply additional refinements to the notion of bio-harmony. 2 or three additional 3-chords emerge depending on whether empty amino-acid is interpreted as a real chord.

5. Geometric description of DNA-amino-acid correspondence

The mathematical structure which suggests itself is already familiar from some earlier attempts to understand genetic code [K29]. For icosahedral part of code one would have a discrete bundle structure with 20 amino-acids defining the base space and codons coding the amino-acid forming the fiber. The number of points in the fiber above based point depends on base point and is the number of codons coding the corresponding amino-acid. A discrete variant of singular fiber bundle structure would be in question.

Forgetting for a moment the 4 troublesome codons, the bundle would be the union of the orbits associated with groups S_3, Z_4 and Z_2 of icosahedral group, and the base would consist of 20 amino-acids, one for each orbit. The point of orbit must be selected so that the selections for orbits of two different groups are different.

The addition of the additional codons, punct and two exotic amino-acids would mean gluing of tetrahedron along one of its faces to icosahedron. This would induce extension of the singular bundle like structure. To each of the new faces one would attach the orbit of triangles representing the codons coding for the corresponding amino-acid.

To sum up, in its strongest form the model makes several purely mathematical predictions, which could easily kill it.

1. The identification of the 3-chords assignable to the triangles of the icosahedron.

2. The existence of $n_2 = 7$ Hamiltonian cycle requiring however the lumping of acidic polar and polar amino-acids in the same class.

How could one construct the Hamiltonian cycles on icosahedron with a minimal computational work?

Although the construction of Hamiltonian cycles is known to be an NP hard problem for a general graph, one can hope that in case of Platonic solids having high symmetries, a direct construction instead of straightforward numerical search might work. The followingis a proposal for how one might proceeed. It relies on paper model for icosahedron.

1. The basic observation about one can get convinced by using paper model is following. One can decompose the surface of icosahedron to three regions $P(I)$, $I = 1, 2, 3$, with pentagonal boundary and containing 5 triangles emanating from center vertex plus one big triangle T containing 4 pentagonal triangles and one lonely small triangle t opposite to it. These 5 regions span the surface of icosahedron. There is clearly a symmetry breaking and there is great temptation to assume that t corresponds to the triangle along which the tetrahedron is glued to the icosahedron in the model of genetic code realizing the modification of $(3, 7, 10)$ bio-harmony.

2. The Hamiltonian cycle must visit at the centers of each $P(I)$: one enters pentagonal region $P(I)$, $I = 1, 2, 3$ along one of the five interior edges beginning at pentagonal vertex $a_{I,i}$, $i = 1, .., 5$ and leaves it along second edge ending at vertex $b_{I,j}$, $j \neq 5$. One can call these edges interior edges. The edges at boundaries of $P(I)$ can be called boundary edges. Interior edge can correspond to $|i - j| = 0, 1$ or $i - j > 1$. For $|i - j| = 1$ the interior edge gives rise to 2-quint triangle. For $i - j = 0$ there is no boundary edge after $b_(I, j)$.

3. Pentagonal boundary edges come in three types. 2 of them are shared with T, 1 with t opposite to it, and 2 with another pentagonal region $P(I)$. One can label $P(i)$ in such a way that the $P(I)$ shares two boundary edges with $P(I + 1)$.

   The boundary edges of small and big triangle are boundary edges of the 3 pentagonal regions so that they are not counted separately.

4. One can assume that the cycles begins from a vertex of T. Since the cycle is closed it returns back to this vertex. The last edge is either at the boundary of T or goes through one or two edges of the small interior triangle of T so that this triangle is either 0-, 1- or 2-quint triangle.

   t can be 0-, 1-, or 2-quint triangle.

5. The total number of the interior edges inside the 3 pentagonal regions is $3 \times 2 = 6$ so that 6 remaining edges must be boundary edges associated with $P(I)$ and interior edges of T: otherwise one would visit some pentagonal center twice and self-intersection would occur. The boundary edges associated with t and T are boundary edges of $P(I)$, $I = 1, 2, 3$

6. At the vertex $b_(I, j)$ of pentagonal region one must turn right or left and move along the boundary edge. One can move at most $n_I = 4 - j$ boundary edges along the pentagonal boundary in clockwise direction and $n_I = j - 2$ edges in counterclockwise direction (clockwise is the direction in which the index labelling 5 vertices grows). The maximum number of boundary edges is 3 and obtained for $j - i \pm 1$.

7. The condition $\sum n_I + n(T) = 6$, where $n(T) = 1, 2$ is the number of interior edges of T, holds true so that one has $\sum n(I) \equiv n_{tot} \in \{4, 5\}$. The numbers and types (shared with pentagon, T, or t) of the boundary edges of $P(I)$, the differences $\Delta(I) = j_I - i_I$, the number of edges in t and the number of interior edges of T characterize the Hamiltonian cycle besides the condition that it is closed. The closedness condition seems possible to satisfy. One must enter big triangle through one of the vertices of T and this vertex is uniqely determined once the third pentagon is fixed. One can therefore hope that the construction gives directly all the Hamiltonian cycles with relatively small amount of failed attempts, certainly dramatically smaller than $n = 2^{24} \sim 10^7$ of blind and mostly un-succesful trials.

8. Each $P(I)$ containing boundary edges gives rise to least 2 2-quint triangles associated with $b_I(I)$ and a_{I+1}.

   If all 3 $P(I)$ have $|i - j| > 1$, one has $n_2 = 3 \times 2 = 6$. The contribution of regions $P(I)$ is larger if some pentagon interiors have $|\Delta(I)| = |j(I) - i(I)| = 1$. $|j(I) - i(I)| = 1$ gives $\Delta n_2(I) = 1$ and $\Delta n_1(I) = 0$ since 2 1-quint triangles are replaced with single 2-quint triangle.

   The interior of the T can give 1 2-quint triangle.

9. The number n_1 of 1-quint triangles can be estimated as follows.

   (a) Each pentagonal interior edge pair leading from $a(I, j)$ to $b(I, j)$ contributes 2 1-quint triangles for $\Delta(I) \neq \pm 1$, otherwise one obtains only 1 2-quint triangle. This would give maximum number of 6 1-quint triangles associated with the interior edges of 3 pentagons.

   (b) $P(I)$ pentagonal boundary edges contribute $2 \times (P(I) - 1)$ additional 1-quint triangles.

   (c) T contributes at most 4 1-quint triangles.

(d) t can correspond 1-quint triangle and would do so if the interpretation of extended code is correct.

10. The construction also breaks the rotational symmetry since the decomposition of icosahedron to regions is like gauge fixing so that one can hope of obtaining only single representative in each equivalence class of cycles and therefore less than 2^{10}. By the previous argument related to icosatetrahedral code, t and the triangle opposite to it cannot however correspond to amino-acids coded by 1 codon as one might guess first. Rather, t corresponds to punct and to 1-quint triangle belonging to Z_2 orbit.

The number of cycles should be 2^{10}. One can try to estimate this number from the construction. Each $b_{I,j}$ can be chosen in 4 ways at the first step but at later steps some vertices of the neighboring pentagon might have been already visited and this reduces the available vertices by $n+1$ if n subsequent edges are visited. At each vertex $b_{I,j}$ one has 4 options for the choice of the boundary edges unless some boundary edges of pentagon (shared with other pentagons) have been already visited. It is also possible that the number of boundary edges vanishes. One can start from any vertex of triangle. This gives the upper bound of 2^4 choices giving $N < 2^{12}$ paths going through 4 pentagon-like regions. The condition that the path is closed, poses constraints on the edge path assignable to T but the number of choices is roughly 24. The condition that path goes through all vertices and that no edge is traversed twice must reduce this number to 2^{10}.

The numerical construction of Hamiltonian cycles should keep account about the number of vertices visited and this would reduce the number of candidates for $b(I,j)$ and for the choices of $P(I)$ for $I > 1$ as well as the number of edge paths associated with T.

Icosahedral Hamiltonian cycles numerically

A couple of months after writing the article I decided to look at the numerical problem of calculating the Hamiltonian cycles for icosahedron. Recall that the earlier source [A4] (`http://tinyurl.com/pmghcwd`) telling that there are 2^{10} different Hamiltonian cycles when orientation is taken into account and one edge is fixed: if orientation does not matter there re 2^9 cycles. If one does not fix one cycle one obtains 2560 cycles - not Hamiltonian paths as I had erratically concluded. The cycles were actually listed (`http://tinyurl.com/yacgzm9x`) and classified to five different basic classes according to their symmetries. Even better, examples of cycles with symmetries were illustrated.

Cycles can be divided to isomorphy classes within which cycles have same shape.

1. It is possible to perform a shift of the edges along the cycle. The shape of the cycle is not affected but cycle changes. Using music terms the key changes. There are 12 different keys.

2. Also the mirror image mapping i^{th} edge to $(13-i)^{th}$ edge is a symmetry which in the generic case produces a new cycle. This symmetry should be distinguished from the change of the internal orientation which does not affect the cycle.

3. Also the isometries of icosahedron leaving the fixed edge as such act as symmetries. Fixed edge belongs to a triangle and the reflection mapping the two other edges of the triangle to each other is this kind of symmetry. Therefore there are two reflection symmetries and the number of cycles of same shape in the generic case is expected to be $4 \times 12 = 48$. If some of the symmetries acts trivially or if some isometries of icosahedron act as its symmetries, the number of isomorphic cycles is reduced.

It is even possible to find illustrations of the symmetric cycles (`http://tinyurl.com/y8ek7ak8`) obtained using Brendan McKay's NAUTY software (`http://tinyurl.com/dkftsr`)! From these illustrations (see **Figs. ??**, **??** and **??**) one can by visual inspection deduce the numbers (n_0, n_1, n_2) charactering the cycle for classes involving symmetries. Also the basic chords can be deduced. If one trusts the condition $n_1 + 2 \times n_2 = 24$, it is enough to count the number n_2 triangles containing to path edges. I have also directly checked that n_1 comes out correctly.

There are following isomorphic collections.

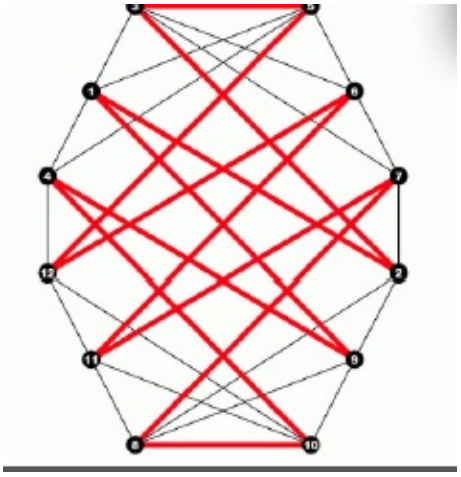

Figure 2.1: $((n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2 reflection symmetries acting in vertical and horizontal directions.

1. 6 asymmetric collections containing the maximal number of 48 cycles each. In this case images are not given.

2. 3 collections with 2-fold rotation symmetry containing 48/2=24 cycles each. One has $(n_0, n_1, n_2) \in \{(0, 16, 4), (0, 16, 4), (4, 8, 8)\}$.

3. 5 collections with reflectional symmetry containing 48/2=24 cycles each. One has $(n_0, n_1, n_2) \in \{(2, 12, 6), (2, 12, 6), (4, 8, 8), (2, 12, 6), (2, 12, 6)\}$.

4. 2 collections with 2 reflectional symmetries containing 48/4=12 cycles each. One has $(n_0, n_1, n_2) \in \{(0, 16, 4), (4, 8, 8)\}$.

5. 1 collection with 6-fold rotational symmetry containing 48/6= 8 cycles. One has $(n_0, n_1, n_2) = (2, 12, 6)$.

There are therefore 5 different notions of harmony and they correspond to $n = \{6, 3, 5, 2, 1\}$ sub-harmonies. This gives altogether 6+3+5+2+1= 17 different notions of harmony.

What is remarkable that the original candidate $(3, 10, 7)$ for bio-harmony is not realized as a cycle possessing symmetries (it might be realized as one of the asymmetric cycles) but that there are at least three realizations for $(4, 8, 8)$, which is forced by the condition that bio-harmony corresponds to the extended genetic code! The three $(4, 8, 8)$ cycles are illustrated in **Figs. ??**, **??** and **??**.

2.6.3 Other Ideas

The book of Merrick discusses also other ideas. The attempts to understand music in TGD framework relate to these ideas.

p-Adic length scale hypothesis and music

One of the key ideas is the reduction of the octave phenomenon to the p-adic length scale hypothesis predicting that octaves and half-octaves correspond to p-adic scalings allowed by the hypothesis $p \simeq 2^k$ for the preferred values of the p-adic primes, and yielding scaled variants of physical systems. This idea will not be discussed in the following: suffice it to say that Pythagorean scale coming as powers of $p = 3$ strongly suggests approximate 3-adicity.

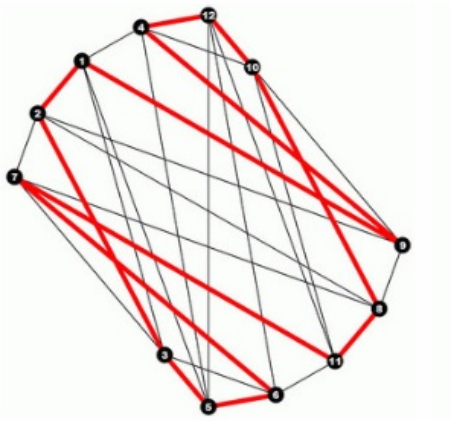

Figure 2.2: $((n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold rotational symmetry acting as 6-quint rotation.

EEG and music

First of the key ideas relates to the idea that genetic code relates to the music scale.

1. Music metaphor is key element of TGD inspired view about biology and neuroscience. In particular, TGD based view about dark matter leads to the proposal that bio-photons are ordinary photons resulting as transformations of dark photons with large Planck constant $h_{eff} = nh$ to ordinary photons. The further hypothesis is that the energy spectrum of bio-photons is universal and contains visible photons and UV photons, which defined transition energies of biomolecules. This hypothesis follows if the value of h_{eff} assignable to a magnetic flux tube characterizes ion and is proportional to its mass number. The notion of gravitational Planck constant identified as $\hbar_{gr} = GMm/v_0$, where v_0 is a velocity parameter assignable to the two-particle system can be identified in the case of elementary particles and ions with h_{eff} and predicts also the universality of bio-photon spectrum.

2. In this framework bio-photons would represent music as light inducing molecular transitions. Notes that is different energies of bio-photons would correspond to different magnetic field strengths at magnetic flux tubes as was proposed much earlier in the quantum model of hearing [K58]. Could the biochemical and physiological aspects involved with the generation of music experience be realized in terms of bio-photon emission induced by the listening of music?

Standing waves and music

Merrick consider the idea that standing waves are essential for music experience. Preferred extremals of Kähler action representing standing waves does not seem to be feasible. The known preferred extremals (with "massless extremals" (MEs) included) would represent superpositions of Fourier components with four-wave-vectors which are proportional to each other. Essentially pulse propagating in fixed direction. For more general extremals this direction can depend on position.

Although standing waves are not feasible, effects which would be explained in Maxwell's theory in terms of standing waves are possible in many-sheeted space-time. A particle in a region of Minkowski space containing several space-time sheets touches all space-time sheets having non-vanishing Minkowski space projection to this region and the forced experience by it is sum of the forces caused by them. This leads to an operational defines of gravitational and gauge fields of Einstein-Maxwell limit of TGD as sum of the deviations of the induced metric from Minkowski metric and sum of the components of the induced spinor connection defining classical gauge potentials in TGD framework.

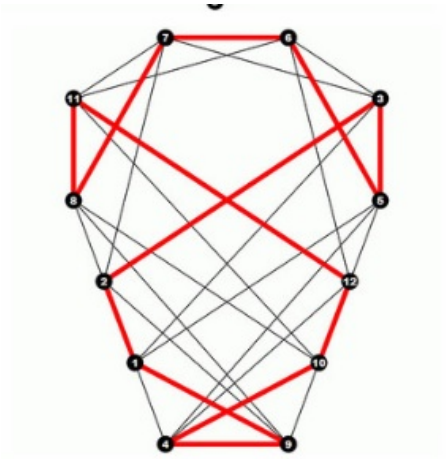

Figure 2.3: $((n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold refection symmetry acting as horizontal reflection.

Test particles can clearly experience the presence of standing waves. It is enough to take two massless extremals with opposite directions of three momentum but same energy with non-empty projections to same M^4 region. Particle with experience standing wave oscillating with the frequency involved. The arrangements in which photons are taken to rest effectively could correspond to this kind of situations since if it is the motion of test particles which serves as a signature. Note however that there are also vacuum extremals for which the light velocity at the space-time surface corresponds to arbitrarily low velocity at the level of embedding space.

Emotions and 4-D character of music experience

Music experience involves in an essential manner time unlike visual experience which is essentially 3-dimensional. Music experience affects also emotions very directly. For instance, we somehow know the key of the piece and expect that it ends to the basic note and chord. We somehow know also the scale used (say major or minor) by the emotional response stimulated by it. All this requires information about entire time evolution of the music piece. The recent neuroscience based models of memory do not help much in attempts to understand how this is possible. The reason is that in the ordinary materialistic view in which the state of the brain at fixed time should determine the contents of consciousness.

The general vision in Zero Energy Ontology and Quantum Classical Correspondence is that space-time surface provide classical physics correlates for quantum states and also quantum jumps: the failure of the strict determinism is essential for the latter. The space-time surfaces are restricted inside causal diamond (CD) and have space-like 3-surface as their ends: the interpretation is as counterparts for the initial and final states of physical events.

The replacement of states with events makes it possible to understand mysterious looking facts about living matter such as standardized temporal patterns - say those appearing during morphogenesis. The maxima of the vacuum function defined by the exponent of Kähler function in term identified as Kähler action for Euclidian space-time regions representing analogs for the lines of Feynman graph correspond to the most probably temporal patterns.

The basic aspect of emotions is positive/negative dichotomy. An attractive identification for the physical correlated of this aspect is whether the quantum jump generating the emotion increases or decreases the negentropy of the subsystem involved. For instance, pain would correspond to a reduction of the negentropy for the body part involved. In music experience negentropy could flow between different parts of the system involved and create also sensation with local negative coloring but with overall positive coloring (by NMP [K41]). The ability of temporal patterns of music to generate negentropy flows inside the system involved could explain its effectiveness in

generating emotions.

Dissonances were used by composes like Bach to generate melancholic emotions which suggests that the dissonance represent local reduction of negentropy. Also vibrato has emotional content. Physically dissonance and vibrato are assignable to the interference of frequencies which are near to each other (`http://tinyurl.com/5r34ch`). The basic formula is

$$cos(x) + cos(y) = cos((x+y)/2) \times cos((x-y)/2) \quad .$$

Acknowledgements: I want to thank Tommi Ullgren for directing my attention to the book of Richard Merrick as well as for fascinating discussions about music.

Does DNA understand speech or should you sing to it?

There is an interesting popular web article (see `http://tinyurl.com/3ghkl7y`) [I15] about the work of Peter Gariaev with whom I have written a couple of articles. A more professional representation about wave DNA of Gariaev *et al* can be found from CASYS2001 conference proceedings [I11]. One of the findings of Gariaev's group is that the intronic portion of the DNA has a statistical resemblance to the structure of language (words of language correspond to DNA codons and Zipf's law (see `http://tinyurl.com/ycevt3jb`) appears to be obeyed [J61]). The question whether introns could code language at molecular level comes to mind.

It is also reported that the connection with language is much more concrete. The words of spoken language generate response at the level of DNA: DNA "hears" and maybe understands language (or is it us who understand the language in this manner?). If one accepts that even water has memory and reacts to signals inducing emotions in living organisms, this would not be so surprising. In fact, in TGD framework water would be primitive life form with dark DNA consisting of protonic strings such that proton states would be in 1-1 correspondence with DNAs, RNAs, amino-acids and perhaps even tRNAs [K44, K31]. Vertebrate genetic code follows from natural assumptions between dark counterparts of DNAs and amino-acids.

So the claim is that spoken language modulating em radiation has effect on DNA. In standard physics context it is difficult to see how this could make sense. The energies of phonons at audible frequencies are simply so low that understanding the effect in terms of phonons does not seem to be possible. Could it make sense in TGD inspired quantum biology? One can at least try and this is what is done in the sequel. The explanation relies on the basic assumptions of TGD inspired quantum biology distilled during last 10 years.

1. Dark matter corresponds to a hierarchy of phases labelled by the values of effective Planck constant given by $h_{eff} = n \times h$ [K25]. This hypothesis can be reduced to the failure of strict determinism for the basic variational principle of TGD and is consistent with the notion of gravitational Planck constant defined as $h_{gr} = GMm/2piv_0$, where v_0 is characteristic velocity assignable to the two particle system consisting of masses m and M [K67]. This formula holds true at flux tubes mediating gravitational interaction in terms of gravitonic "massless extremals" (MEs) topologically condensed at them.

   For elementary particles, ions, atoms, even biomolecules this formula is consistent with $h_{eff} = h_{gr}$. Equivalence Principle implies that the formula for h_{gr} must be assumed only for them to explain approximate Bohr orbitology for planetary orbits. For Earth-charged particle system the formula predicts Planck constant for which dark cyclotron photon energies in endogenous magnetic fields are in visible and UV range at which also biophoton energies are. Gravitational Compton length does not depend on the mass of particle - essential for macroscopic quantum coherence and consistent with Equivalence Principle. For Earth-Sun system the gravitational Compton lengths is of the order Earth radius, which suggests that at dark matter level Earth is macroscopic quantum system.

2. This picture conforms with the hypothesis that biophotons are ordinary photons resulting in h_{eff} changing phase transition conserving four-momentum [K14]. Since the energy levels of biomolecules belong to visible and UV range, dark photons could control biochemistry by dark-to-bio-photon transitions. This would give the missing interaction link between biochemistry and magnetic body. The standard hypothesis is that biophotons are side products

of biochemistry: in TGD Universe biophotons would become active controllers of biochemistry and would be used by magnetic body.

3. Living matter as a random soup of biomolecules is replaced with a highly organized structure. Dark matter can be seen as a library of "Akashic records" realized in terms of negentropic entanglement [K41]. Each dark particle, atom, molecule, etc is at its own magnetic flux tube characterized by $h_{eff} = h_{gr}$. One can say that each book in the Akashic library resides neatly at its own book shelf labelled by the value of magnetic field strength and h_{eff}. The communication between levels of dark matter hierarchy (book shelves) would take place by using h_{eff} changing transition of dark photons having a universal energy spectrum independent of the particle mass and depending on the strength of magnetic field at the flux tube. Visible photons correspond to single energy octave which suggests connection with music discussed in [K58].

In this framework it is not too difficult to understand how DNA could "hear" and maybe even "understand".

1. DNA codons carry -2 units of em charge per single nucleotide due to the presence of one diphosphate in the sugar backbone. The ratio $Q_{tot}/M_{tot} = 2N(tot)e/M_{tot} = 2e/M(ave)$ to which cyclotron frequency is proportional, is inversely proportional to the average mass $M(ave)$ of the unit of DNA sequence. Hence DNA sequences are coded by cyclotron frequencies and to "wake up" given unit of DNA it is enough to irradiate it with dark photons at this cyclotron frequency. For long sequences of DNA cyclotron frequency becomes essentially constant if DNAs obey statistical a distribution with single Gaussian peak. One can consider the possibility that the distribution is many-peaked and fractal.

   This is not the only one possible option that one can imagine. Cyclotron frequencies could be also assignable - not to DNA itself but - to charged particles at the flux tubes associated with the basic units of DNA.

2. There are two ways to "wake up" DNA: frequency resonance at the level of dark matter and energy resonance at the level of visible matter. The first manner to wake up DNA is by a transformation of acoustic signal to dark photons at cyclotron frequencies which are also cyclotron frequencies assignable to DNA molecules. DNA units would be analogous to the frequency specific hair cells in cochlea. The TGD inspired model of hearing indeed assumes that the hair cells carry out this transformation. Second manner to wake up DNA is to transform the dark photons first to biophotons with a transition energy of DNA molecule and thus inducing the chemical transition. These dark photons could then excite the DNAs resonantly at cyclotron frequencies or a chemical transition energies after transition to biophoton. This mechanism breaks quantum coherence.

   If the excited DNAs correspond genes or to a portion of DNA inducing gene expression, acoustic signal (say speech) would be transformed to genetic expression and thus generate a physiological response. Introns could also generate em signals transformed to acoustic signals giving eventually rise to internal speech. Here the cyclotron resonance mechanism could be at work. This mechanism respects quantum coherence.

3. Right brain sings - left brain talks metaphor suggests an interpretation for these two mechanisms. For the singing right brain the cyclotron resonance for dark photons could dominate. For the talking left brain the chemical excitation using biophotons could dominate.

The experiments of Gariaev *et al* [I15, I11] suggest that amplitude modulation of light signal by acoustic signal, say speech, is enough.

1. The carrier wave with single frequency modulated by single frequency would consist of a superposition of signals with frequencies which correspond to sum and difference for the frequencies involved. They could naturally correspond to parallel space-time sheets (MEs) (but this is not necessary): the test particle touching both sheets indeed experiences the sum of the effects caused by the two signals. The naïve expectation would be that these signals are detected as such. This would not however allow the proposed mechanism.

Another possibility is that the resulting photons at either or both space-time sheets having frequency and energy of (say) visible photons are transformed to dark photons with the frequency of phonon in the frequency range involved with the speech. This condition fixes the value of h_{eff} to be essentially the ratio of visible and audible carrier frequencies and fixes also the value of the endogenous magnetic field strength from the condition that cyclotron energy scale is same as the energy of visible photon. The MEs in question should be topologically condensed at the magnetic flux tubes.

2. These dark photons transform to biophotons inducing a response both at the level of biochemistry and at the level of DNA sub-units (talking and singing): if h_{eff} in question is correct, the DNA sub-unit corresponding to flux tubes with the value of h_{eff} associated with dark photons is excited and can induce protein translation or some other form of gene expression so that the incoming signal finds expression.

3. One can consider also acoustic signals transformed directly to dark photon electromagnetic signals propagating along flux tube-massless extremal pairs to DNA since living matter consists of piezo-electrets performing these transformations. These would correspond to communication by "singing": singing could correspond basically frequency modulation induced by the modulation of magnetic field strength ("whale's song"). The variation of membrane voltage by waves and by nerve pulses induce similar frequency modulation.

2.7 Geometric Theory Of Harmony

For some time ago I introduced the notion of Hamiltonian cycle as a mathematical model for musical harmony and also proposed a connection with biology: motivations came from two observations [L12], [K58, K79]. The number of icosahedral vertices is 12 and corresponds to the number of notes in 12-note system and the number of triangular faces of icosahedron is 20, the number of amino-acids and the number of basic chords for the proposed notion of harmony. This led to a group theoretical model of genetic code and replacement of icosahedron with tetra-icosahedron to explain also the 21st and 22nd amino-acid and solve the problem of simplest model due to the fact that the required Hamilton's cycle does not exist.

This article was meant to be a continuation to the mentioned article providing a proposal for a theory of harmony and detailed calculations. It however turned out that the proposed notion of bio-harmony was too restricted: all isosahedral Hamilton cycles with symmetries turned out to be possible rather than only the 3 cycles forced by the assumption that the polarity characteristics of the amino-acids correlate with the properties of the Hamiltonian cycle. This working hypothesis had to be given up. The fuel of the minirevolution was the observation the symmetries of the Hamiltonian cycles (Z_6, Z_4, Z_2) are nothing but the icosahedral symmetries needed to predict the basic numbers of the genetic code and its extension to include also 12st and 22nd amino-acids. Thus icosahedral Hamiltonian cycles predict genetic code without further assumptions.

One also ends up with a proposal for what harmony is leading to non-trivial predictions both at DNA and amino-acid level.

1. 3-adicity and also 2-adicity are essential concepts allowing to understand the basic facts about harmony. The notion of harmony at the level of chords is suggested to reduce to the notion of closeness in the 3-adic metric using as distance the distance between notes measures as the minimal number of quints allowing to connect them along the Hamilton's cycle. In ideal case, harmonic progressions correspond to paths connecting vertex or edge neighbors of the triangular faces of icosahedron.

2. An extension of icosahedral harmony to tetra-icosahedral harmony was proposed as an extension of harmony allowing to solve some issues of icosahedral harmony relying on quint identified as rational frequency scaling by factor 3/2.

   This extension is kept also now. One must however give up the idea about correlation between polarity characteristics of proteins and properties of Hamilton cycles. One must allow *all* 11 icosahedral harmonies with symmetries as bio-harmonies: their symmetry groups Z_6, Z_4, Z_2 can be identified as the symmetry groups defined the decomposition of 60 DNA codons

to 20+20+20 codons in the model of the genetic code. The 4 remaining DNAs and amino-acids can be assigned to both tetra-icosahedron and tetrahedron and icosahedron regarded as defining separate genetic codes. This explains why stopping codons can code for the 21st and 22nd amino-acid under some circumstances.

Tetrahedral code is second member in the hierarchy of genetic codes [K29] inspired by the notion of Combinatorial Hierarchy $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$ giving the numbers $2, 4, 7, 64, 2^{126}, ...$ as numbers of DNA codons. The fourth member would correspond to what I called "memetic code" allowing representation of codons as sequences of 21 DNAs. It is not known whether the Combinatorial Hierarchy of Mersenne primes continues as Hilbert conjectured.

3. The notion of bio-harmony is partially characterized by the triplet $n = (n_0, n_1, n_2)$, characterizing the numbers of 0-, 1-, and 2-quint chords which in turn correspond to DNA codons in consistency with the observation that codons indeed correspond to triplets of nucleotides. n-quint chord corresponds to a triangle (face of icosahedron) containing n edges of the Hamiltonian. Particular bio-harmony requires a selection of a specific Hamiltonian cycle from each class of cycles (1 Z_6 symmetric cycle having $n = (2, 12, 6)$, 2 Z_4 symmetric cycles $n \in \{(0, 16, 4), (4, 8, 8)\}$, 3 $Z_2 = Z_2^{rot}$ with $n \in \{(0, 16, 4), 1(2, 12, 6), (4, 8, 8))\}$ and 5 $Z_2 = Z_2^{refl}$ symmetric cycles with $(n \in \{(2, 12, 6), (4, 8, 8)\}$. Note that the are only three different triplets n.

4. The original idea was that the rules of bio-harmony could be applied to amino-acid sequences interpreted as sequences of basic 3-chords. DNA would have represented the notes of the music. For *given choice of harmony* as Hamiltonian cycle meaning selection of of 4, 5 or 10 amino-acids coded by the 20 DNAs in question, the hypothesis had to be modified by replacing amino-acid sequences with DNA sequences.

   These DNA sequences however define also amino-acid sequences identifiable as specific triangle at the orbit of Z_n defining the DNA codons assigned to that amino-acid (there is a singular fiber space structure). Together the three 20-plets of DNAs define an amino-acid harmony with (4+5+10 =19 chords with tetrahedral extension defining a harmony with 22 chords/amino-acids). Hence both DNA sequences and amino-acid sequences define "bio-music".

5. The assumption that harmonic transitions between chords (DNA codons) minimize the distance between chords defined by quint-metric leads to highly non-trivial and testable predictions about both DNA sequences and amino-acid sequences. Negentropy Maximization Principle (NMP) [K41] suggests that evolution favors the generation of harmony which should thus increase in the proposed sense for DNA sequences defining particular genes or other functional units of DNA during evolution. Large quint-distances between subsequent codons/chords would tend to polished out under evolutionary pressures.

6. Could icosahedron, tetrahedron, and tetra-icosahedron have direct physical counterparts in living matter? For instance, water molecules form icosahedral clusters and the chlathrates associated with synaptic contacts have icosahedral symmetries. Tetra-icosahedron has 13 vertices with the added vertex representing one note- say E- in C-key as note with slightly different frequency to resolve the basic problem of rational number based 12-note scale (12 quints give slightly more that 7 octaves). Intriguingly, microtubules consist of basic structures consisting of 13 tubulins with 2 states defining bit: could these bit sequences define representation for the 3-chords and thus representation of sequence of DNA codons and realization of genetic code.

7. Music is language of emotions and peptides are molecules of emotion as Candace Pert [J23] expressed it. Could bio-harmonies serve as direct correlates for emotions? What is bio-music? A natural TGD inspired guess is that sounds can be replaced with $h_{eff} = n \times h$ dark photons with low frequencies and having energies in the range of bio-photons (visible and UV range maximally effective biologically) as proposed on basis of some physical facts and theoretical ideas [K58]. The frequency spectrum of dark cyclotron photons along magnetic

flux tubes would define bio-music as "music of dark light" and bio-harmonies would correlate with emotions and moods.

If one can find various icosahedral Hamilton's cycles one can immediately deduce corresponding harmonies. This would require computer program and a considerable amount of analysis. My luck was that the all this has been done. One can find material about icosahedral Hamilton's cycles (see `http://tinyurl.com/pmghcwd`) in web, in particular the list of all 1024 Hamilton's cycles with one edge fixed [A3, A4] (this has no relevance since only shape matters). If one identifies cycles with opposite internal orientations, there are only 512 cycles. If the cycle is identified as a representation of quint cycle giving representation of 12 note scale, one cannot make this identification since quint is mapped to fourth when orientation is reversed. The earlier article about icosahedral Hamiltonian cycles as representations of different notions of harmony is helpful [L12].

The tables listing the 20 3-chords of associated with a given Hamilton's cycle make it possible for anyone with needed computer facilities and music generator to test whether the proposed rules produce aesthetically appealing harmonies for the icosahedral Hamiltonian cycles. Biologist with access to DNA sequences could experiment with DNA codons to see whether their are harmonious in the sense that the distance between subsequent chords assignable to DNA codons tend to be small in quint metric. Note that DNA decomposes to pieces corresponding to different Hamiltonian cycles (harmonies) so that the comparison is not quite straightforward.

2.7.1 What Could Be The Basic Principles Of Harmony?

It indeed seems that the idea about definition of notion of harmony in terms of Hamiltonian cycles makes sense.

Icosahedral harmonies

1. Chords (major and minor) are labeled by their basic tones and comes either as major or minor. Harmony in classical sense requires that the transitions from key to another take place by a small number of quints and that the piece does not wander too far from the major key, say C.

   If quint corresponds to a step along the edge of the cycle in the direction of its orientation, the notion of tonal closeness corresponds to the closeness in the metric of icosahedron. For instance C, F, and G are commonly used keys in same piece and correspond to 3 subsequent points along Hamiltonian cycle. Note that the number of ♯s of the key increases by one unit in standard direction and the number of ♭s by one unit in opposite direction.

2. It turns out that major and minor 3-chords and are mapped to each other in the orientation reversal for icosahedral path so that basic moods "happy" and "sad" in music have this orientation as a geometric correlate. The effect of orientation reversal does not actually depend on the icosahedral representation but is implied by quint cycle representation alone. C and half-octave $F\sharp$ defining the tritonus interval are the fixed points of the orientation reversal. Orientation reversal induces pairings ($C \leftrightarrow C$, $F\sharp \leftrightarrow F\sharp$, $G \leftrightarrow F$, $D \leftrightarrow B\flat$, $A \leftrightarrow D\sharp$, $E \leftrightarrow G\sharp$, $H \leftrightarrow C\sharp$. Quints of cycle correspond to the fourths of oppositely oriented cycle so that majors and minors are mapped to each other and one can say that the moods "happy" and "sad" have geometric correlates in the sense that majors and minors are transformed to each other in the reversal of orientation of the cycle.

The notion of harmony can be characterized in terms of numbers of basic 3-chords identified as faces of the icosahedron and their neighborhood relationship telling when corresponding chords are near to each other or vertex or face neighbours. The wall neighbours assignable to given edge are expected to be in very special relationship harmonically since they possess a common quint.

The basic classification is according to the number $n = 0, 1, 2$ of edges of cycle contained by them and the triplet $n = (n_0, n_1, n_2)$ for the numbers of faces of various kinds gives the first rough classification. 2-quint chords have common edge and thus two common notes with two 1-quint chords and are therefore natural intermediates in transitions between them. 0-quint chords are tonal loners having no edge neighbours turns out that they involve dissonances since they consists of three notes spanning length of 1 or 3/2 steps (say EFG, $EF\sharp G$ or $D\sharp EF$). Maximally symmetric

harmony is an exception: 0-quint chords correspond to augmented chords of type $CEG\sharp$ with two major thirds.

The numbers of three different kinds of face neighbor pairs for the 12 edges of the path serve as an additional classification criterion in terms of the $p = (p_{1,1}, p_{1,2}, p_{2,2})$ for the numbers $p_{i,j}$ of different kind of edges. Note that the neighbor faces of an edge correspond to 3-chords, which possess two common notes and are in this sense close to each other. These numbers characterize the most natural transitions between the chords of the harmony. A further criterion is the distribution of these neighbor pairs along the cycle.

Why quints are near to each other harmonically?

The naïve expectation would be that frequencies near to each other (using half-note as unit) are close to each other. This is not true. Their simultaneous presence is experienced as dissonance. This probably has a neurophysiological correlate: in ear the hair cell groups detecting notes which are near to each other in frequency space are overlapping. This explanation does not however tell why the conscious experience is dissonance.

The distance measure for notes could be formulated in terms of distance defined as the number of quints connecting them. For quint the distance would be minimal. This measure applies also to chords and allows to understand the basic rule of classical harmony stating that harmonic transitions take place the chords related by quint shift of the basic note (adding either one $\sharp$ or one $\flat$ to the scale). Also the key changes can be understood using the same rule: consider the changes C$\rightarrow$ G and C$\rightarrow$F as examples. Note that in this case the chords have common note.

One could of course question the assumption that it is possible to choose the shortest route. The notes obtained by quint scaling are not quite same in the two directions and means that $\sharp$ is the inverse of $\flat$ in well tempered scale only. Could it be that people with absolute ear are able to distinguish between the two slightly differing scales and experience notes of quint C-G as harmonically close when 1 quint connects them but as harmonically distant 11 quints in opposite direction connects them?

If cognition is p-adic, one can ask whether the notion of harmony can be formulated in terms of p-adic distance concept.

1. By octave equivalence the scaling by power of two means nothing so that the scalings by $3/2$ are equivalent with scalings by 3 and the distance defined by 3-adic norm having values 3^k, where k is the number of quints makes sense. The distance defined as quints could be identified the absolute value of k along the quint cycle in the direction in which the distance is shorter. If so, the maximal distance is 6 units.

2. 3-adic measure of distance seems to be rather realistic. Quint corresponds to 1 unit distance. Half step corresponds to a distance of 5 units and 6 units defines the largest distance and corresponds to the tritonus interval which was forbidden by catholic church. Fourth (C-F) corresponds to 1- step in opposite direction and 11 steps in standard direction.

3. There is also a problem. Second (C-D) corresponds to 3 quints but third (C-E) corresponds to 4 quints and small third to 3 quints in opposite direction. Major third would thus correspond to a longer harmonic distance than second. This is a genuine problem, whose solution might be provided by the extension of icosahedral scale to icosatetrahedral one bringing in one additional note which is very near to one of the icosahedral notes and is major or minor third of icosahedral note.

4. Could one use the number of icosahedral edges as distance between notes but not as a minimal distance along the Hamiltonian cycle but along a minimal edge path along icosahedron? The icosahedral measure of distance would be analogous to a distance between points of object along shortest route in space that it inhabits and depends on harmony characterized by the shape of icosahedral cycle. C and E (and also C and $F\sharp$!) could be close to each other in some harmony and distant from each other in some other harmony. Icosahedral geometry would become an active determinant of the harmony.

To sum up, music seems to have both 2-adic (octave equivalence) and 3-adic (12-note scale by quint scalings) characters. The principle of tonal unity for classical music stating that modulations of key should not lead too many quints away from the basic chord would have 3-adic interpretation.

What could be the rules for building a harmony?

What guarantees good harmony when one has fixed the key/harmony/representation of particular Hamilton cycle?

1. One should pose conditions on the allowed transitions between chords. Are there principles would imply harmonic smoothness in geometric sense? Could the transitions occur only between chords with a common note? Or can one require a common pair of notes? Or can one require even a common quint. If so, 0-quint chords would become tonal hermits and could not be used at all. In practice their dissonant character has eliminated them in popular music and much of classical music too.

   The standard quint and fourth transitions (say C to G and C to F) are basic examples in which there is only one common note between chords, and it seems that one cannot require more than this in the general case. Playing with the chords of bio-harmony however suggests that smooth bossa nova/jazz emotionally ambivalent mood is created if common pair of notes or even quint connects the neighboring chords. The rule is that only transitions between chords with same basic note are allowed. Obviously this is too stringent a condition.

2. Could 2-quint chords act as bridges between two 1-quint chords? For instance, for the maximally symmetric harmony consisting of disjoint groups of chords related by half-octave scaling the augmented chords ($F^{aug} = FAC\sharp$ and G^{aug} mapped to each other both by half-octave scaling and reversal of orientation could serve as mediating bridges.

3. Could harmonic transitions take place only between neighboring faces of icosahedron (see `http://tinyurl.com/ns9aa`) or should it only tend to minimize the quint distance between subsequent chords (this distance vanishes if they have a common note)? For the 0-quint distance harmony, the harmonic movement could be seen as a path in dodecahedron which is dual of icosahedron. In the most general case the transition can take place to both wall and vertex neighbors, whose total number is 3+3=6. In this geometric picture harmony and melody could be seen as duals of each other.

   Dodecahedron is dual of icosahedron and one can ask whether the harmonic motion could correspond to a path at dodecahedron. The vertex of dodecaehdron is pentagon and has 3 neighbours (see `http://tinyurl.com/mp5d8`). The above argument gives $3 + 3 > 3$ neighbors for the triangle of icosahedron. Are the wall neighbors of icosahedral triangle mapped to nearest neighbor vertices? If so then transitions between vertex neighbor triangles should correspond to longer steps at dodecahedron. By the duality triangles of icosahedron correspond to three pentagons associated with the vertex of dodecahedron. The rule that comes in mind is that steps can occur between vertices for which the 3-pentagons have one or 2 common pentagons.

   Note that if the dodecahedral path is Hamiltonian cycle, it is unique apart from isometries of dodecahedron and would define a unique chord progression. One can - and of course must - allow self-intersecting harmonic paths. The condition that there exists a basic chord from which everything begins and to which everything ends implies that closed but in general self-intersecting path is in question.

4. An interesting test for the idea would a computerized generation of random chord sequences satisfying at least one common vertex rule and finding whether they are aesthetically appealing. Incidence matrix (see Appendix) for the icosahedral (and tetra-icosahedral) triangles wholes element tells how many common vertices two chords have have allows computational construction of the allowed chord sequences as random sequences.

5. For most harmonies 0-quint chords involve dissonances induced by three nearby notes (such as $CC\sharp D$) and spanning large number of quints (maximally symmetric harmony has 2 0-quint chords, which do not have dissonances and second harmony with 2 reflection symmetries has no 0-quint chords). Also $\mathrm{maj}7_-$, $sus4_+$, and 6_- 1-quint chords have half-note dissonances. Dissonances as such are however not un-sesthetical. For instance, Bach used them to create a deeply melacholic feeling.

More general notion of harmony

The notion of harmony discussed in previous section is rather conservative and certainly too stringent.

1. 0-quint rule is too restrictive already in chord based music. For instance, the downwards progression Am, G, F, E appearing in Spanish music and music forms like Passacaglia would have chords with 1-quint distance. Hence one must consider also a weaker notion of harmonic chord progression according to which this distance is minimized and below some maximum value k_{max}. One quint would define the smallest non-vanishing maximal distance. One can define incidence matrices for chords with n-quint distance. The incidence matrices with different values of k_{max} have disjoint sets of non-vanishing elements and the total incidence matrix is their sum.

2. Even this is not enough. The direction of step matters for scales (major-minor difference) and it seems to matter also for chord harmonies. The inverse E, F, G, Am of the above mentioned progression does not sound harmonic in the same Am key. The impression of achieving the goal/ending down to something dictated by fate is lost.

   Instead of $EFGA$ one often has $EF\sharp G\sharp A$ as a melodic progression and with $E, B7, E7, Am$ as a chord progression having only 0-quint steps. The rule seems to be that 1-quint steps are possible only downwards in minor harmony, whereas upwards steps are 0-quint steps. Climbing slowly upwards by 0-quint steps and falling down by 1-quint steps! Could this "gravitational analogy" serve as a metaphor?

   Also the number of n-quint steps between chords matters. The larger this number, the closer the chords are. Two 0-quint steps means that chords have two common notes, 1 0-quint stet that they have single common note. The two 1-quint steps for downwards step $Am - G$ are between 3rd and 1st ($C \to G$) and 5th and 3rd ($E \to H$). For upwards 0-quint steps $E - H7$ 1-quint steps are between 5th and 5th ($H \to F\sharp$) and 1st and 1st ($E \to H$). For $H7 \to E$ the reversals of these steps occur. For $E7 \to Am$ one has 3 1-quint steps: (the reversals 1-quint steps $E \to A$ and $H \to E$ steps and 1 quint step $D \to A$. The laste step seems to be the smallest one in a well-defined sense.

   For G-F step the number of 1-quint steps is one ($C \to C$): same is true for F-E step (A and E).

   Using geometry language, for chords connected by 1-quint step(s) the mutual orientation of corresponding triangles with shape defined by the intervals involved matters since the number of 1-quint steps depends on the orientation.

The notion of chord harmony does not apply as such to polyphonic music with several simultaneous melodies unless on can say that it involves definite chord sequence. One could try to apply the concept of harmony for melody also in this case. The challenge is to guess what harmony for melodies could mean.

1. A conjecture inspired by the genetic code is that the codons defining the allowed melody notes associated with a given chord are in one-one correspondence with the triangles at the orbit of the triangle associated with the chord under the group Z_6, Z_4, or Z_2 characterizing the chord as a counterpart of amino-acid. In table 2.6 the Z_6 orbits are represented as groups of 6 similar chords (2 for 1-quint chords and 1 for 2-quint chords). In table 2.7 for Z_4 chords the groups consist of 4 similar chords and in the tables 2.8 and 2.9 for Z_2 harmony the chord groups consist of 2 similar chords.

2. The first guess is that the union of the notes of these chords could define the chords, whose notes are compatible with chord in the time scale shorter than the duration of the chord. Note that same triangle can appear at orbits of several chords since the orbits of each group span entire icosahedron.

   If the note lasts for a duration of several chords, the notes must be consistent with all the chords involved. The rule would explain why fast chromatic sequences (in the scale of chord duration) sound harmonic but slow chromatic sequences do not.

For melodies in Am key $EFGA$ is rare and does sound harmonic being often replaced with $E, F\sharp, G\sharp, A$. As far as intervals are considered, this is the inversion $D\sharp, F, G, G\sharp$ of $AGFE$ shifted upwards by 5 quints. Could one regard progressions (say Am, G, F, E) breaking the strongest rule for chord harmony as polyphonic progressions satisfying the rules for polyphonic progressions.

To conclude whether the DNA inspired notion of harmonic is realistic, one should understand how the sub-groups Z_n, $n = 6, 4, 2$ of the isometries of the icosahedron and defining the genetic code act on the Hamiltonian cycles.

1. The simplest guess is that these groups are represented as subgroups of Z_{12} (also a subgroup of icosahedral group) representing quint cycle. Z_n generator would shift the basic note of the chord by $12/n$ - that is $2, 3, 6$ quints.

2. Z_n maps chords of same type to chords of same type only if it is a *rotational* symmetry of the harmony. For instance, the action of Z_6 (see **Fig. ??**) on icosahedron allows doublet orbit consisting of $Xaug$ type chords, since Z_3 maps 2 0-quint triangles in the middle of the figure to themselves and reflection group Z_2 permutes them. 6-element orbits consist of either minor or major chords. More generally, the inspection of the cycles shows that the cyclic orbits of triangle under Z_n correspond to the orbits of corresponding subgroups of icosahedral group.

3. Z_2refl maps the shape of the chord to its mirror images and so that the character of the chord can vary along Z_4 orbits. The rules are $(M \leftrightarrow m)$, $(6 \leftrightarrow 7)$). For other chords the character is unaffected.

4. Any subgroup of icosahedral isometry group $A_5 \times Z_2^{refl}$ having 120 elements must map chords to chords (faces to faces). In particular any Z_n) even if it is not a symmetry of a particular harmony. The character of the chord is not preserved and the number of quints can change. Whether these maps have interpretation in terms of music remains unclear.

These considerations forced me to finally realize that the 3 groups Z_6, Z_4, and Z_2 that I had assigned to 20+20+20 DNA codons in the model of the genetic code are nothing but Z_6-, Z_4-, and Z_2-symmetric Hamilton cycles! The numbers of amino-acids associated with various types would be 3+1=4, 5, and 10 (with empty amino-acid included). Tetrahedral extension based on gluing of tetrahedron at triangle corresponding to $X6$ type chord possessed by all Z_2^{refl} type harmonies would give 3 additional real amino-acids giving altogether real 22 amino-acids as required. This has implications.

1. All 11 Hamilton cycles are realized separately as DNA level harmonies. Amino-acid level harmonies would correspond to selection of three Hamiltonian cycles, one for each Z_n.

2. To get something one must give something away. Now one must give up the idea that $(4, 8, 8)$ is special via the corresponding of n-quint property with polarity properties. This is a pity, since just taking this correspondence seriously led to the extension of the icosahedral cycles to tetra-icosahedral ones. Fortunately, the extension itself makes sense for all Hamiltonian cycles.

To understand the action of symmetries one must look how the groups Z_n act on C major chord.

1. Z_2 would induce half-octave shift and map $C = (C, E, G)$ to $F\sharp m = F\sharp, B\flat, D\sharp)$. The assignment of $F\sharp$ -tritonus - with C note sounds strange in the ears of harmonic conservatives.

2. Z_4 would map $C = (C, E, G)$ to $A = (A, C\sharp, E)$, $F\sharp = (F\sharp, B\flat, C\sharp)$ and $D\sharp = D\sharp = (D\sharp, G, B\flat)$. These would span 8 notes since $E, G, B\flat, C\sharp$, appear twice. Note that C, E, G, A are the notes assignable to the tetrahedron in the extension of the scale and pentatonic scale corresponds to C, D, E, G, A. Z^4 orbit does not contain the notes $DFG\sharp H$ but the orbit of G chord does so. The orbit of C chord plus $G7$ chord alone define the notes of C major key.

3. Z_6 would map C and E to the same "impressionistic" 6-note scale consisting of 6 whole notes. Together with the Z_6 image of G one obtains all 12 notes of the scale.

2.7.2 Harmony And Biology

Could harmonic principles be realized in biology?

The basic idea behind icosahedral harmony is connection with biology suggested by the fact that the number of icosahedral basic chords is 20 which is also the number of amino-acids. Actually there are two additional amino-acids and one ends up to an extension of genetic code by attaching to icosahedron a tetrahedron and thus adding one vertex more. The number of DNA codons increases from 60 for icosahedral code to 64 for the real code. The triangle along which icosahedral and tetrahedral amino-acids are attached together corresponds to punct coded by stopping codons. Also the following amusing observation supports the notion of bioharmony. Simple music pieces tend to begin with the basic chord CM or Am. Interestingly, mRNA starts always with a codon coding met which could correspond to $CM = CEG$ for one of the tetrahedral faces (see `http://tinyurl.com/3b9ymnq`)

Could the application of harmonic principles to biology make sense? The triangles of icosa-tetrahedon correspond to amino-acids or DNA codons for the amino-acids coded by 20 codons in question.

1. The strictest rule stating that there must be common edge of Hamiltonian cycle between the amino-acids/DNAs cannot be satisfied since 0-quint amino-acids/DNA codons would be total loners and effectively eliminated from biology.

2. The weaker "common edge or vertex" rule could however make sense. A given codon in the group of 20 codons/amino-acid could be followed only by 3+3 different nearest neighbor similar codons/amino-acids. If the first amino-acid is fixed there would be only 6^N N-amino-acid sequences instead of 20^N sequences. This kind of symmetry would have been probably observed if exact but one can ask whether harmonic pairs could more probable than completely random pairs.

3. A more plausible formulation is obtained by restricting the rule to the level of DNA sequences and generalizing it so that it applies also to transitions between harmonies with different symmetries so that a transition between corresponding amino-acids is induces.

4. An even weaker formulations states that the transitions occur with highest probabilities between codons/amino-acids having shortest quint distance.

A natural conjecture is that evolution favors the generation of harmony even in the very concrete sense that proteins defined by harmonious chord sequences for bio-harmony are emerge as what Darwinist would call the fittest ones.

1. Icosahedral water clusters made from tetrahedra

The obvious questions concern the concrete realization of the icosahedron - or more generally icosahedral symmetries. One should also understood what the attachment of tetrahedron to icosahedron means (note that tetra-icosahedron is not the same thing as icosi-tetrahedron, which is Archimedean (not Platonic) solid (`http://tinyurl.com/6onvry`)). What comes in mind is attachment of an information molecule to the receptor of cell membrane.

Water molecules form icosahedral structures and - what is amazing to me - Plato regarded icosahedron as a symbol of water (`http://tinyurl.com/y7bo9omm4a3378c13bcad793a52213a325db7db0-30.html`)! The page "Water structure and science" of Martin Chaplin gives illustrations about the rather complex icosahedral structures. Icosahedral structures of size 3 nm can be formed from 20 14-molecule tetrahedral water molecule clusters containing 280 water molecules altogether. They can also consists of cyclic pentamers and tricyclo-decamers and also from bi-cyclo-octomers. The 20 tetrahedrons correspond to the faces of the icosahedron and tetra-icosahedron would be formed as tetrahedron is glued to the icosahedron along one of the faces.

The bioharmonies could manifest themselves already in the structure of water molecules. Second - more plausible - option is that they differ only at the level of the magnetic body of the biomolecule. Bio-harmony suggests that 3 radial magnetic flux tubes or flux tube pairs emerge from each water tetrahedron. Hamilton's cycle could be realized as a flux tube connecting the vertices of the icosahedron and assigning the quint cycle to the cyclotron frequencies (magnetic field strengths).

This scenario raises several questions related to the pairings between ordinary DNA/amino-acids, their icosahedral representations, and their representations as dark proton sequences.

Suppose that one takes seriously the idea that genetic code is represented as dark proton sequences with the states of dark protons formed from 3 quarks representing DNA and RNA codons, amino-acids, and even tRNA.

1. How dark proton sequences are realized? Could one regard them as icosahedral bound states of 20 dark protons? Or with a Hamiltonian cycle consisting of penta-quarks and representing dark nuclear string? Could the icosahedral representation as dark nucleus consisting of 20 dark protons and dodecahedral representation as dark nucleus consisting of 12 dark 5-proton states be dual ways to interpret the state or are they different states related duality. Equivalence of the two pictures would require that dark protons are color excited and in an entangled state.

2. Could dark proton sequences correspond to sequences of icosahedrons connected by flux tubes connecting the dark protons assignable to the dark proton states assignable to the faces of the icosahedrons? These dark nuclei would be definitely different from those possibly associated with the Hamiltonian cycle.

3. What about the tetrahedral part of the genetic code in relation to dark protons sequences? What dark proton states could tetrahedral codons and amino-acids correspond? Are they associated with water tetrahedrons representing the faces of the water icosahedron? Note the amusing numerological co-incidence that the vertices of tetrahedron have 3 quarks associated with them and those of icosahedron 5 and that the quint for icosahedral edge is replaced with third for tetrahedral edge.

4. Could the chords correspond to triplets of cyclotron frequencies for quarks associated with the three flux tubes emanating from the each face of the icosahedron? Could the breaking of the rotational symmetry from SO(3) to SO(2) - now actually $Z_3 \subset SO(2)$ - assumed to occur for dark proton states correspond to the reduction forced by the triangular geometry?

5. How DNA -amino-acid correspondence is represented at the level of dark DNA? The correspondence should be realized in terms of magnetic flux tube triplets connecting dark DNA and dark amino-acid and resonance condition would be essential. When the chords at the orbits of Z_n are of same type, different DNAs correspond to the same chord but with different key. When Z_2^{refl} is involved, the two chords at the orbit are not of same type (note the analogy with left and right-handed biomolecules). The only manner to circumvent the problem is to assume that the chord associated with amino-acids magnetic body is that of DNA. Information is not actually lost in translation, it is only transformed to different kind of information perhaps representing correlates of emotions.

6. Could the non-representability of one of the Z_6 codons as amino-acid have an analog?

The fiber space having icosahedron as a base and 3 copies of icosahedron assigned with 3 regions of icosahedron corresponding to Z_n, $n = 6, 4, 2$, defines a formal geometric representation of genetic code. Could this space represented in terms of water icosahedra?

1. Perhaps one should first try to identify the function of water icosahedrons. The first guess is that they serve as local bridges between dark DNA/amino-acid sequences and ordinary DNA/amino-acid sequences. This would suggest that dark proton of dark DNA forms a flux tube connection with the face of water icosahedron dictated by the state of the dark proton: this would take place by flux tube reconnection and cyclotron resonance. Water icosahedron in turn couples with the DNA/amino-acid like DNA conjugate codon with codon so that kind of double helix is formed.

2. What about the pairing of ordinary DNA/amino-acids and water icosahedrons? Water icosahedron has size of about 3 nm. The size of single DNA codon is about 1 nm. Single codon corresponds to a twist of $3\pi/5$=36 degrees, an angle closely related to Golden Mean. If the radius of the helix consisting of water icosahedrons is above some minimal radius which is easy to estimate from an equation for the helix. There are 10 DNAs per $L(151) = 10$ nm

and they correspond to a total twist of $3 \times 2\pi$. Therefore the twist angle is $\Delta\Phi = \pi/5 = 36$ degrees for single codon and corresponds to a distance of $L(151)/10 = 1$ nm). From this one has equation for DNA and icosahedron helices as $z = k\Phi$, $k = h/(6\pi)$, $h = L(151) = 10$ nm (radii are constant). Single codon corresponds to a distance $s = \sqrt{dz^2 + R^2 d\phi^2}\Delta\Phi$ along the water icosahedron helix of radius R accompanying DNA helix. One must have $s \geq L = 3$ nm defining the size of water icosahedron in order to avoid overlap. $\Delta s \geq L = 3$ nm gives the condition $R \geq 10 \times \sqrt{2}/(3\pi)$ nm $\simeq 1.5$ nm.

3. If the representation of genetic code is possible, do the fiber icosahedrons correspond to subsets of faces of the icosahedron itself? Or do they correspond to faces the of icosahedrons in some manner associated with the amino-acid icosahedron. Direct attachment is not possible but association could be achieved by connecting the icosahedrons by flux tubes with the tetrahedron at the ends of flux tubes identified as representation of the same amino-acid. This kind of structure with three icosahedra emanating from a given icosahedron could be iterated and one would obtain a fractal structure representing a binary tree. Could the water icosahedrons organize in this manner to form larger clusters?

What could be the physical correlates of Hamilton cycles representing harmonies?

1. Could Z_6, Z_4 and Z_2 orbits associated with the Hamiltonian cycles be realized even in the structure of water icosahedrons? Could they be realized as structures formed by the water tetrahedra and correspond to three separate regions of these icosahedral structures? Could one assign to each of the three regions of icosahedron icosahedron such that the attached icosahedron decomposes to the orbits associated with that particular region? Could the hierarchy of the icosahedral symmetry breakings have a direct counterpart at the level of the icosahedral structures formed by water molecules? My intuitive feeling is that the answer to these questions is negative.

2. Could Hamiltonian cycles be realized only at the level of dark photons as quint cycles defined by closed flux tube giving rise to dark nucleus, that is in terms of 3-chords formed by dark photons propagating along flux tubes emanating from the icosahedron? If cyclotron frequencies of dark quarks are in question then the magnetic fields associated with the flux tubes would define the notes.

3. The breaking of Z_2^{refl} symmetry is of special interest since it could serve as a prebiotic analog of chiral selection and could relate to dark variant of weak physics with effectively massless weak bosons in nano-scales. This would require dark magnetic body. Half-octave scaling is second broken symmetry and would have also an analog in Z_2^{refl} variant of icosahedron. Note that 256 variants of the bio-harmony are predicted and could be realized for magnetic body naturally. The presence of electric fields at flux tubes is possible and if the electric and magnetic fields are non-orthogonal, U(1) instanton density is non-vanishing and induces parity breaking. Is this breaking associated with Z_2^{refl} only?

2. Clathrin molecules as icosahedral structures

Clathrin (`http://tinyurl.com/y8ho23zf` is a structure appearing at the ends of microtubules and necessary for the transmission of signals between the presynaptic and post-synaptic neurons. Clathrin consists of triskelions - kind of triangular structures with three spiral like legs and having as symmetries the rotational symmetry group Z_3 of equilateral triangle. Clathrins can form hexagonal planar lattices and pentagonal icosahedral lattices consisting of 12 pentagonal faces - the number of vertices of icosahedron. One can associate 3 triskelions with each pentagonal face: this makes $12 \times 3 = 36$ triskelions altogether. One can regard the centers of the 12 faces as vertices of icosahedron and assign to this structure 20 faces, which are triangles formed by 3 pentagons.

If proteins and other molecules attach to the faces of clathrin, one can ask whether each icosahedral triangle of this kind has an address formed by the three notes associated with it and serving as a password: only those molecules, which "know" this password can attach to the face. The realization would be in terms of three U-shaped magnetic flux tubes emerging from the 3 pentagonal faces representing the three notes as frequencies of dark $h_{eff} = n \times h$ cyclotron

photons with ELF frequencies but energies of bio-photons (in visible and UV range). The binding of the molecule to the face triangle would be preceded by reconnection of U-shaped flux tubes of the clathrin and molecule, by a resonant interaction by dark cyclotron photons, and by an h_{eff} reducing phase transition bringing the molecule to the face.

3. Microtubules as music instruments?

It has become clear that microtubules have a central role in biology, neuroscience and perhaps also in consciousness theory and the evidence that they are quantum coherent systems is accumulating. Could music metaphor could help to understand microtubules?

1. Tetra-icosahedron has 13 vertices with the added vertex representing one note- say E- in C-key as note with slightly different frequency to resolve the basic problem of rational number based 12-note scale (12 quints give slightly more that 7 octaves). Intriguingly, microtubules consist of basic structures consisting of 13 tubulins with 2 states defining bit: could these bit sequences define representation for the 3-chords and thus representation of sequence of DNA codons and realization of genetic code.

2. The recent TGD inspired model of microtubules [L10], [K55] was inspired by the findings of the group of Bandyopadhyay (see `http://tinyurl.com/ze366ny`) [J13], [J60] relies on the general vision about bio-communications and control as being based on dark cyclotron photon radiation travelling along magnetic flux tubes.

   These dark photons have a universal energy spectrum in the range of bio-photons (visible and UV) to which they transform as the value of $h_{eff} = n \times h$ reduces to its standard value. Frequencies would span a wide energy range but EEG frequencies would be of special importance since they would also couple to acoustic vibrations. The precise value of the energy scale of cyclotron photons would be determined by the strength of the magnetic field at flux tube.

3. Frequency modulation would be the general manner to code information in living matter: "whale's song" would be a good metaphor for it. This is assumed in the model for cell membrane as generalized Josephson junction: the modulation would be now induced by the variations of generalized Josephson frequency by variations of the membrane potential. Also microtubules have been proposed to base their communications on frequency modulation.

4. The first possibility coming in mind is that the continually varying microtubule length codes for the frequency [L10]. The change of the frequency by say octave would however require quite fast and large variations of microtubule length. Neither does this realization conform with the idea that the state of single tubulin corresponds to frequency. Microtubule length could also code for the length of the music piece represented by the microtubule serving as a music instrument or musician at the bio-molecular level. It would also the number of microtubular units and thus the size of the orchestra consisting of 13-units.

5. Another possibility inspired by the proposal is that magnetic flux tubes form an analog of 3-D grid ideal for communication purposes using 12-note (or actually 13-note) system as a code equivalent with genetic code. Also microtubules would involve three kinds of flux tubes [L10] defining coordinate grid of cylindrical coordinates: longitudinal, radial and those which rotate along the microtubule. Radial flux tubes would be ideal for communication using 13-note system as a realization of genetic code.

6. 13-note system as cyclotron frequency spectrum for given value of h_{eff} would be determined by the spectrum of the magnetic field strengths going transversally through the microtubule and each tubulin would correspond to one particular note represented as magnetic field strength. The system would be highly analogous to the system formed by hair cells in cochlear. Note would indeed characterize single tubulin molecule rather than entire microtubule as required if one wants to code chords using the two tubulin conformations as a bit. Tubulin conformation would determine whether the tubulin serves as a sending/receiving antenna or not.

7. Melody in 12-note system can be interpreted as a discretized version of frequency modulation with frequency being piece-wise constant in time. Obviously the 13 bit sequences defined by tubulin conformations code for the chords of rational 12-note scale involving a representation of one particular note (the third note of the Pythagorean scale) with two slightly different frequencies in order to avoid problems caused by the rational number ratios of frequencies. 13th bit could also serve as a kind of period. Also chords could be coded up to a chord with 13 notes so that microtubules would have quite a high representative power.

   The is an objection against the model.

1. One could argue that a unit consisting of 13 tubulins allows only one octave to be represented. One can of course assume that the magnetic field strengths for subsequent units differ by octave. What makes this interesting is that microtubules allow two variants, called A and B. B type microtubules appear as 13-units since microtubular surface has a gap so that the helical symmetry is broken. For variant A, which is not found in vivo or in vitro, 13-units integrate to form longer helical units. This is assumed in Penrose-Hameroff model and the experimental absence of A type microtubules is one of the basic objections against Penrose-Hameroff hypothesis.

2. The TGD inspired proposal is that A type microtubules corresponds to a critical state having therefore an enhanced symmetry and long range correlations: criticality would explain their experimental absence. The experiments of the group of Bandyopadhyay support that the critical state is induced by a resonant excitation at specific AC frequencies [L10]. Long range correlations would mean enchance helical symmetry - that is fusion of several 13-units to form a longer helical structure. This structure would allow an interpretation as a structure with frequency spectrum of several octaves represented coherently in terms of magnetic field strength: the 10 octave span for hearing would mean the integration of 10 microtubule units meaning length scale of order micrometer assuming that tubulin size is of order 10 nm.

3. If the field strength for subsequent units differ by octave, one can argue that for variant B various octaves play their own music without knowing of each other and thus without coherence. In state A they would play together forming something analogous to orchestra or choir.

   If the octave is same for all 13-units, the phase transition would involve octave scaling of the magnetic field strength at the flux tubes. The flux tube radius should suffer p-adic scaling by an integer number of half-octaves, which makes sense if one accepts p-adic length scale hypothesis. This kind of phase transition have been proposed as candidate for a basic step of energy metabolism since they can store or liberate cyclotron energy as metabolic energy.

4. Microtubules could directly couple with both DNA and clathrin molecules if they represent 12 note system as a resonant system able to receive the radiation with corresponding frequencies. 12-note system and the 3-chord system associated with it could define universal communication code allowing communications between DNA, proteins, and microtubules.

To sum up, 13-note extension of 12-note system could be seen as a realization of the genetic code in terms of frequencies. The existence of kind of realization was obvious from the beginning and I proposed it in the model of microtubules as quantum antennas during the first years of TGD inspired theory of consciousness [K50]. Discovering the precise realization of the proposal has however required time.

Could biology help in the understanding of musical harmony?

One can also ask whether biology could provide ideas about the notion of harmony. Could icosatetrahedral harmony possessing additional 13th note very near to the fourth of basic major chord provide a better view about harmony?

1. The extension of the ideas about harmony to the case of isosatetrahedron is a non-trivial task. If one assumes that the extended Hamiltonian cycle is obtained by deforming tetrahedral Hamiltonian cycle according to the proposal made earlier, one ends up with a problem since

the cycle makes a wedge while making a side track of two steps via the new vertex. The two steps must give one quint so that the new vertex must correspond to either minor or major third of note where it started from (and ended to). This would add to the scale a chord of type CGD a chord of type CEG or $CE\flat G$ (plus two other chords containing major or minor third. Depending on the orientation of the cycle one would obtain major or minor key. The remarkable feature of icosahedral harmonies is that they often lack a unique basic chord. Could it be that the addition of tetrahedron breaks the symmetry and fixes the key?

2. The added third could be slightly different from the icosahedral third and this could allow to resolve the problems due to the fact that quint cycle does not quite close ($(3/2)^12 = 2^7$ does not hold true exactly. The problems can be of course solved by introducing well-tempered scale defined in terms of powers of $2^{1/12}$: for this choices the topologically induced by these scalings is same as that induced by real topology in frequency space. Algebraically this means introduction of an algebraic extension of rationals. The problem is that persons with absolute ear prefer rational number based scale and experience tempered scale as unaesthetic.

The problem with 3-adic distance of notes was already described: the distance is 4 quints for major third (C-E) and 3 quints for minor third ($C - E\flat$). A smaller distance is suggestive for major third.

1. The proposed extension of the scale would break symmetry by bringing a third which is indeed nearest neighbor of the basic note plus two other notes, which are in corners of a *1-quint* triangle in the biological realization. Thus chord CEGandchord containing EG and third note would be introduced.

2. Using the general results one can readily find the possible extensions of harmony if one assumes that both major and parallel minor with same number of $\sharp$s or $\flat$s are obtained. The chord chosen for extension must be CGA, which an be seen as part of $C6$ or $Am7$. If the added vertex corresponds to E one obtains $C = CEG$, $Am = CEA$, and the GEA which is part of $C6/Am7$ as also the lost chord. In amino-acid analog CGA would become "empty" amino-acid, punct, and would be replaced with GEA contained also in C6. One can perform this kind of realization for all 11 harmonies and/or their mirror images. The modification induces symmetry breaking and defines a key which is otherwise not obvious for the icosahedral harmonies. Also half-octave symmetry is broken.

3. One can perform the modification also for the inverted harmony. The transformation to reverted harmony $X \to Y$ corresponds to $X7 \leftrightarrow Y6$ and vice versa so that the presence of $X7$ type chords in harmony guarantees the existence of the required type extension in the reverted harmony. One can of course define extension also using X^7 type chords. This would generate besides CEG two dissonant chords of type $GEE\flat$ and $CEE\flat$.

4. In maximally symmetric harmony (2, 12, 6) with 6-fold rotation symmetry, there are as many as 6 ways to perform this modification so that any note of the 6-note scale spanning "impressionistic" octave can define the key. The key is either F, G, A or $Dm, E, F\sharp m$. The harmony contains however no $X7$ type chords and since the transition to the reverted harmony acts as $X6 \leftrightarrow Y7$, it does not allow a modification generating both major and parallel minor. There are also other harmonies possessing no $X6$ type chords such as $(2, 12, 6)$ and bio-harmony $(4, 8, 8)$ with 2-fold rotational symmetry so that the extension in the simplest form can be performed only for their reversals.

5. For the two harmonies with 4-fold reflection symmetry there are 2 ways to perform the modification and modified chords are related by half-octave shift. With the conventions of Table **??** the modification introduces key which is either A ($F\sharp m$) or $D\sharp$ (Cm) for both harmonies (second one is bio-harmony $(4, 8, 8)$).

About the interpretation of bio-harmonies

1. How ideas about harmony evolved?

A brief summary about the evolution of the notion of bio-harmony is in order.

1. The first guess [L12] was that amino-acids could be understood as chords of icosahedral bio-harmony characterized by 3-tuples (3, 10, 7), where the integers tell the numbers of icosahedral triangles with 0, 1, or 2 edges of the Hamiltonian cycle and identifiable as 3-chords with 0, 1, or 2 quints. The interpretation was that 3 0-quint chords correspond to 3 basic polar amino-acids, 10 1-quint chords to the 10 non-polar amino-acids, and 7 2-quint triangles to the 7 polar and acidic polar amino-acids. It turned out however that (3, 10, 7) does not appear as Hamiltonian cycle although it satisfies the necessary conditions.

2. I introduced also a model of genetic code motivated by the properties of the code table suggesting that 60 DNA codons are grouped into 3 groups of 20 codons. The idea that DNA codons coding for a given amino-acid form an orbit of a subgroup of icosahedral group with order which is not smaller than the number of these DNAs and has the aminocid at it. Three subgroups Z_6, Z_4, and Z_2 would predict 3 amino-acids coded by 6 codons and two amino-acids coded by 1 codon, 5 amino-acids coded by 4 codons, and 10 amino-acids coded by 2 codons. The total number of codons would be $3 \times 6 + 2 + 4 \times 5 + 10 \times 2 = 20 + 20 + 20 = 60$ rather than 64. The number of doublets is 10 instead of 9. Could one Z_2 orbit corresponds to punct coded by two stopping codons? But what about the codon triplet associated with Ile? Something is clearly missing.

   There is also second problem: a really realistic model of genetic code should include also 21st and 22nd amino-acids (Pyl and Sec). Pyl or pyrrolysine is modification of Lys and is basic polar amino-acid so that the number 3 of basic polar amino-acids increases to 4. Contrary to the original naïve extrapolation Sec (selenocystein) is acidic polar rather than non-polar so that the number 2-quint triangles increases from 7 to 8. For the properties of amino-acids see `http://tinyurl.com/y8b7fumq`. The notion of hydrophobicity is discussed at `http://tinyurl.com/9qr8e7q`).

3. The solution of the problems came from the extension of icosahedral code with tetrahedral code bringing 4 additional codons and 3 amino-acids assigned with the external faces of the tetrahedron (Ile, Pyl, and some standard non-polar amino-acid), and increasing the number of stopping codons from 2 to 3. This gives 60+3+1=64 codons but one should code also Pyl and Sec. The solution of the problem would be that stopping codons code also these under some conditions. Are DNA codons or their mRNA counterparts pairing with tRNAs - perhaps their magnetic body - modified somehow?

   For instance, Pyl and Sec could correspond to icosahedral codons before fusion. After fusion they cease to be coded - most naturally because the group orbits containing punct are replaced with those associated with tetrahedron. The 3 ordinary amino-acids represented by tetrahedron are Ile, 1-quint amino-acid and 2-quint amino-acid. As fusion is broken temporarily Pyl and Sec are coded.

4. The geometric correlate for the fusion of the codes is gluing of tetrahedron to icosahedron along one face which corresponds to "empty" face identifiable as punct coded by stopping codons. The icosahedral Hamiltonian cycle (4, 8, 8), which exists as two variants, is extended to (4, 10, 8) with two new amino-acids.

5. The music analogy for the fusion of tetrahedron is symmetry breaking bringing in a definite key by introducing the major and minor chords as 1-quint chord (but with 2-edges since tetrahedral edges correspond to major and minor thirds).

2. Understanding the misunderstanding

This was the picture as I started to work again with the notion of bio-harmony. Just when I thought that I understand the notion, I realized that something very essential is missing and even wrong.

1. One could argue that the assumption about the correlation of forms of amino-acid polarity with character of Hamiltonian cycle leading to (4, 4, 8) identification is ad-hoc: why not allow all harmonies? One can also wonder whether the group structure behind the genetic code leading to the identification of sets of DNA codons coding for a given amino-acid as

orbit of the corresponding triangle can be totally dependent on the group structure emerging from the construction of the Hamiltonian cycles.

2. The question whether the group structures associated with genetic code and with the Hamiltonian cycles might have something to do with each other leads to the realization of the obvious: the groups involved are the same: Z_6, Z_4, and Z_2! The symmetries of DNA are the symmetries of cycles. DNA code would be inherent to the Hamiltonian cycles, and the triangles of the icosahedron representing the harmony would correspond to DNA codons! 20+20+20 icosahedral triangles to 60 genetic codons and 4 icosahedral triangles the remaining 4! The three 20-plets corresponds to 3+1 amino-acids coded by 6 (resp 2) codons, to 5 amino-acids coded by 4 codons, and to 10 amino-acids coded by two codons.

   By direct inspection of the illustrations of the appendix one can indeed convince oneself that the groups in question map chords to chords of same type and one obtains appropriate number of orbits. This of course follows from group theory alone.

3. One must give up the assumption that the integers $n = (n_0, n_1, n_2)$ correspond to the numbers of the basic polar, non-polar, and polar and acidic polar implying that only $n = (4, 4, 8)$ would define bio-harmony. All Hamiltonian cycles with symmetries define bio-harmonies and both Z_2^{rot} and Z_2^{refl} define Z_2 type bio-harmonies assignable to 10 amino-acids coded by 2 codons. This is somewhat frustrating outcome, since just this correspondence served as guideline leading to the extension of the icosahedral code. The extension as such is however independent of this identification and needed in order to get the 4 missing DNA codons and to understand the coding of 21st and 22nd amino-acids Pyl and Sec.

   What do the Hamiltonian triplets n then correspond? Harmonies correlate with moods in music: maybe the serve as mathematical correlates for emotions and moods.

4. Harmonies are not for amino-acids but for DNAs coding them. One can however identify amino-acids as specific triangles the orbits and the chords associated with the amino-acids define much more restricted notion of harmony involving one representative of each basic type of chord. Perhaps the additional chords correspond to modulations of the harmony.

5. The rules of harmony generalize as such to transitions between DNA codons regarded as chords. If chords are near to each other with respect to the distance measured as quints, the transition between the chords respects harmony. One must think that DNA codons form a singular fiber space such that the union of fibers for type n gives the space of 20 amino-acids. The "gauge group" Z_n acting in the fiber is different in the 3 regions of the amino-acid space and the number of elements in the fiber is factor of n actually equal to n for $n \neq 6$ and having values 6 and 2 for $n = 6$. Each choice for the 3 Hamilton cycles of type Z_n, $n = 6, 4, 2$ defines a variant of this fiber space. The distance along the fiber isomorphic to the space of amino-acids is measured as minimal quint distance.

   Note that the DNA codons for two different variants of the fiber space need not define same kind of chord so that also given amino-acid can correspond to several different chords. It is enough that the notes of the chords are specified - as they indeed are. The Z_n, $n = 6, 4, 2$ in turn can correspond to any Hamilton cycle with symmetry Z_n so that for $n = 1, 4, 2$ one can have $1, 2, 3 + 5 = 8$ different fiber spaces. The hierarchy of Fibonacci numbers is involved. A hierarchy of symmetry breakings is highly suggestive and leads to increasingly richer harmonies.

   Z_6 has maximal symmetry but Z_4 is not a subgroup of Z_6 so that only the symmetry breakings $Z_4 \to Z_2^{rot}$ and $Z_4 \to Z_2^{refl}$ can be said to occur. Note that transition between different realizations of the covering space has interpretation as a phase transition and that it could occur at RNA rather than DNA level. These phase transitions need not relate to the biochemistry but to serve as correlates for emotions and moods. Also the degeneracy due to the existence of several DNAs coding given amino-acid could have similar interpretation.

   One can of course play with more stringent scenarios for the transitions between DNAs or RNAs). For instance, the assumption that transitions can occur between chords of same type, leads to contradiction since the $Xaug$ chords of Z_6 harmony do not appear in any other harmony.

In any case, the quint-rule in its various forms is readily testable for DNA sequences.

6. An open question concerns the change of the key. The convention of the illustrations is that 1-2 edge corresponds to C-G quint. Should one allow the DNAs at various sheets of covering space to be in different keys? Change of the key could be identified as a rotation by some number of quints. It would change the graph representing icosahedron and change the chords. Z_{12} would allow to realize all keys. Z_{12} is not however a subgroup of the icosahedral isometries (whereas $Z_6 = Z_3 \times Z_2^{rot}$ is) so that the transformation should be interpreted as a translation in quint space acting as coordinate transformation.

   The active transformations induced by isometries of icosahedron do not change the graph and would map chords to new ones. The action of Z_6 is well-defined also for other harmonies than Z_6 symmetric ones. Could the modulations of the basic key correspond to Z_6 transformations. If so, one would have 6 keys. Unfortunately, the most common modulation by quint ($G \to G$) would be missing.

   The change of key could correspond also the change of the chords defined by the extension to tetra-icosahedral harmony. One can choose the chord for extension in several ways for Z_2^{rot} and Z_2^{refl} and these choices could define the allowed modulations of the key.

7. What would be the correlates of different keys the level of DNA? An attractive assumption is that notes are realized in terms of dark photons, which could also transform to ordinary sound since living matter is piezo-electric system. The general hypothesis is that dark photons have universal energy spectrum, which is that of bio-photons. Change of key corresponds to a change of frequency scale and would correspond the change of either Planck constant or of magnetic field strength the flux tubes of the magnetic body associated with DNA codon (or amino-acid perhaps). This would mean that 12-note scale would correspond to 12-note scale for the magnetic fields strength to which cyclotron frequency is proportional or equivalently for the thickness of the flux tube since magnetic flux is quantized if monopole fluxes are in question. 12-note scale could mean in biology a standardization of frequencies used.

One must modify the extension of the icosahedral Hamiltonian cycles to tetra-icosahedral ones appropriately.

1. The Z_6 symmetric 20-plet contains 3 6-plets and 1 doublet and the Z_2 symmetric code contains 10 doublets so that here is one 11 DNA doublets in the icosahedral code. "Ordinary" amino-acids have only 9 doublets. The interpretation is that the Z_6 doublet corresponds to ile and the additional ile is coded by tetrahedral codon. The second surplus doublet can be identified as 2 codons coding for punct, "punct". This gives 4+5+ 10 =19 amino-acid if "punct" is counted.

2. What is lacking is one ile, met, trp, plus Pyl and Sec. Also 4 DNA codons are needed. One of them must code ile, one met, one for punct, and one for trp. The tetrahedral codons would thus correspond to orbits of Z_1. This is actually the only possible subgroup since for the choices $Z_n = 2, 3, 4$ the numbers of codons and amino-acids are not correct. This exhausts all DNA codons.

3. The only manner to proceed is to assume that icosahedral and tetrahedral codes can appear also as unfused versions. This would naturally occur for Z_2^{ref} for which all cycles contain $X6$ type chord but can occur also for Z_2^{rot} if the completion is done for the inverse harmony and then mapped to the harmony back. The icosahedral code would be as already described. The "free" tetrahedral codes would correspond to Z_1 and the faces coding punct in the two codes would code for Pyl and Sec. The fusion of the tetrahedral and icosahedral codes codes gives just the ordinary genetic code so that the proposal is consistent with the proposal that dark proton sequences realize genetic code [K31].

4. Note that geometrically this extension means only that the amino-acid sheet of the fiber space is extended by tetrahedral sheet.

The challenge is to construct the covering space of the icosahedron representing amino-acids.

1. The has as a local fiber the orbit under Z_n associated with the amino-acid defining base point. The space of amino-acids decomposes to disjoint regions corresponding to the 20+20-20 DNA codons. Z_n is the analog of gauge group and by symmetry breaking is different from three different regions of amino-acid space. There are $1 \times 2 \times 8 = 16$ variants of this space due to existence of several harmonies for given symmetries. There are actually only three different options for n given by $n = (0, 16, 4)$, $(2, 12, 6,$ and $(4, 8, 8)$.

2. The Z_n orbits of the three disjoint amino-acid regions (containing 3+1=4, 5, resp. 10 amino-acids) intersect each other. The challenge is to choose the representative amino-acids from the orbits of Z_n in such a way that the chosen amino-acids belong to the three disjoint regions. It remains to be proven that this is possible. One must also understand how uniquely this can be done.

3. One could think of choosing a set P_2 of 10 representatives from the 10 orbits of Z_2 related by 6-quint scaling along Hamiltonian cycle. The 3+1+5=9 amino-acids associated with Z_6 and Z_4 would belong to the mirror images $P(S)$ of this 10-element set. $P(S)$ decomposes into set P_6 of 3+1 triangles and set P_4 of 5 triangles and there are 2-element, 4-element and 6-element orbits connecting the elements of the sets P_2, P_4, and P_6.

The following observations lead to a rather detailed and surprisingly simple picture.

1. The key observation is that the construction of the covering space - that is identifications of amino-acids at the orbits of the groups involved - depends only on whether the choice of Z_2 as Z_2^{rot} or Z_2^{refl}! Thus the two codes (ordinary one and code with Pyl and Sec coded by stop codons) are distinguished by different DNA-amino-acid covering spaces. The details of the Hamiltonian cycle do not matter. Only the structures and mutual relationships of the groups $Z_6 = Z_3 \times Z_2^{refl}$, $Z_4 = Z_2^{rot} \times Z_z^{refl}$ and Z_2^{rot} and Z_2^{refl} matter. Furthermore, the actions of the groups Z_2^{rot}, Z_3 and Z_2^{refl} determine also the actions of Z_6 and Z_4. Only Z_2^{rot} and Z_3 are non-commuting actions.

2. One can decompose amino-acids to 10 pairs of Z_2^{ref} orbits and visualize the 20 codons involved as two layers on top of each other such that two on top of each other correspond to the same 2-orbit - 2 boxes on top of each other. The choice of the two layers is not unique since one can permute the members of any vertical box pair.

3. By a suitable choice of the members of vertical box pairs one can arrange that Z_3 and Z_2^{rot} act along the two layers horizontally. Z_2^{rot} orbits divide each layer to 5 pairs of horizontal boxes. One can also permute the vertical pairs horizontally in such a way that the 5+5 Z_2^{rot} orbits correspond to neighboring horizontal boxes along upper and lower layer giving 2+2+2+2+2 decomposition. This still leaves the possibility to permute these 5+5 horizontal pairs defining 4-orbits of Z_4 horizontally with each other.

   Simply by drawing one find that Z_3 orbits divide each layer to 3 triplets and 1 singlet and by a suitable choice Z_3 singlets correspond to the 10th box on the right for both layer. The Z_3 orbits and Z_2^{rot} orbits overlap in such a way that the middle Z_3 orbit contains entire Z_2^{rot} orbit.

4. It is clear how to choose amino-acids from the orbits.

   (a) Consider first the $Z_2 = Z_2^{refl}$ case. The lower layer corresponds to the 10 Z_2^{refl} amino-acids (punct included) coded by 2 codons. One must choose from each Z_4 orbit consisting of a square of 4 boxes one upper box to represent Z_4 amino-acid (ala, val, gly, pro, thr). Each 4-unit contains one free upper box to which one can assign 1 Z_6 amino-acid. One cannot however put two amino-acids on 3-orbit. There are 3+1 Z_6 amino-acids and 5 boxes so that one box remains unused. This must be the case. The used box must belong to either second or third horizontal Z_2^{rot} 2-box: if it were filled, the middle Z_3 3-orbit would contain 2 Z_6 amino-acids and the fiber space-structure would fail.

   Contrary to the original intuition, the unfilled box is *not* at the 2-orbit of Z_6 containing as Ile but at the middle upper 3-orbit, which would contain 2 amino-acids if filled.

4	6	4	6	4		4	6	4	6(2)
2	2	2	2	2	2	2	2	2	2
2	6	2	6	2		2	6	2	6(2)
4	2	4	2	4	2	4	2	4	2

Table 2.4: The representations of the associations of amino-acids to the orbits of of Z_n, $n = 6, 4, 2$ for $Z_2 = Z_2^{refl}$ (upper two rows) and $Z_2 = Z_2^{rot}$ (lower two rows). The integer n in box tells that the amino-acid associated with that box corresponds to Z_n type amino-acid. "(2)" tells that the Z_6 orbit in question consists of 2 codons.

It is associated with one of the 10 amino-acids coded by two codons and is same for both Z_2^{rot} and Z_2^{refl}. One expects that this amino-acid is somehow special: maybe it is punct. Also the corresponding 6-amino-acid (Ser, Arg, or Leu) might be somehow special.

(b) $Z_2 = Z_2^{rot}$ can be treated similarly. The upper row of boxes is filled in the same manner as in the previous case. The horizontal box pairs in the lower row contain one $Z_2 rot$ box and one Z_4 box. The difference to the previous case is that Z_2 boxes are now shared by the both rows: in the previous case they belonged to the lower row.

5. The assignment of amino-acids to the orbits is not unique: for n similar orbits there are n! different assignments. Inside orbit there is also some non-uniqueness.

Table 2.4 represent the two situations graphically.

3. Music and physical correlates of emotions

Peptides are regarded as molecules of emotion and also information and positive/negative coloring of emotions would naturally correlate with the increase/reduction of negentropic resources of the system as negentropy is transferred to or from it away or increases as a whole. Music induces and expresses emotions. Therefore the idea that music in generalized form - say represented by dark photons with ELF frequencies and having energy spectrum in visible and UV energy range of bio-photons- could be the fundamental correlate of emotions and whether tetra-icosahedral music could be in special role (note that one can associated Hamilton's cycles and "music" with any graph).

There are 11 candidates for the icosahedral harmony and its extensions. The candidates have either Z_6 (**Fig. ??**, Z_4 reflection symmetry (**Figs. ??**, **??**), or Z_2 rotation symmetry (**Figs. ??**, **??**, **??**), and Z_2 reflection symmetry (**Figs. ??**, **??**, **??**, **??**, **??**). For the first case Z^2 reflection symmetry and for the second case Z_2 rotation symmetry are represented as as half-octave shift. Second reflection symmetry corresponds geometrically to reflection in horizontal direction. The extension assigns to them definite key and adds to 1-quint chords minor and major chords absent for the icosahedral bio-harmonies. The question is whether one of these harmonies is selected in biology or whether all three can appear and are perhaps realized at the level of magnetic bodies of amino-acids.

The reversal of the harmony differs from the original one and major-minor transformation takes place. Could it be that both "moods" are realized at the level of magnetic body and even serve as the physical correlates of moods and emotions? Could emotions be realized at the level of amino-acid magnetic bodies as phase transitions affecting parts of organism or even entire organisms and in this manner changing the mood. Peptides are regarded as molecules of emotion: could these phase transitions occur only for peptides and other information molecules involving proteins? Could peptides also serve as seeds of these phase transitions? Could even the Hamiltonian cycle be changed for the magnetic body of the entire organism and correspond to some importance two-valued characteristic of emotional profile?

Could orientation reversal relate to time reversal, which in Zero Energy Ontology (ZEO) corresponds to state function at opposite boundary of causal diamond (CD)? This reversal would

occur in volitional acts: the subsequent reduction would not affect the quantum state in positive energy but in TGD framework they affect the state at opposite boundary CD and in this manner give rise to the experience flow of time.

The simplest extension of the harmony in the proposed form requires that harmony possesses X_6 chord. It does not exist for for the candidate with Z_2^{rot} symmetry but for its reversal 4 of them are present as images of $D7, E7$ and $G\sharp 7, B\flat 7$ which are chords of type X^6. One can however map the harmony to its reversal, perform the completion for it, and perform the reversal back to the original harmony. The reversal depends on what note remains invariant in the reversal. One can require that it is the basic note of the chord to itself: with this condition one would obtain $Dm, Em, G\sharp m, B\flat m$ and major keys $C\sharp, F, A, H$. 4 different harmonies would result. Without the restriction the number of harmonies is different and each has different emotional characteristics.

4. Religious myths, music, and biology

These symmetries define a hierarchy of symmetry breakings. This hierarchy has amazing connections with the myths, which I believe to reflect deep facts about consciousness and biology at fundamental level expected if also consciousness is fractal. The story of genesis is a good representative in this respect.

1. The hierarchy of symmetry breakings proceeding from Z_6 down to Z_2^{refl} brings strongly in mind evolution as loss of innocence. For Z_6 one as 4 orbits. One orbit contains 2 triangles (chords, DNA codons assignable to ile). The other orbits correspond to six codons assignable to amino-acids ser, arg, and leu. The chords at the orbits are major chords and 7-chords, and minor chords and 6-chords for the inverse of the harmony.

   There are no dissonant chords in 0-quint sector: dissonances appear only for the remaining groups as 0-quint chords. This is musical representation of paradize. This harmony is based on 6-note scale for the basic notes of the chords and used by impressionistic composers. Amino-acids correspond to selections of preferred chord from each orbit and there are only four different chords: this sub-harmony is very simple. Life in paradize is simple!

2. Next comes an intriguing observation. The number of amino-acids obtained as projections of the icosahedral DNA orbits is 19, not 20. Could it be impossible to have 20 amino-acids as projections of the orbits and that 19 is the maximum number? The reason for 19 is that the number of amino-acid of type Z_6 is $3 + 1 = 4$ rather than 5. Therefore there is one "non-playable" chord - located at some "paradize orbit" -, which does not correspond to any amino-acid.

   The first guess for the non-playable chord is as one of the *aug* type chords (say $CEG\sharp$, which is the last breath in many finnish tangos telling about unhappy love end - it is something between happy CM and sad Am, "raueta" is finnish word for this manner to come to an end: "expire" might be the nearest english counterpart). This chord is located at the 2-chord orbit related to the other chord of the orbit by half-octave shift (chords could be $CEG\sharp$ and $F\sharp B\flat D$), the tritonus denied by church.

   Unfortunately, this identification is not consistent with the argument identifying the amino-acid chords at Z_n orbits (see table 2.4) the non-playable chord must belong to an intersection of 6-orbit and 4-orbit and is not completely unique without further assumptions. It belongs to a 2-orbit of Z_2^{refl}: if it is somehow special, it could belong to the 2-orbit assignable to punct. If the chords at the 2-orbit have basic notes differing by tritonus, the inspection of the Table 2.9 shows that it is possible to find a unique chord pair having this property for all 5 Z_2^{refl} cycles.

   One cannot avoid the associations between non-playable chord and the denied fruit hanging in the tree of good and bad knowledge in the story of Adam and Eve, and its analog in many fairy tales. The non-playable chord also brings in mind the hilarious story of Gödel-Escher-Bach about non-playable record (a truth unprovable in given axiom system).

3. The hierarchy of symmetry breakings leading from Z_6 to Z_2^{refl} encourages one to continue with the biblical analogies. Z^6, Z_4 and Z_2^{rot} cycles have half-octave shift as a symmetry: good and evil do not exist in paradise, but dissonances are already there for Z_4 and Z_2 harmonies

- the evil snake! These states correspond to the consciousness of animals, children, and saints. Note that bio-harmony corresponds to the presence of one sub-harmony of type Z_n, $n = 6, 4, 2$.

4. The banishing from the paradize takes place as Z_2^{refl} symmetric harmony replaces Z_2^{rot} harmony: half-octave shift is not a symmetry anymore, and one can tell between good and evil, and eventually church decides to deny tritonus as a symbol of evil! Paradise is left as icosahedral and tetrahedral code are fused to form the tetra-icosahedral code - the ordinary genetic code leading to the breaking of Z_2^{refl} symmetry.

5. In banishment punct ("empty" amino-acid) as a counterpart of chord shared by tetrahedron and icosahedron emerges and means stopping of the music piece altogether. Death of the sinner! For unfused codes this chord is playable as Sec/Pyl and the music piece is never-ending: life is eternal in paradise! No notion of time, no sin, no death! Amusingly, impressionist music with 6-note scale is music of "now", attempt to catch this moment.

6. Also the holy trinity finds an analog as $Z_6 - Z_4 - Z_2$ trinity of the bio-harmony. Holy Spirit, Father, Son: perhaps in this order. Even more, Z_2^{rot} can be associated with Son in Heaven and $Z_2 refl$ with Son at Earth as ordinary mortal!

5. What do DNAs/amino-acids sound like?

If DNA/amino-acid sequences correspond to chord sequences of tetra-icosahedral harmony, one can ask what they sound like. The best manner to study this question is to build concrete simulations of the DNA/amino-acid sequences.

1. This requires specification of harmony by selecting one Hamiltonian cycle from the cycles belonging to the groups of cycles with Z_n, $n = 6, 4, 2$ symmetry and decomposing amino-acids to 3 groups correspondingly (those coded by 6, 4, and 2 codons). One must include tetrahedral codons and amino-acids.

2. The basic rule of harmony would be the minimization of quint distance between initial and final chords of the transition. One can consider probabilistic versions of this rule or pose strict form of the rules stating in the most stringent form that only transitions with vanishing quint distance (between neighboring triangles) are possible.

3. The transitions between different amino-acid regions would be governed by this rule. Aso the transitions between different variants of the DNA-amino-acid space defined by different choices of the Hamilton cycles would be governed by the same rule

4. The most plausible looking model considers only transitions between DNA codons since DNA sequences induce amino-acid sequences.

Appendix represents an example about randomly generated chord sequence assignable to bio-harmony defined as a composite of 3 harmonies - one from each symmetry type and $Z_2 = Z_2^{refl}$ involving tetra-icosahedral extension. Anyone having garage band skills in guitar playing can check what these chord sequences sound like and maybe try to build a melody on the background. One could also test the proposal that codons at the orbit of amino-acid define the melody by finding a concrete representation for the orbits and building random melodies defined by DNA sequences coding for the chord sequence.

Magnetic body, bio-harmonies, morphogenesis, and epigenetics

What TGD can possibly give to biology is the vision about magnetic body as an intentional agent using biological body as a sensory receptor and motor instrument and about various mechanism used by magnetic body for control and communication purposes. A new element is brought in by Zero Energy Ontology: magnetic body is 4-dimensional and thus correlate for a behavioral pattern rather than 3-D state for part of organism. Also the notion of bio-harmony suggests itself as a correlate for quantum coherence at the level of basic bio-molecules. The discussion below raises and tries to answer general questions.

The finding that behavioral patterns of planaria can be remembered also by the piece of split planaria without the brain is consistent with the idea that replication of magnetic body coding for behaviors is behind biochemical replication. That alleles of the same gene have different expression could be understood if the bio-harmony assignable to gene carries additional information besides the biochemical information. An alternative explanation is that emotional memories associated with conditioning are realized at the level of the body of planaria.

These notions might also provide a fresh approach to epigenetics. Histone modification and DNA methylation are believed to induce kind of geometric locking preventing transcription. They could also affect the frequency assignable to DNA codon or some key unit so that the resonance condition making possible reconnection of U-shaped flux tubes allowing biomolecules to get in contact fails and transcription cannot proceed. Epigenetic inheritance could reduce to the inheritance of bio-harmony: the magnetic bodies of cells of offspring get in tune with those of parent. To how high degree magnetic body and bio-harmony are inherited? This becomes the key question.

1. Basic ideas related to magnetic body

Recall first some key ideas of TGD inspired quantum biology.

1. In TGD framework magnetic body extends the pair formed by organism and environment to a kind of holy trinity. Magnetic flux tubes and the realization of genetic code in terms of dark proton sequences has been the key hypothesis. The model for cold fusion [L18] suggests that also more general dark nuclei must be allowed. Dark neutron sequences could correspond to genes separated by dark protons. Dark weak interactions with large value of h_{eff} effectively massless below neuron size scale would play central role and induce large parity breaking effects (chiral selection).

   The chemistry would not be all that matters. DNA-nuclear/cell membrane as topological quantum computer with braided magnetic flux tubes would explain why organisms with virtually identical genomes are so different (we and our ancestors for instance). The hierarchy of magnetic bodies would be responsible for the development of intelligence and for cultural evolution. Flux tubes connecting DNA and mRNA as well as mRNA and tRNA molecules are present but it is difficult to say anything concrete.

2. Ontogeny could be seen as a kind of editing process for the text defined by the DNA. Control of control of... is involved so that situation is very complex. Who performs the editing? Does DNA edit itself and is the editing process defining evolution of genome coded by genome? Or is the editing performed by Darwinian selection at cell level (see `http://tinyurl.com/nd9a9ks`)? Or is the magnetic body the editor using genome also as its tool as TGD would suggest? What is important that in TGD framework self-organization in 4-D sense implied by Zero Energy Ontology replaces ordinary self organization leading to asymptotic spatial patterns and select spatiotemporal patterns as asymptotic behavioral patterns defining various biological functions. The role of magnetic body is central in this process.

3. Magnetic body contains cyclotron Bose-Einstein condensates and cyclotron frequencies determined by the strength of magnetic field would give for DNA and other biomolecules additional characteristics. In TGD based model for musical harmony DNA codons would correspond quite concretely to 3-chords but played using dark photons (also ordinary music represented as sounds could be transformed to dark photon music). If one accepts the icosahedral model of bio-harmonies predicting genetic code correctly, there would be 256 fundamental harmonies characterised by the allowed collection of 3-chords and they would add to the information carried by DNA molecules. I have constructed a program building random sequences of the allowed chords using the additional harmonic rule that two subsequent chords contain at least one common note and this music sounds rather harmonic (albeit boring in absence of any other elements!)

4. Could one distinguish between different states/phases of DNAs, mRNAs, tRNAs, and amino acids in terms of harmony? Could their functioning depend on the harmony? With the inspiration coming from the connection of emotions and musical harmonies I have proposed

that the harmony associated with a gene or organ could correlate with something analogous to an emotional state or mood - maybe micro-mood or microemotion could be the proper notion. Could amino-acids be happy, hilarious, melancholic, sad, depressed? Could one distinguish between different phases of DNA, RNA, tRNA, aminoacid collections characterized by the harmony in turn characterizing the of a cell, organelle, organ, or even organism? tRNA defines the map of the harmony associated with DNA codons to amino-acid harmony. Is the information about DNA codon and about corresponding 3-chord represented at the level of magnetic body of amino-acid- that is as the 3-chord, which it represents, and realized as the rules telling with which tRNAs amino-acid can reconnect?

In contrast to DNA codons, which represent local information, harmony could represent holistic information and characterize entire genes or their intronic portions.

2. Problem

There is however a problem. DNA codons coding for the same amino-acid correspond to different 3-chords of harmony. One of these chords corresponds to amino-acid itself and the codons coding for amino-acid correspond to the orbit of this chord under subgroup of isometries of icosahedron moving the triangles of icosahedron along the orbit. This would apply also to mRNA and maybe also to tRNA. The chords at the orbit of amino-acid are isomorphic (intervals are same) and obtained as transposes of each other.

The chords are isomorphic but not identical and this leads to the problem with resonance paradigm unless one gives up the idea that amino-acid corresponds to a unique DNA codon and assumes that there is analog of gauge invariance allowing to choose the preferred codon freely.

1. The assumption about preferred DNA codon could be given up if one can choose the preferred DNA codon freely so that also the magnetic bodies of amino-acids are characterized by 3-chords and thus carry information about what DNA codon coded them. This is possible if one has the analog of fiber space structure with DNA codons coding for amino-acid defining the fiber and amino-acids defining the base. This fiber structure with discrete gauge invariance is strongly suggestive and I have proposed it for two decades ago but it seems that it poses strong conditions on the orbits of the subgroups of isometries of icosahedron.

   This condition is very restrictive. Simplifying somewhat: one considers 60 codons decomposing into 20+20+20 codings and each group of 20 codons codes for amino-acids belonging to different groups. There are twenty of them. The 20 triangles of icosahedron correspond to 3 DNA codons each and each of them corresponds to one and only one amino-acid. One has 3 subgroups of isometries corresponding to 20+20+20 decomposition.

   Can one perform a global gauge transformations realized as isometries and moving triangles along the orbits of one of the 3 subgroups involved - say isometry g_1 of G_1? These transformations would move the entire orbits of 2 subgroups involved - call them G_2 and G_3. What happens to the chords of G_2 and G_3: is their character changed completely so that these harmonies would be destroyed? It seems that this cannot work. Should one replace G_2 and G_3 with their automorphs $g_1 G_2 g_1^{-1}$ and $g_1 G_3 g_1^{-1}$. Does this make sense? 3-chords defining give orbit should be invariant under automorphisms of G_i? This does not seem to be a realistic condition.

2. Could different automorphs correspond to different collections of chords physically just as global gauge transformations generate different physical situations? Isometries of groups G_i would therefore define physically different realizations of bio-harmonies such that for each of them only one of the DNA codons coding for given amino-acid could actually perform the coding. Ordinary genetic code with many-to-one correspondence would make sense in statistical sense only. If this is true, the cyclotron frequency 3-chord assignable to amino-acid depends on the DNA coding it and implies physical distinctions.

3. One can consider also a third alternative. DNA codon with same 3-chord as coding for amino-acid is in special role in that only it can resonate with the amino-acid! Could DNA codons codons correspond to same cyclotron frequency triplet (magnetic fields) but different value of h_{eff} so that one would have chord with respect to energy rather than frequency.

Different values of h_{eff} for DNA codons coding for the same amino-acid would scale their cyclotron frequencies to the same amino-acid frequency while keeping cyclotron energies invariant? Cyclotron energy ratios for codons correspond to rational valued ratios $E_i/E_j = h_{eff}(i)/h_{eff}(j) = n(i)/n(j)$. Amino-acid would correspond to fixed h_{eff} and this creates a problem: can DNA codon code for amino-acid with different value of h_{eff}. This option does not look attractive.

Second option looks most plausible. Of course, it is early to talk about a prediction: it might well be that I have mis-understood something.

3. Questions about bio-harmony

One can pose a lot of questions about bio-harmony.

1. It is not necessary to assign any interpretation on the harmony. Just the harmony could be enough if it is forced to be same for DNA, corresponding mRNA, tRNA, and aminoacids. One can however make questions. Is the harmony inherited invariant and could it distinguish between different personality types about which we learned in old books of psychology? Or could the harmonies correlate with our own moods?

2. Could differentiation selecting particular genes as expressed genes apply also to harmonies so that given gene would correspond only to a particular harmony and different copies of gene could correspond to different harmonies. Could this selection rely on the same mechanisms as ordinary differentiation realized in terms of epigenetic mechanisms and DNA editing? From the magnetic bodies of genes the harmony would be automatically transferred to the magnetic bodies of mRNA, tRNA and aminoacids since otherwise the transcription and translation do not work since magnetic bodies do not have common resonance frequencies and reconnection and resonant interaction is not possible.

3. Does given harmony characterize given gene or the entire cell? All basic biomolecules associated with a gene would naturally correspond to the same harmony. If the rRNAs associated with ribosomes are in harmony mutually cellular harmony seems to be the only option. If ribosomes have their own harmonies, only certain ribosomes can translate given gene. This would bring in additional control tool. The most plausible picture is that the situation depends on what happens in the self-organization process. Some organs/organisms are more harmonious, others not so harmonious. Harmony need not be given fixed to remain the same: magnetic body can have motor actions changing the cyclotron frequencies. Moods could reflect the character of harmony at gene level.

4. Does magnetic body control the differentiation by posing restrictions on gene expression or vice versa? The idea about magnetic body as intentional agent suggests that the first option is correct. There would be hierarchy of magnetic bodies with magnetic bodies at the higher level controlling bodies at the lower level. The value of Planck constant would label the hierarchy levels and also DNA codons would be characterized by "intelligence quotient" defined by h_{eff}/h. This would be nothing but the analog for the hierarchy of program modules and I have earlier considered the realization of this hierarchy [L21].

5. The selection of harmony could take place and be analogous to cell differentiation. This would be a self-organization process in which magnetic bodies of genes, cells, etc.. tune themselves to resonance with each other by modifying their magnetic fields by controlling their thickness (for monopoles flux the flux is invariant). Something analogous to the development of social skills. This could pose resonance as a constraint on processes like replication, transcription, reverse transcription, silencing, enhancing, editing, etc.... It might induce the differentiation at gene level.

   Editing processes for genome could be seen as being induced by the motor actions of the magnetic body involving reconnection and change of the value of h_{eff} changing the length of the flux tube and bringing biomolecules near to each other or separating them. This selection would also apply to the intronic part of DNA proposed to be responsible for topological quantum computation like processes. The copies of same fragment appearing in intronic portion and copies of genes could correspond to different harmonies.

4. Can the notions of magnetic body and bio-harmony explain something that ordinary genetic cannot?

It would be nice to identify some biological phenomenon difficult to understand in standard framework but having an elegant explanation in terms of magnetic body.

1. The notion of harmony could manifest itself at the level of genes as different expressions for the copies of same gene if they correspond to different notions of harmony. The copies of gene are known as alleles (see `http://tinyurl.com/bpee49t`). The alleles can indeed give rise to different phenotypic traits such as different pigmentation.

2. Morphogenesis provides examples of this kind of phenomena [I21, I22, I31]. The first key idea is that DNA and cell replication is induced by the replication of magnetic bodies serving as information carriers [K55]. The second key idea is that in zero energy ontology (ZEO) magnetic body is 4-dimensional and represents behavioral patterns rather than only 3-dimensional patterns. For instance, memory as behavioral patterns can be inherited by the piece of planaria worm not containing the brain. The explanation could be that the magnetic body carries behavioral patterns replicated in the splitting of the worm.

3. Epigenetics (see `http://tinyurl.com/4xpwcm`) studies changes of gene expression not caused by the change of DNA itself. Epigenome (see `http://tinyurl.com/y9xkfb2u`) is the highly dynamic part of DNA controlling expression of the rather stable part of genome. One might regard stable part of genome as hardware and epigenome as topological quantum computer programs assignable to magnetic body and modifying gene expression epigenetically. Comment sign in computer code serves as a computer scientific metaphor for epigenetic control by repression.

The modelling of epigenesis in terms of magnetic body and bio-harmonies deserves a separate discussion.

1. The modification of transcription rate is the basic tool of epigenetic regulation. There are two basic mechanisms involved. Histone modification (see `http://tinyurl.com/y8ywse5v` affects the histones of chromatin so that the transcription is repressed or activated. Histone modification takes place by several mechanisms. DNA methylation occurs for CpG pair and if it occurs for a promoter region it represses the transcription and serves as a kind of gene lock. The degree of methylation serves as a measure for the effectiveness of repression. I do not know whether the locking is absolute at the level of single gene or whether only the transcription rate is reduced. Two mechanisms are mentioned in the Wikipedia article (see `http://tinyurl.com/y9kwrvwx`). Methylation can impede geometrically some step in the transcription. Methylated site can be also accompanied by proteins affecting histones in chromatin and in this manner impede transcription.

2. The notions of magnetic body and bio-harmony suggest an alternative - one might even hope fundamental - mechanism of repression. Methylation (histone modification) could affect some cyclotron frequency associated with DNA codon (histone). In the optimal situation for transcription the DNA and protein catalyzing the transcription or mRNA are in resonance. When cyclotron resonance condition is not exactly satisfied, the reconnection rate for the U-shaped flux tubes associated with the molecules involved in the process is reduced and also transcription is repressed.

   I have considered also the radical possibility that the dynamics at the level of magnetic body is fundamental for biology and that magnetic body defines templates for the bio-molecular self-organization making dark matter dynamics visible. This is probably too extremist view and it would seem that biochemistry affects the cyclotron frequencies assignable to the magnetic body by affecting the strengths of magnetic fields also at dark magnetic flux tubes.

3. The notions of epigenetic code (see `http://tinyurl.com/y8ztzzza`) and histone code (see `http://tinyurl.com/y854w58p`) have been proposed. Epigenetic code would consist of histone modifications and additional modifications such as DNA methylation. The codeword of the epigenetic code could code for some larger unit than protein: say gene or entire cell.

The hypothesis is that the chromatin-DNA interactions are induced by histone tail modifications (such as methylation, acetylation, ADP-ribosylation, ubiquitination, citrullination, and phosphorylation). There are 4 histones and the position of modification varies as well as the modifier (the above modifications are not the only ones) so so that the number of modifications is very large.

The addition of bioharmonies to the genetic information could simplify the situation dramatically since the modifications could be seen as defining of of the 256 bio-harmonies with 64 chords each (this for fixed scale which varies if the value of magnetic field strength is varied: biophoton spectrum in visible is proposed to represent the range of values of magnetic field). The most plausible starting hypothesis is that given harmony characterizes the gene. Much simpler option would be that the harmony characterizes entire cell or even group of cells.

If the modification by kicking cyclotron frequency out of harmony is enough to repress transcription, almost endless number of bio-chemical ways to achieve would exist but the epigenetic code could be very simple at the basic level as TGD would predict. Each bioharmony [L9] [K58] would provide a representation of genetic code in terms of 3-chords predicting correctly the DNA-amino-acid correspondence (there are actually two slightly differing codes explaining the presence of 21st and 22nd amino-acid and deviations from the standard code). The states of dark protons (or neutrons) are also proposed to realize genetic code [K44, K31]: it is an open question whether these codes imply each other as they should.

4. The understanding of transgenerational epigenetic inheritance (see `http://tinyurl.com/h6qg64c`) raises difficult challenges. One should understand how histone modification and DNA methylation are transferred to daughter cells in cellular division or inherited by the offspring. Transgenerational interaction of the genomes seems necessary. In TGD framework the interaction of magnetic bodies of via resonance mechanism could transfer the epigenetic programs to the offspring. Offspring could "learn" the epigenetic programs of the mother by tuning.

5. Gregory Carey (see `http://tinyurl.com/ydyznsaq`) gives nice real life examples about the complexities of epigenesis identified quite generally as gene regulation (see `http://tinyurl.com/zb97cgs`). He compares the gene regulation involved with the handling of a stressful situation to "nightmarish Rube Goldberg mousetrap" and sees the process as extremely ineffective from engineering point of view. For instance, the hormones secreted to blood circulation are distributed to the entire body. The whole thing could be carried out in brain! He also wonders why evolution is so inefficient. All cells have same genome although most of the genes are silenced. Second strand of DNA is totally un-used and most of DNA consists of introns. His explanation is that evolution does not make long term plans but finds just a solution to a particular without thinking it from a wider perspective: "If it ain't broke, don't fix it".

   I tend to see this differently. If entire body is coherent quantum entity, engineering based thinking does not make sense. Entire body and also magnetic body must be informed from the stress situation since the reaction is holistic. The genes which are not used for gene expression might be used for other purposes. Topological quantum computation could be this purpose in TGD framework and repressed genes could be thus used for quantum information processing. Information processing could be actually the dominating function of the DNA of higher vertebrates.

To sum up, magnetic body could be seen as the "boss" controlling the gene expression and also the evolution of genome in longer scales. Magnetic body would use bio-molecular mechanisms for its purposes. This would bring in a new kind of inheritance: bio-harmony would be inherited. The most spectacular almost-prediction would be that genetic code is many-to-one only in statistical sense.

5. RNA is transferred between soma cells and germ cells

The basic question of epigenesis is how the information between soma cells and germ cells is transferred. In standard genetic the transfoer RNA or DNA molecules is necessary to achieve this. In TGD dark DNA, RNA, tRNA, and aminocids consisting of dark nucleons realized as nuclear

strings and accompanied by the corresponding biomolecules is one possibility. The extremist view would be that the dynamics of the dark variants of basic bio-molecules induces the dynamics of their molecular shadows making them only visible. Also the transfer of information as cyclotron radiation can be considered in TGD framework and cyclotron resonance could serve as a fundamental mechanism of epigenetic control. The above model suggest that epigenetic control mechanisms rely on resonance mechanism for 3-chords associated with DNA codons and other biomolecules giving them "names" is also at work besides purely geometrical silencing.

The popular article "No Sex Required: Body Cells Transfer Genetic Info Directly Into Sperm Cells, Amazing Study Finds" (see `http://tinyurl.com/hhdth5j`) summarizing the findings discussed in the article [I10] (see "Soma-to-Germline Transmission of RNA in Mice Xenografted with Human Tumour Cells: Possible Transport by Exosomes" (see `http://tinyurl.com/yde7wb55`) as very interesting concerning this basic question.

The abstract of the article gives for a professional a readable summary.

Mendelian laws provide the universal founding paradigm for the mechanism of genetic inheritance through which characters are segregated and assorted. In recent years, however, parallel with the rapid growth of epigenetic studies, cases of inheritance deviating from Mendelian patterns have emerged. Growing studies underscore phenotypic variations and increased risk of pathologies that are transgenerationally inherited in a non-Mendelian fashion in the absence of any classically identifiable mutation or predisposing genetic lesion in the genome of individuals who develop the disease. Non-Mendelian inheritance is most often transmitted through the germline in consequence of primary events occurring in somatic cells, implying soma-to-germ line transmission of information. While studies of sperm cells suggest that epigenetic variations can potentially underlie phenotypic alterations across generations, no instance of transmission of DNA- or RNA-mediated information from somatic to germ cells has been reported as yet.

To address these issues, we have now generated a mouse model xenografted with human melanoma cells stably expressing EGFP-encoding plasmid. We find that EGFP RNA is released from the xenografted human cells into the bloodstream and eventually in spermatozoa of the mice. Tumor-released EGFP RNA is associated with an extracellular fraction processed for exosome purification and expressing exosomal markers, in all steps of the process, from the xenografted cancer cells to the spermatozoa of the recipient animals, strongly suggesting that exosomes are the carriers of a flow of information from somatic cells to gametes. Together, these results indicate that somatic RNA is transferred to sperm cells, which can therefore act as the final recipients of somatic cell-derived information.

Some background is needed to understand this rather technical summary.

1. Darwinism has dominated biology since Darwin. The rules of classical Mendelian inheritance conform with the Darwinian view and can be reduced to genetic level. Various traits are inherited genetically by sexual reproduction and genome would change during lifetime only through mutations. Genome changes exremely slowly by random changes for offspring from which selection pressures choose the survivors.

   Lamarckian view in turn assumed that the external circumstances experienced by organism leave a trace, which can be inherited but it could not be formulated in terms of modern molecular biology whereas the Darwinian dogma could be formulated in terms of Weissman's genetic barrier. Information flows from germ cells to soma but never in opposite direction. If it would do so, the soma interacting with environment could transfer information to germ cells and the experiences during lifetime could leave inheritable trace to germ cells.

   An analogous dogma is that information is always transcribed from DNA to RNA to proteins but never in opposite direction. It is now known that this takes place in case of viruses and retroviruses: there are so called jumping genes which can also make copies of themselves. 5 per cent of human genome conists of endogenous retroviruses capable of doing the same. The huge genome of maize is due to this kind of proces.

2. The development epigenetics has started to shatter the belief on Wessimann's genetic barrier. Gene expression is not fixed by genome alone and can be change even when genes are unaffected. Silencing of genes by DNA methylation and histone modification allow to modify gene expression. Silencing is essentially a locking of gene preventing its expression by transcription followed by translation.

It is now known that epigenetic changes in the gene expression can be inherited. The mechanisms are still poorly understood. What seems however clear the genome is more like a slowly changing hardware and gene expression or whatever is behind it is the software and programs can change very rapidly by just adding or deleting comment signs in the code. A deeper understanding of this software is needed.

3. Epigenetic inheritance requires that genetic information is transferred from soma cells to germ cells. If only DNA or RNA are capable of representing genetic information, then DNA or RNA must be transferred from soma cells to germ cells. No instance of direct DNA or RNA mediated information from soma to germ cells had been observed before the above mentioned experiments. One can of course challenge the assumption about DNA and RNA as the only representations of genetic information.

The basic idea of the experiment was simple. Use a marker for RNA by using plasmids (DNA strands not belonging to chromosomes) genetically engineered to code for a marker protein making itself visible by fluorescence. Then one just follows the fate of these proteins generated in soma cells and looks whether they end up inside germ cells and how this happens.

More technically: mouse model was xenografted with human melanoma cells stably expessing EGFP-coding plasmid (expressed in a way possibly evoking emotions: human melanoma cancer tissue was implanted in mouse). EGFP-RNA is released from xenografted human cells to blood. One just looks whether it eventually ends up to the sperm cells of mice and tries to identify the transfer mechanism. Only transfer to sperm cells was studied. One might expect that the transfer of RNA can happen also to ovum. I guess that the sperm cells are easier to study.

What was observed?

1. The transfer of RNA from soma cells to sperm cells was indeed found to occur. The transferred RNA can in turn induce epigenetic effects in germ cells known to be inherited by a mechanisms, which however remain poorly understood. Epigenetic mechanisms seem to be involved in the cases considered so that DNA is not changed, only its expression.

2. The transfer mechanism was identified. The transferred RNA is contained by exosomes analogous to synaptic vesicles transferring neurotransmitters from presynaptic to postsynaptic cell. Transfer of RNA takes place via fusion of the membranes just like transfer of neurotransmitters. Maybe genetic engineering using exosomes or analogous structures to transfer the needed material to cells has been tried.

The implications of the findings are dramatic but already implied by the earlier work in epigenetics. What is important that Lamarckian view can be now defended by a concrete genetic mechanism. Lamarckism implies that the time scale of inheritance becomes the time scale for the appearence of a new generation. Nutrition, environment, lifestyle and even meditation and similar practices, are already now known to affect gene expression on daily basis: we are not victims of genetic determinism and are epigenetically responsible for our own well-being. Epigenetic information can be transferred also to germ cells so that we responsible also for the well-being of our children. Our children suffer our sins and share our sufferings.

The precise mechanism of inheritance of epigenetic modifications remains still poorly understood although it seems that the transfer or RNA to germ cells occurs. There are also other hints: it is known that alleles (variants of game gene) can express themselves differently. One allele can also induce other allele to express in the same manner. Somekind of "social pressure" like interaction seems to be involved.

As explained, TGD suggests the notion of magnetic body and cyclotron resonance as this interaction. The DNA of offspring get tuned to the DNA of mother during pregnancy and this gives to epigenetic inheritance. Various epigenetic mechanisms such as methylation and histone modification could affect cyclotron frequencies besides purely geometric modifications of DNA and locking at the level of gene could be accompanied kicking out of tune at the level of magnetic body. In this framework the transfer of RNA to germ cells would be necessary to affect the cyclotron frequencies.

E_8 symmetry, harmony, and genetic code

Bee gave in Facebook a link to an article about a connection between icosahedron and E_8 root system [B11] (see `http://tinyurl.com/zotpm4b`). The article (I have seen an article about the same idea earlier but forgotten it!) is very interesting.

The article talks about a connection between icosahedron and E_8 root system (see `http://tinyurl.com/y7csb6uh`). Icosahedral group has 120 elements and its double covering $2\times120 = 240$ elements. Remarkably, E_8 root system has 240 roots. E_8 Lie algebra is 248 complex-dimensional contains also the 8 commuting generators of Cartan algebra besides roots: it is essential that the fundamental representation of E_8 co-incides with its adjoint representation. The double covering group of icosahedral group acts as the Weyl group E_8. A further crucial point is that the Clifford algebra in dimension $D = 3$ is 8-D.

One starts from the symmetries of 3-D icosahedron and ends up with 4-D root system F_4 assignable to Lie group and also to E_8 root system. E_8 defines a lattice in 8-D Euclidian space: what is intriguing that dimensions 3,4, 8 fundamental in TGD emerge. To me this looks fascinating - the reasons will be explained below.

1. What I might have understood

I try to explain what I have possibly understood.

1. The notion of root system is introduced. The negatives of roots are also roots but not other multiples. Root system is crystallographic if it allows a subset of roots (so called simple roots) such that all roots are expressible as combinations of these simple roots with coefficients having the same sign. Crystallographic root systems are special: they correspond to the fundamental weights of some Lie algebra. In this case the roots can be identified essentially as the quantum numbers of fundamental representations from which all other representations are obtained as tensor products. Root systems allow reflections as symmetries taking root system to itself. This symmetry group is known as Coxeter group and generalizes Weyl group. Both H_3 and H_4 are Coxeter groups but not Weyl groups.

2. 3-D root systems known as Platonic roots systems (A_3, B_3, H_3) assignable to the symmetries of tetrahedron, octahedron (or cube), and icosahedron (or dodecahedron) are constructed. The root systems consist of 3 suitably chosen unit vectors with square equal to 1 (square of reflection equals to one) and the Clifford algebra elements generated by them by standard Clifford algebra product. The resulting set has a structure of discrete group and is generated by reflections in hyper-planes defined by the roots just as Weyl group does. This group acts also on spinors and one obtains a double covering SU(2) of rotation group SO(3) and its discrete subgroups doubling the number of elements. Platonic symmetries correspond to the Coxeter groups for a "Platonic root system" generated by 3 unit vectors defining the basis of 3-D Clifford algebra. H_3 is not associated with any Lie algebra but A_3 and B_3 are.

   Pinors (spinors) correspond to products of arbitrary/even number of Clifford algebra elements. Spinors induced orientation preserving transformations and pinos also orientation reversing ones. They mean something else than usually a bein identified as elements of the Clifford algebra acting and being acted on from left or right by multiplication so that they always behave like spin 1/2 objects since only the left(right)-most spin is counted. The automorphisms involve both right and left multiplication reducing to SO(3) action and see the entire spin of the Clifford algebra element.

3. The 3-D root systems (A_3, B_3, H_3) are shown to allow an extension to 4-D root systems known as (D_4, F_4, H_4) in terms of 3-D spinors. D_4 and F_4 are root systems of Lie algebras (see `http://tinyurl.com/y97dzqc2`). F_4 corresponds to non-simply-laced Lie group related to octonions. H_4 is not a root system of any Lie algebra.

4. The observation that the dimension of Clifford algebra of 3-D space is $2^3 = 8$ and thus allows embedding of at most 8-D root system must have inspired the idea that it might be possible to construct the root system of E_8 in 8-D Clifford algebra from 240 pinors of the double covering the 120 icosahedral reflections. Platonic solids would be behind all exceptional symmetry groups since E_6 and E_7 are subgroups of E_8 and the construction should give their root systems also as low-dimensional root systems.

2. McKay correspondence

The article explains also McKay correspondence stating that the finite subgroups of rotation group SU(2) correspond to simply laced affine algebras assignable with ADE Lie groups.

1. One considers the irreducible representations of a finite subgroup of the rotation group. Let the number of non-trivial representations be m so that by counting also the trivial representation one has $m+1$ irreps altogether. In the Dynkin diagram of affine algebra of group with m-D Cartan algebra the trivial representation corresponds to the added node. One decomposes the tensor product of given irrep with the spin 2 representation into direct sum of irreps and constructs a diagram in which the node associated with the irrep is connected to those nodes for which corresponding representation appears in the direct sum. One can say that going between the connected nodes corresponds to forming a tensor product with the fundamental representation. It would be interesting to know what happens if one constructs analogous diagrams by considering finite subgroups of arbitrary Lie group and forming tensor products with the fundamental representation.

2. The surprising outcome is that the resulting diagram corresponds to a Dynkin diagram of affine (Kac-Moody) algebra of ADE group with Cartan algebra, whose dimension is m. Cartan algebra elements correspond to tensor powers of fundamental representation: can one build any physical picture from this? For $m = 6, 7, 8$ one obtains E_6 , E_7 , E_8. The result of the article implies that these 3 Lie-groups correspond to basis of 3 3-D unit identified as units of Clifford algebra: could this identification have some concrete meaning as preferred non-orthogonal 3-basis?

3. McKay correspondence emerges also for inclusions of hyper-finite factors of type II_1 [K83] The integer m characterizing the index of inclusion corresponds to the dimensions of Cartan algebra for ADE type Lie group. The inclusions of hyperfinite factors (HFFs) are characterized by integer $m \geq 3$ giving the dimension of Cartan algebra of ADE Lie groups (there are also C, F and G type Lie groups). $m = 6, 7, 8$ corresponds to exceptional groups E_6 , E_7 , E_8 on one hand and to the discrete symmetry groups of tetrahedron, octahedron, icosahedron on the other hand acting as symmetries of corresponding 3-D non-crystallographic systems and not allowing interpretation as Weyl group of Lie group.

3. Connection with the TGD based model of harmony

These findings become really exciting from TGD point of view when one recalls that the model for bioharmony [K58] [L9] (see `http://tinyurl.com/yad4tqwl`) for 12-note harmonies central in classical music in general relies on icosahedral geometry. Bioharmonies would add something to the information content of the genetic code: DNA codons consisting of 3 letters A,T,C,G would correspond to 3-chords defining given harmony realized as dark photon 3-chords and maybe also in terms of ordinary audible 3-chords. This kind of harmonies would be roughly triplets of 3 basic harmonies and there would be 256 of them (the number depends on counting criteria). The harmonies could serve as correlates for moods and emotional states in very general sense: even biomolecules could have "moods". This new information should be seen in biology. For instance, different alleles of same gene are known to have different phenotypes: could they correspond to different harmonies? In epigenetics the harmonies could serve as a central notion and allow to realize the conjectured epigenetic code and histone code. Magnetic body and dark matter at them would be of course the essential additional element.

The inspiring observations are that icosahedron has 12 vertices - the number of notes in 12-note harmony and 20 faces- the number of amino-acids and that DNA codons consist of three letters - the notes of 3-chord.

1. Given harmony would be defined by a particular representation of Pythagorean 12-note scale represented as self-non-intersecting path (Hamiltonian cycle) connecting the neighboring vertices of icosahedron and going through all 12 vertices. One assumes that neighboring vertices differ by one quint (frequency scaling by factor 3/2): quint scale indeed gives full octave when one projects to the basic octave. One obtains several realizations (in the sense of not being related by isometry of icosahedron) of 12-note scale. These realizations are

characterized by symmetry groups mapping the chords of harmony to chords of the same harmony. These symmetry groups are subgroups of the icosahedral group: Z_6, Z_4, and two variants of Z_2 (generated by rotation of π and by reflection) appear. Each Hamiltonian cycle defines a particular notion of harmony with allowed 3-chords identified by the 20 triangles of icosahedron.

2. Pythagoras is trying to whisper me an unpleasant message: the quint cycle does not quite close! This is true. Musicologists have been suffering for two millenia of this problem. One must introduce 13th note differing only slightly from some note in the quint cycle. At geometrical level one must introduce tetrahedron besides icosahedron - only four notes and four chords and gluing along one side to icosahedron gives only one note more. One can keep tetrahedron also as disjoint from icosahedron as it turns out: this would give 4-note harmony with 4 chords something much simpler that 12- note harmony.

3. The really astonishing discovery was that one can understand genetic code in this framework. First one takes three different types of 20-chord harmonies with group Z_6, Z_4, and Z_2 defined by Hamiltonian cycles: this can be done in many different maners (there are 256 of them). One has 20+20+20 chords and one finds that they correspond nicely to 20+20+20=60 DNA codons: DNA codons coding for a given amino-acid correspond to the orbit of the triangle assigned with the amino-acid under the symmetry group of harmony in question.

   The problem is that there are 64 codons, not 60. The introduction of tetrahedron brings however 4 additional codons and gives 64 codons altogether. One can map the resulting 64 chord harmony to icosahedron with 20 triangles (aminoacids) and the degeneracies (number of DNA codons coding for given amino-acid in vertebrate code) come out correctly! Even the two additional troublesome amino-acids Pyl and Sec appearing in Nature and the presence of two variants of genetic code (relating to two kinds of Z_2 subgroups) can be understood.

4. What could the interpretation of the icosahedral symmetry?

An open problem is the proper interpretation of the icosahedral symmetry.

1. A reasonable looking guess would be that it quite concretely corresponds to a symmetry of some biomolecule: both icosahedral or dodecahedral geometry give rise to icosahedral symmetry. There are a lot of biomolecules with icosahedral symmetry, such as clathrate molecules at the axonal ends and viruses. Note that dodecahedral scale has 20 notes - this might make sense for Eastern harmonies - and 12 chords and there is only single dodecahedral Hamiltonian path found already by Hamilton and thus only single harmony. Duality between East and West might exist if there is mapping of icosahedral notes and to dodecahedral 5-chords and dodecahedral notes to icosahedral 3-chords and different notions of harmony are mapped to different notions of melody - whatever the latter might mean!).

2. A more abstract approach tries to combine the above described pieces of wisdom together. The dynamical gauge group E_8 (or Kac-Moody group) emerging for m=8 inclusion of HFFs is closely related to the inclusions for the fractal hierarchy of isomorphic sub-algebras of super-symplectic subalgebra. $h_{eff}/h = n$ could label the sub-algebras: the conformal weights of sub-algebra are be n-multiples of those of the entire algebra.

   The integers n_i resp. n_f for included resp. including super conformal sub-algebra would be naturally related by $n_f = m \times n_i$. $m = 8$ would correspond to icosahedral inclusion and E_8 would be the dynamical gauge group characterizing dark gauge degrees of freedom. The inclusion hierarchy would allow to realize all ADE groups as dynamical gauge groups or more plausibly, as Kac-Moody type symmetry groups associated with dark matter and characterizing the degrees of freedom allowed by finite measurement resolution.

3. E_8 as dynamical gauge group or Kac-Moody group would result from the super-symplectic group by dividing it with its subgroup representing degrees of freedom below measurement resolution. E_8 could be the symmetry group of dark living matter. Bioharmonies as products of three fundamental harmonies could relate directly to the hierarchies of Planck constants and various generalized super-conformal symmetries of TGD! This convergence of totally different theory threads would be really nice!

5. Experimental indications for dynamical E_8 symmetry

Lubos (see `http://tinyurl.com/htjp55h`) (thanks to Ulla for the link to the posting of Lubos) has written posting about experimental finding of E_8 symmetry emerging near the quantum critical point of Ising chain at quantum criticality at zero temperature. Here is the abstract (see `http://tinyurl.com/zulzk9y`):

Quantum phase transitions take place between distinct phases of matter at zero temperature. Near the transition point, exotic quantum symmetries can emerge that govern the excitation spectrum of the system. A symmetry described by the E_8 Lie group with a spectrum of eight particles was long predicted to appear near the critical point of an Ising chain. We realize this system experimentally by using strong transverse magnetic fields to tune the quasi–one-dimensional Ising ferromagnet CoNb2O6 (cobalt niobate) through its critical point. Spin excitations are observed to change character from pairs of kinks in the ordered phase to spin-flips in the paramagnetic phase. Just below the critical field, the spin dynamics shows a fine structure with two sharp modes at low energies, in a ratio that approaches the golden mean predicted for the first two meson particles of the E8 spectrum. Our results demonstrate the power of symmetry to describe complex quantum behaviors.

Phase transition leads from ferromagnetic to paramagnetic phase and spin excitations as pairs of kinks are replaced with spin flips (shortest possible pair of kinks and loss of the ferromagnetic order). In attempts to interpret the situation in TGD context, one must however remember that dynamical E_8 is also predicted by standard physics so that one must be cautious in order to not draw too optimistic conclusions.

In TGD framework $h_{eff}/h \geq 1$ phases or phase transitions between them are associated with quantum criticality and it is encouraging that the system discussed is quantum critical and 1-dimensional.

1. The large value of h_{eff} would be associated with dark magnetic body assignable to the magnetic fields accompanying the E_8 "mesons". Zero temperature is not a prerequisite of quantum criticality in TGD framework.

2. One should clarify what quantum criticality exactly means in TGD framework. In positive energy ontology the notion of state becomes fuzzy at criticality. For instance, it is difficult to assign the above described "mesons" with either ferromagnetic or paramagnetic phase since they are most naturally associated with the phase change. Hence Zero Energy Ontology (ZEO) might show its power in the description of (quantum) critical phase transitions.

   Quantum criticality could correspond to zero energy states for which the value of h_{eff} differs at the opposite boundaries of causal diamond (CD). Space-time surface between boundaries of CD would describe the transition classically. If so, then E_8 "mesons" would be genuinely 4-D objects - "transitons" - allowing proper description only in ZEO. This could apply quite generally to the excitations associated with quantum criticality. Living matter is key example of quantum criticality and here "transitons" could be seen as building bricks of behavioral patterns. Maybe it makes sense to speak even about Bose-Einstein condensates of "transitons".

   The finding suggests that quantum criticality is associated with the transition increasing $n_{eff} = h_{eff}/h$ by factor $m = 8$ or its reversal - maybe the standard value $n_{eff}(i) = 1$. $n_{eff}(f) = 8$ could correspond to the ferromagnetic phase having long range correlations. Could one say that at the side of criticality (say the "lower" end of CD) the $n_{eff}(f) = 8$ excitations are pure gauge excitations and thus "below measurement resolution" but become real at the other side of criticality (the "upper" end of CD)?

3. The 8 "mesons" associated with spin excitations naturally correspond to the generators of the Cartan algebra of E_8. If the "mesons" belong to the fundamental (= adjoint) representation of E_8, one would expect 120+120 additional particles with non-vanishing E_8 charges. Why only Cartan algebra? Is the reasons that Cartan algebra is in preferred role in the representations of Kac-Moody algebras in that charged Kac-Moody generators can be constructed from Cartan algebra generators by standard construction used also in string models. Could this explain why one expects only 8 "mesons". Are charged "mesons" labelled by the elements of double covering of icosahedral group more difficult to excite?

2.7.3 Icosahedral Harmonies

In the following the icosahedral harmonies are discussed in detail. This includes overall summary and tables giving the 20 3-chords of the harmonies and illustrations of the Hamiltonian cycles.

About symmetries of the icosahedral harmonies

Some words about the symmetries associated with the icosahedral harmonies and genetic code are in order.

There are 3 different kind of bio-harmonies characterized partially by the symmetry group which can be Z_6, Z_4 or Z_2 which acts either as rotations or reflections.

1. The first variant as $Z_3^{rot} \times Z_2^{refl}$ subgroup of icosahedral group as symmetries and its orbits correspond to 3 6-plets and 1 2-plets for which Z_3 leaves the triangle invariant. The counterparts for the orbits are 3 DNA 6-plets and one 2-plet.

2. The second variant has Z_4 symmetry generated by two commuting reflection as symmetries as is obvious from figures **??**, **??**: the reflections act on vertical and horizontal coordinates. The orbits are five 4-plets of chords. Vertical reflection induces half-octave shift and horizontal one permutes the note sequences $B\flat CDG\sharp F\sharp E$ and $D\sharp C\sharp HFGA$.

3. Z_2^{rot} or Z_2^{refl} acts as symmetries of the remaining 3+5 cycles. The covering space of 10 amino-acids involved defined by 20 DNA codons decomposes to 10 2-plets.

   The 2-fold rotation symmetry of the Hamiltonian cycles is obvious from the illustration **??**: it corresponds to 6-quint rotation and the chord sets must be invariant under this rotation. This rotation corresponds to the 1/2 octave shift realized as rotation. These symmetries are realized as "coordinate transformations" for the cycle - a curve in the "embedding space" defined by icosahedron but induced from the "embedding space symmetries" acting as isometries of icosahedron.

   DNA codons have also almost exact Z_2 symmetry discussed in [K79, K3, **?**].

1. For the last codon the reflection A-T, C-G is an almost symmetry broken only for special cases. This approximate symmetry could be understood as following from the fact that the number of DNAs coding given amino-adic is even in most cases. The exceptions are ile, met, trp coded by odd number of DNA codons. By mapping DNAs to binary sequences one can order the situation so that the 6: th binary digit is the almost-symmetry digit.

2. What is trivial is that RNA has chosen the third bi-digit to be the almost symmetry digit with the ordering UCAG of the nucleotides so that a genuine physical symmetry is in question. An interesting question is how this symmetry relates to the model of genetic code based on tetra-icosahedral orbits.

   The restriction of DNAs to 60 icosahedral DNAs demonstrates that this symmetry originates from the icosahedral Z_2. The tetrahedral extension of the code breaks this symmetry by extending ile and punct multiples by one codon and introducing also 4 singlets met, trp, Pyl, and Sec.

The detailed correspondence between chords of the harmony and DNA codons is also a problem to be solved.

1. The correspondence matters in the proposed scenario since the chords at at the orbits are different and the gluing of tetrahedron breaks the symmetry in Z_2 sectors so that quint rule determining harmonic DNA sequences is different.

2. The common face of tetrahedron and icosahedron corresponds to punct so that the quint rule for different representations says something about the pairs of form codon-stop codon that is about the codon preceding the last codon of gene! This codon could allow to recognize what Hamiltonian cycle is in question. If C-major is one of the added chords, stop codons correspond to what was $C6 = CGA$ chord and its Z_2 image, which is $X7$ type chord. By the strongest form of the quint rule only the chords having common notes with these chords would correspond to DNA codons of Z_6 and Z_4 cycles which can precede stopping codon.

$$\begin{array}{llll} CEG \equiv C\ , & CD\sharp G \equiv Cm\ , & CD\sharp F\sharp \equiv C^o\ , & CEG\sharp \equiv Caug\ , \\ CFG \equiv C4\ , & CF\sharp G \equiv C4_+\ , & CGG\sharp \equiv C6_-\ , & CGA \equiv C6\ , \\ CGB\flat \equiv C7\ , & CGB \equiv Cmaj7\ , & CGC\sharp \equiv C9_-\ , & CGD \equiv C9\ . \end{array} \tag{2.7.1}$$

Table 2.5: Notation of chords inspired by popular music notations.

3. There are some restrictions on the correspondence. Z_2^{refl} symmetry would correspond to the flipping of the 6th bit for the bit representation defined by nucleotides representing 2-bits in the case of $Z^3 = Z_3 \times Z_2^{refl}$. $Z_4 = Z_2^{rot} \times Z_2^{refl}$. For $Z_2 = Z_2^{rot}$ the role of Z_2^{refl} must be taken by Z_2^{rot}. One can of course ask whether Z_2^{rot} cycles are realized at all. For Z_4 cycles Z_2^{rot} would correspond to symmetry permuting the AT, CG doublets for the first nucleotide. For Z_6 subgroup Z_3 would cyclically permute the 3 doublets with respect to third nucleotide. These constraints do not fix the correspondence completely.

To sum up, there is a connection between genetic code and the groups acting along the Hamiltonian cycle. The simplest option fixes the orbits of the triangles and therefore also the representation of genetic code.

Summary of the basic results

One can find the list of Hamiltonian cycles at `http://tinyurl.com/yacgzm9x`. The edge $\{1, 2\}$ is fixed and cycles are oriented so that there are 1024 of them. All of them are relevant from the point of music interpretation and the change of orientation corresponds to major-minor duality, albeit not in the simplest sense. Note that this duality does not affect the characteristics listed above.

The general following general results hold true as one can learn at `http://tinyurl.com/pmghcwd`. One can classify the cycles using their symmetries which can correspond to isometries of icosahedron leaving them fixed or to a reflection taking the vertex n at the cycle to vertex $12 - n$. This symmetry is not same as change of orientation which is purely internal operation and cannot change the cycle.

One can even find images of the cycles possessing symmetries at `http://tinyurl.com/y8ek7ak8` and deduce the triplets n and p characterizing them by visual inspection. Also one can write explicitly the 3-chords defined by the three kinds of faces. I have deduced the triplets n and the 3-chords defining the harmony by the inspection of the images. "Bio-harmony" (4, 8, 8) forced by the model of extended genetic code involving also the 21st and 22nd amino-acids is of special interest.The classes of cycles with symmetries 6-fold rotational symmetry and two distinct reflection symmetries realize it.

Before continuing some terminology and notation is in order. Take C as the major key. Submediant or relative minor corresponds to Am, subdominant (sharp or flat) to F major (F) or Fminor (Fm), dominant to G. The notation for chords is such that quints correspond to subsequent notes in the chord. For 1-quint chords this means that first two notes define the quint. **Table 2.5** the notation inspired by the popular music notation. The basic different is that the third is in most cases excluded so that the emotional character of the chord is not fixed.
Besides these notions it is convenient to introduce additional notations for various dissonant chords appearing as 0-quint chords.

$$\begin{array}{llll} CC\sharp D \equiv Cex1\ , & CC\sharp D\sharp \equiv Cex2\ , & CDD\sharp \equiv Cex3\ , & CDE \equiv Cex4\ , \\ CD\sharp E \equiv Cex5\ , & CC\sharp E \equiv Cex6\ , & CDF\sharp \equiv Cex7\ , & CDG\sharp \equiv Cex8\ . \end{array} \tag{2.7.2}$$

Clearly, the sets {ex1}, {ex2, ex3}, {ex4, ex5, ex6}, {ex7}, {ex8}, corresponds to the span of 2, 3, 4, 6, 8 half notes for the chord. The following summarizes the results. Note that $Cex7$ can be seen as part of $D7$ chord.

1. There are 6 collections of cycles without any symmetries containing 48 cycles each: these 48 cycle are mutually isometric so that one can say that there 6 different harmonies.

2. There is a collection with 6-fold rotational symmetry, 48/6=8 examples. $n = (2, 12, 6)$. The chords of this scale define 6-note scale involving only total steps. CDF and its 6 translates by integer number of steps define 6 1-quint chords. $CE\flat G$ (Cm) and its 6 translates (they obviously correspond to the 6-fold rotational symmetry) define also 6 1-quint chords. The reflection transforms these series to those defined by $GB\flat G$ and its translate and byFAC (F major) and its translates. Impressionists like Debussy used 6-note scale of this kind. Half-octave shift is an exact symmetry. 1-chords lack the third so that one cannot assign to 3-chords any emotional quality. The extension to 4-chord can however bring either "happy" or "sad" quality. Clearly, these harmonies have "jazzy" character.

   0-quint chords are $Faug \equiv FAC\sharp$ and $Gaug \equiv GHD\sharp$ are transformed to each other by both half-octave shift and inversion.

3. There are 2 collections with 2 distinct reflectional symmetries with 12=48/4 representatives in each. Half-octave scaling is a symmetry of both these scales as one might guess.

   The first cycle (see **Fig. ??**) has $n = (0, 16, 4)$ so that there are no 0-quint chords which in general are dissonant. Second cycle (see **Fig. ??**) realizes $n = (4, 8, 8)$ bio-harmony and deserves some comments. It will be discussed in detail later.

   (a) The 8 2-quint chords consist of $B\flat FG \equiv B\flat 9$, C9, F9, G9 and their half-octave scalings. Clearly, the simple four-note scale appears here.

   (b) Using the popular notion introduced earlier 1-quint chords consist of two 4-plets $Dmaj7$, $E9_-$, $A7$, $A6$ and $G\sharp maj7$, $B\flat 9_-$, $D\sharp 7$, $D\sharp 6$ related by half-octave shift. The harmony contains no "simple" major or minor chord and only the extension to tetrahedral harmony can provide them. The same is true for the second bio-harmony.

   (c) The 4 0-quint chords are $Cex3 \equiv CDD\sharp$ and $Eex2 \equiv EFG$ and their half-octave scalings $F\sharp ex3 \equiv F\sharp G\sharp A$ and $B\flat ex2 \equiv B\flat BC\sharp G$.

4. There are 3 collections with Z_2 rotational symmetry with $48/2 = 24$ representatives in each. The triplets n are $(0, 16, 4)$ (see **Fig. ??**), $(2, 12, 6)$ (see **Fig. ??**), and $(4, 8, 8)$ (see **Fig. ??**). All these harmonies are symmetric with respect to half-octave shift (tritonus), which obviously corresponds to the Z_2 rotation. Tritonus would not have been tolerated by catholic church! This symmetry characterizes all 3 harmonies. Basic 3-chords do not contain pure minor and major chords. The reflection of the scale does not leave the collection of chords invariant but it is not clear whether this corresponds only to a change of scale, probably not.

   Consider the (4, 8, 8) case (see **Fig. ??**).

   (a) The 8 2-quint chords appear as four-plet $H9, C\sharp 9, D\sharp 9, F9$ and its half octave shift (tritonus interval) acting as a symmetry of the harmony. 2-quint chords are always of type X^9 (note that the third is missing) but also 1-quint chord can be of form X^9 as explicit construction of chords demonstrates: I have denoted these 1-quint chords by symbol $X4$ (CDG is obviously equivalent with CDG).

   (b) Using the popular music notation introduced earlier, the 8 1-quint chords are $D7, Amaj7, A4_+, E7$ and their half-octave shifts $G\sharp 7$, $D\sharp 7, D\sharp 4_+, B\flat 7$.

   No major and minor chords are included and only the extension to tetra-icosahedral harmony can provide them and also break the symmetry giving rise to well-defined key.

5. The four 0-quint chords appear in two types. $D\sharp ex2 \equiv D\sharp EF\sharp$ and its half-octave shift $Aex2 \equiv AB\flat C$ plus $Hex3 \equiv HC\sharp G$ and its half-octave shift $Fex3 \equiv FGC\sharp$. According to usual thinking these chords involve dissonances. This dissonance character is a rather general phenomenon for the harmonic loners and classical views about harmony would exclude them as asocial cases! In the case of maximally symmetric harmony the loners are diminished chords and thus not so dissonant. In some cases there are no 0-quint chords.

$(\mathbf{n_0}, \mathbf{n_1}, \mathbf{n_2})$	**0-chords**	**1-chords**	**2-chords**
(2, 12, 6)	$(Faug, Gaug)$	$(Cm, Dm, Em, F\sharp m, G\sharp m, B\flat m)$,	$(C9, D9, E9, F\sharp 9, G\sharp 9, B\flat 9)$.
		$(F6, G6, A6, B6, C\sharp 6, D\sharp 6)$.	

Table 2.6: Table gives various types of 3-chords for harmonies with Z_6 rotational symmetry. Note that half-octave shift is an exat symmetry. Note that $G^{aug} = CEG\sharp, F^{aug}$ act as bridges between the groups related by half octave shift. The chords have been arranged so that they form orbits of Z_6. "Amino-acid chords" correspond to preferred chords at the orbits.

$(\mathbf{n_0}, \mathbf{n_1}, \mathbf{n_2})$	**0-chords**	**1-chords**	**2-chords**
(0, 16, 4)		$(D7, D6, G\sharp 7, G\sharp 6)$,	$(B\flat 9, B9, E9, F9)$.
		$(G4+, A9-, C\sharp 4+, D\sharp 9-)$,	
		$(Emaj7, Gmaj7, B\flat maj7, C\sharp maj7)$,	
		$(C9-, A9-, F\sharp 9-, D\sharp 9-)$.	
(4, 8, 8)	$(Cex3, Eex2, F\sharp ex3, B\flat ex2)$.	$(Dmaj7, E9-, A7, A6)$,	$(B\flat 9, F9, C9, G9)$.
		$(G\sharp maj7, B\flat 9-, D\sharp 7, D\sharp 6)$.	$(E9, B9, F\sharp 9, C\sharp 9)$.

Table 2.7: Table gives various types of 3-chords for the two harmonies with $Z_4 = Z_2^{rot} \times Z_2^{refl}$ symmetry. 4-plets represent the orbits. First cycle has no harmonic loners. Second cycle gives rise to bio-harmony (4, 8, 8) for which 0-quint chords are dissonant. Both cycles have Z_2 rotation symmetry acting as a vertical reflection symmetry in figures and realized also as half-octave shift so that 4-plets contains chords and their half-octave shifts. The genuine reflection symmetry acts as a horizontal reflection symmetry in figures. The cycles correspond to figures **??**, **??**

There are 5 collections with Z_2 reflection symmetry having 24 representatives in each (see **Figs. ??**, **??**, **??**, **??**, **??**). The integer triplets n are $(2, 12, 6), (2, 12, 6), (4, 10, 6), (2, 12, 6), (2, 12, 6)$. Bio-harmony has representative also in this class (see **Fig. ??**). The half-octave scaling symmetry is broken for these harmonies. I have not found simple characterization for the symmetry which corresponds to reflection in the direction of x-axis since it changes the interval structure of the chords.

Some comments $(4, 8, 8)$ case are in order (see **Fig. ??**).

1. 2-quint chords appear as reflection related multiplets $C9, D9, H\sharp 9, D\sharp 9$ and $C\sharp 9, H9, F9, B\flat 9$.

2. 1-quint chords appear as symmetry related mutiplets $G, D7, Amaj7, E7$ and $C\sharp m, F\sharp 6, H6\_, E6$. Key G major and $C\sharp$ minor would be natural looking keys even without tetrahedral extension. For the mirror image $B\flat$ minor and E major would be the natural looking keys. For extension E major would be the key.

To sum up, half octave shift is a symmetry of all harmonies expected those having only Z_2 reflection symmetry, and fails thus also for the corresponding bio-harmonies.

Tables of basic 3-chords for the icosahedral harmonies with symmetries

The tables below give list for the three types of 3-chords for the 11 harmonies possessing symmetries. One must remember that the reversal of the orientation for the cycle induces the transformation $C \leftrightarrow C$, $F\sharp \leftrightarrow F\sharp$, $H \leftrightarrow C\sharp$, $F \leftrightarrow G$, $D \leftrightarrow B\flat$, $E \leftrightarrow G\sharp$, $A \leftrightarrow D\sharp$ and produces a new scale with minor type chords mapped to major type chords and vice versa. Also one must remember that all 3-chords except those which are simple majors or minors lack the third so that their emotional tone remains uncharacterized. For instance, $C6$ does could be replaced with $Cm6$ and $G7$ with $Gm7$. The reader can check the chords by direct inspection of the figures. The convention used is that vertex number one corresponds to C note.

$(\mathbf{n_0}, \mathbf{n_1}, \mathbf{n_2})$	**0-chords**	**1-chords**	**2-chords**
(0, 16, 4)		$(Em, B\flat m), (Cm, F\sharp m),$	$(D9, G\sharp 9),$
		$(G6, C\sharp 6), (A6, D\sharp 6),$	$(E9, B\flat 9).$
		$(D4+, G\sharp 4+), (B4+, F4+),$	
		$(Cmaj7, F\sharp maj7), (G6-, C\sharp 6-).$	
(2, 12, 6)	$(Aex4, D\sharp ex2).$	$(Am, D\sharp m), (G9-, C\sharp 9-),$	$(C9, F\sharp 9),$
		$(C4, F\sharp 4), (E4+, B\flat 4+),$	$(A9, D\sharp 9),$
		$(Dmaj7, G\sharp maj7),$	$(D9, G\sharp 9).$
		$(Bmaj7, Fmaj7).$	
(4, 8, 8)	$(Aex2, Hex8, D\sharp ex2, Fex8).$	$(D7, G\sharp 7), (Amaj7, D\sharp maj7),$	$(G9, C\sharp 9), (A9, D\sharp 9),$
		$(A4+, D\sharp 4+), (E7, B\flat 7).$	$(B9, F9), (E9, B\flat 9).$

Table 2.8: Table gives various types of 3-chords for harmonies with Z_2 rotation symmetry acting as half-octave shift. The doublets represent 2-chord orbits. The cycles correspond to figures **??**, **??**, and **??**.

$(\mathbf{n_0}, \mathbf{n_1}, \mathbf{n_2})$	**0-chords**	**1-chords**	**2-chords**
(2, 12, 6)	$(F\sharp ex3, Hex4),$	$(Am, D\sharp), (A6, D\sharp 7),$	$(C9, F9), (B9, F\sharp 9),$
		$(D7, B\flat 6), (G6-, Fmaj7),$	$(E9, C\sharp 9).$
		$(D4+, B\flat 9-), (E9-, G\sharp 4+),$	
(2, 12, 6)	$(Dex4, Hex4).$	$(F, Fm), (C6-, B\flat maj7),$	$(C9, D\sharp 9),$
		$(D7, G\sharp 6), (Gmaj7, D\sharp 6-).$	$(D\sharp 9, C\sharp 9),$
		$(C\sharp 4-, A4+), (E4+, F\sharp 6).$	$(E9, B9).$
(4, 8, 8)	$(Fex1, D\sharp ex3, G\sharp ex1, Aex2).$	$(E7, E6), (Amaj7, B9-),$	$(D9, B9), (C9, C\sharp 9),$
		$(G, C\sharp m), (D7, F\sharp 6).$	$(F9, G\sharp 9), (D\sharp 9, B\flat 9).$
(2, 12, 6)	$(Hex3, Eex7).$	$(D7, G\sharp 6), (G, D\sharp m),$	$(C9, D\sharp 9),$
		$(F, Fm), (C6-, B\flat maj7),$	$(D9, C\sharp 9),$
		$(A9-, C\sharp 4+), (E7, F\sharp 6).$	$(E9, B9).$
(2, 12, 6)	$(F\sharp ex2, Fex3).$	$(F, B\flat m), (C7, G\sharp 6),$	$(B\flat 9, D\sharp 9),$
		$(Amaj7, B9-), (E6, E7),$	$(C9, C\sharp 9),$
		$(G, C\sharp m), (D7, B6).$	$(D9, H9).$

Table 2.9: Table gives various types of 3-chords for harmonies with single reflection symmetry. The cycles correspond to figures **??**, **??**, **??**, **??**, **??**.

C	G	D	A	E	H	F+	C+	G+	D+	B-	F
C	F	$B\flat$	D+	G+	C+	F+	H	E	A	D	G

Table 2.10: Inversion of the scale leaving C (and also $F\sharp$) invariant.

M, 0	m, 0	sus4, 0	aug, 0	4, 0	9, 0	4+, 0	9-, 0	6-, 0	maj7, 0
m, 11	M, 11	sus, 0	aug, 0	4, 0	9, 10	9-, 11	4+, 11	maj7, 11	6-, 11
6, 0	7, 0	ex1, 0	ex2, 0	ex3, 0	ex4, 0	ex5, 0	ex6, 0	ex7, 0	ex8, 0
7, 11	6, 11	ex1, 10	ex3, 3	ex2, 3	ex4, 8	ex6, 8	ex5, 80	ex8, 6	ex7, 6

Table 2.11: Table gives the transformation of inversion leaving C invariant on the basic chords having C as basic note.

2.7.4 Appendix

Chord tables for some harmonies and their inverses

The formula for inversion of the harmonic keeping note X as fixed can be represented as a product of translation takin X to C, inversion keeping C fixed, and translation taking C back to X. The inversion maps the chord having C as basic note to its mirror image so that the order of notes can change and basic note can change. For instance, the major chord $CM = CEG$ goes to minor chord $CG\sharp F = Fm$ so that $k = 0$ goes to $k \equiv \Delta k_{inv} = 11$. This delicacy must be taken into account. If X remains fixed inversion is just the transformation

$$k \to k_{inv} = (2 \times k(X) - \Delta k_{inv}) \ \ mod \ \ 12 \ . \tag{2.7.3}$$

Table 2.10 gives the inversion of the scale leaving C (and also $F\sharp$) invariant:
The inversion for the types of the chords does not depend on the basic note as is clear from the distance preserving character of the inversion. **Table 2.11** gives the inversion of for the types of the chords leaving C fixed. The elements of the rows give the type of the chord and the number of quints k corresponding to it. For chords having C as basic note one has $k = 0$. It is easy to deduce the transformation formula in more general case from the table.

The following tables give the chords and corresponding inverse chords for the 11 icosahedral harmonies.

Calculation of incidence matrices

The most stringent definition of harmonic chord progression is as a chord sequence in which two subsequent chords have at least one common note: the distance between subsequent chords defined as the minimal distance between triangles representing them vanishes. Some general comments are in order.

1. Incidence matrices can be computed by using expressions of chords as sets of three notes (possible in Python) and just counting the number of common notes defining the value of the element of the incidence matrix. The quint distance between the chords vanishes if they have common notes. More general incidence matrices would correspond to a larger quint distance.

2. In the case of genetic code and amino-acids one Hamilton cycle from each class labelled by Z_n, $n \in \{6, 4, 2\}$ is involved.

   (a) There are $N = 1 \times 3 \times 8 = 24$ cycle combinations if one does not allow the inverse harmonies. Allowing them gives $N = 8 \times 24$ combinations. If transitions between all representations are possible, there are $M = N^2$ 20×20-dimensional incidence matrices

ro6	iro6	re41	ire41	re42	ire42	ro21	iro21
F.aug	F.aug	D.7	A.6	C.ex3	A.ex2	E.m	F.M
G.aug	D+.aug	D.6	A.7	E.ex2	F.ex3	B-.m	B.M
C.m	F.M	G+.7	D+.6	F+.ex3	D+.ex2	C.m	A.M
D.m	D+.M	G+.6	D+.7	B-.ex2	B.ex3	F+.m	D+.M
E.m	C+.M	G.4+	E.9-	D.maj7	B.6-	G.6	D.7
F+.m	B.M	A.9-	D.4+	E.9-	A.4+	C+.6	G+.7
G+.m	A.M	C+.4+	B-.9-	A.7	E.6	A.6	C.7
B-.m	G.M	D+.9-	G+.4+	A.6	E.7	D+.6	F+.7
F.6	C.7	E.maj7	G.6-	G+.maj7	F.6-	D.4+	G.9-
G.6	B-.7	G.maj7	E.6-	B-.9-	D+.4+	G+.4+	C+.9-
A.6	G+.7	B-.maj7	C+.6-	D+.7	B-.6	B.4+	B-.9-
B.6	F+.7	C+.maj7	B-.6-	D+.6	B-.7	F.4+	E.9-
C+.6	E.7	C.9-	B.4+	F.9	D+.9	C.maj7	A.6-
D+.6	D.7	A.9-	D.4+	C.9	G+.9	F+.maj7	D+.6-
C.9	C.9	F+.9-	F.4+	G.9	C+.9	G.6-	D.maj7
D.9	B-.9	D+.9-	G+.4+	E.9	E.9	C+.6-	G+.maj7
E.9	G+.9	B.9	G.9	B.9	A.9	D.9	D.9
F+.9	F+.9	E.9	D.9	F+.9	D.9	G+.9	G+.9
G+.9	E.9	F.9	C+.9	C+.9	G.9	E.9	C.9
B-.9	D.9	B-.9	G+.9	B-.9	B-.9	B-.9	F+.9

Table 2.12: Pairs "X" and "iX" of columns give the chords of the bio-harmonies and their inversions depicted in figures **??**, **??**, **??**, **??**.

ro22	iro22	ro23	iro23	re21	ir21	re22	ir22
A.ex4	G.ex4	A.ex2	B-.ex3	F+.ex3	D+.ex2	D.ex4	E.ex4
D+.ex2	C.ex3	H.ex8	B-.ex7	H.ex4	B-.ex4	H.ex4	F+.ex4
A.m	B-.M	D+.ex2	E.ex3	A.m	E.M	F.M	E.m
D+.m	E.M	F.ex8	F.ex7	D+.M	B-.m	F.m	E.M
G.9-	C.4+	D.7	A.6	A.6	E.7	C.6-	A.maj7
C+.9-	F+.4+	G+.7	D+.6	D+.7	B-.6	B-.maj7	B.6-
C.4	C.4	A.maj7	D.6-	D.7	B.6	C.9-	A.4+
F+.4	F+.4	D+.maj7	G+.6-	B-.6	D+.7	D.7	G.6
E.4+	D+.9-	A.4+	D.9-	G.6-	F+.maj7	G+.6	C+.7
B-.4+	A.9-	D+.4+	G+.9-	F.maj7	G+.6-	G.maj7	D.6-
D.maj7	F.6-	E.7	G.6	D.4+	B.9-	D+.6-	F+.maj7
G+.maj7	B.6-	B-.7	C+.6	B-.9-	D+.4+	C+.4	C+.4
B.maj7	G+.6-	B-.9	G+.9	G+.4+	F.9-	A.4+	C.9-
F.maj7	D.6-	G.9	B.9	E.9-	A.4+	E.4+	F.9-
C.9	D.9	C+.9	F.9	C.9	G+.9	F+.6	D+.7
F+.9	G+.9	A.9	A.9	F.9	D+.9	D+.9	C+.9
A.9	F.9	B.9	G.9	B.9	A.9	C+.9	D+.9
D+.9	B.9	F.9	C+.9	F+.9	D.9	E.9	C.9
D.9	C.9	E.9	D.9	E.9	E.9	B.9	F.9
G+.9	F+.9	D+.9	D+.9	C+.9	G.9	D+.9	C+.9

Table 2.13: Pairs "X" and "iX" of columns give the chords of the bio-harmonies and their inversions depicted in figures **??**, **??**, **??**, **??**.

re23	ire23	re24	ire24	re25	ire25		
F.ex1	F.ex1	H.ex3	G.ex2	F+.ex2	F.ex3		
D+.ex3	G+.ex2	E.ex7	F+.ex8	F.ex3	F+.ex2		
G+.ex1	D.ex1	D.7	A.6	F.M	B-.m		
A.ex2	D.ex3	G+.6	D+.7	B-.m	F.M		
E.7	B.6	G-.M	B.m	C.7	D+.6		
E.6	B.7	D+.m	G+.M	G+.6	G.7		
A.maj7	F+.6-	F.M	F+.m	A.maj7	F+.6-		
B.9-	E.4+	F.m	F+.M	B.9-	E.4+		
G.M	G+.m	C.6-	B.maj7	E.6	B.7		
C+.m	D.M	B-.maj7	C+.6-	E.7	B.6		
D.7	C+.6	A.9-	D.4+	G.M	G+.m		
F+.6	A.7	C+.4+	B-.9-	C+.m	D.M		
B-.9	C.9	E.7	G.6	D.7	C+.6		
D.9	G+.9	F+.6	F.7	B.6	E.7		
B.9	B.9	C.9	F+.9	D+.9	G.9		
C.9	B-.9	D+.9	D+.9	C.9	B-.9		
F.9	F.9	D.9	E.9	C+.9	A.9		
G+.9	D.9	C+.9	F.9	B-.9	C.9		
D+.9	G.9	E.9	D.9	D.9	G+.9		
C+.9	A.9	B.9	G.9	H.9	B-.9		

Table 2.14: Pairs"X" and"iX" of columns give the chords of the bio-harmonies and their inversions depicted in figures **??**, **??**, **??**.

to be calculated for the icosahedral restriction of the code. Incidence matrices are symmetric so that only $D(D+1)/2 = 20(20+1)/2 = 210$ independent matrix elements need to be calculated for given 20×20-D incidence matrix.

(b) Equivalently, one can calculate the incidence matrix for a space with $N \times 20$ points which is Cartesian product of N amino-acid spaces with 20 points. N has values 24 and 8×24. Remarkably, the magic number 24 of also stringy mathematics appears.

(c) If the transitions can be restricted to single triplet of cycles, one must calculate 6 20×20-dimensional incidence matrices. This situation could be realistic for portions of the genetic code if the transitions between different cycle triplets are analogous to phase transitions. The number of incidence matrices (one can also use single 60×60 incidence matrix) is still reasonably small and can be documented in written form. In a model for random chord sequences one must specify the probabilities for the transitions between chords with different n for Z_n. Simplest starting point assumption is that the probabilities are identical.

3. For the extended genetic code the most natural assumption is that the extension of the code to icosa-tetrahedral code take places place only in Z_2 sector meaning the extension of amino-acid space by 4 amino-acids and the increase of the number of DNA codons from 60 to 64. There are two kinds of transitions between icosahedral and tetrahedral codons. Tetrahedral codon can correspond to a codon, which is outside the icosahedron having at least one common vertex with the icosahedral codon: this allows 3+3 transitions. Tetrahedral codon can correspond also to punct. Unless the codon/amino-acid contains at least one of these notes, it cannot precede stopping codon. These chords extend the harmony by the counterparts of CM and Am and punct corresponds to $C6 = CGA$.

4. Also the situation in which tetrahedral and icosahedral codes are disjoint must be considered. In this case there are no transitions between tetrahedral and icosahedral sectors. In tetrahedral sector the distances between faces always vanish so that the calculation of this part of the incidence matrix is trivial. Icosa-tetrahedral part of the incidence matrix can be readily written. The difficult part of the calculation of incidence matrices reduces to that for the icosahedral case such that the common face corresponds to either punct or Sec/Pyl. This gives selection rules telling which codons/amino-acids can precede stopping codon/punct in given bio-harmony.

Simulation of harmonic DNA sequence

The following sequence represents a random harmonic sequence based on zero quint distance between neighboring chords (at least one common note). The harmony if combination 3 harmonies **??**, **??**, and **??** extended by adding chords $B\flat$, Gm and $G7$ and associated $B\flat 6$ representing stopping codon and punct in tetra- icosahedral codeandSec or Pyl in their unfused variants. These three harmonies correspond to groups of 20, 20, and 24 DNA codons at orbits of Z_6, Z_4, and Z_2 which is now taken to be Z_2^{refl}. To deduce DNA sequence one must assume detailed correspondence between the codons at the orbits and corresponding chords.

It is assumed that all transitions between neighboring DNAs occurs with the same probability and induce the transitions between amino-acids.

```
Faug, A6, Dm, G6, G6, G6, Em, G6, Cm, G6, F6, Faug, F+m, Dm, G6, G6,
Gaug, G+m, Cm, F6, Dm, Dm, F+m, Dm, F6, F6, B-m, C+6, B-m, F6, Dm, G6,
G6, G6, Gaug, G+m, Cm, Gaug, G6, Dm, B-m, F6, Faug, A6, G6, Gaug, G+m,
Cm, F6, Faug, F6, Cm, F6, G6, Gaug, Gaug, B6, Gaug, G6, Gaug, Em, Gaug,
Em, A6, F+m, B-m, F6, Cm, Gaug, Em, A6, Faug, B-m, B-m, Faug, F6, G6,
G6, F6, Faug, F6, Dm, G6, F6, Dm, F+m, Dm, F+m, A6, Faug, F6, Faug, Dm,
Dm, B-m, B-m, C+6, C+6, G+m, B6, A6, F+m, Faug, B-m, Dm, B-m, C+6, B-m,
F+m, B6, Gaug, Cm, G+m, Cm, F6, F6, B-m, Dm, F6, F6, G6, Dm, G6, G6, Em,
A6, G6, Cm, Cm, G+m, B6, G+m, C+6, C+6, C+6, Faug, B-m, Dm, Dm, G6, Cm,
Gaug, Cm, F6, Cm, G6, Gaug, G6, F6, Dm, F6, Faug, Faug, Faug, A6, Em,
Em, G6, Dm, Faug, F6, B-m, F6, Cm, F6, B-m, F+m, Dm, G6, F6, F6, Cm, Cm,
Em, G+m, Em, A6, Em, A6, F+m, B-m, B-m, B-m, F+m, B6, A6, Em, G+m, B6,
B6, Em, G6, Dm, B-m, Dm, Dm, B-m, Dm, Faug, Faug, F6, Cm, G6, Gaug, B6,
G+m, Em, G6, G6, Dm, Faug, Faug, F6, Cm, Gaug, G+m, Gaug, B6, F+m, A6,
G6, Em, Cm, F6, Dm, Dm, Dm, G6, Em, Em, A6, Em, Gaug, Em, Cm, Cm, Gaug,
G6, G6, Cm, F6, Dm, Faug, A6, Faug, A6, Faug, F+m, F+m, B-m, C+6, G+m,
Em, Gaug, G6, Gaug, G6, G6, Dm, G6, Dm, Dm, F6, B-m, F6, G6, Cm, G+m,
Em, G+m, B6, G+m, Cm, Cm, F6, Faug, Faug, Faug, F6, Dm, G6, Dm, F+m,
Faug, Faug, B-m, C+6, G+m, C+6, Faug, F+m, B-m, Faug, Faug, A6, G6, Em,
Cm, F6, G6, Cm.
```

Illustrations of icosahedral Hamiltonian cycles with symmetries

The figures below illustrate the Hamiltonian cycles involved. Quite generally, the Z_n symmetry acts by a shift by $12/n$ quints along the cycle and the orbits of chords consist of at most n chords of same type as the reader is encouraged to verify.

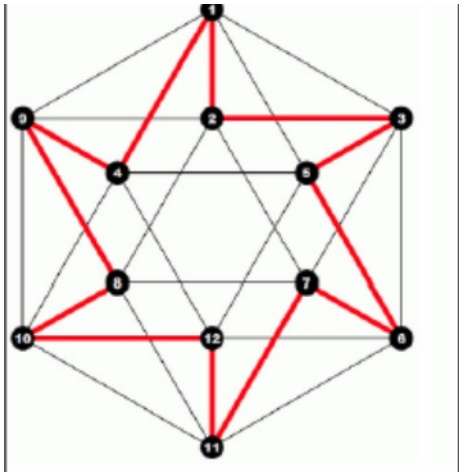

Figure 2.4: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 6-fold rotation symmetry acting shifts generated by a shift of 2 quints.

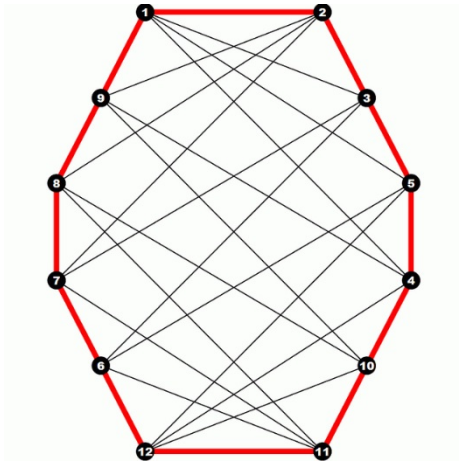

Figure 2.5: $(n_0, n_1, n_2) = (0, 16, 4)$ Hamiltonian cycle with 4 reflection symmetries generated by reflections in vertical and horizontal directions.

2.8 What could be the physical origin of Pythagorean scale?

I was contacted for a couple years ago by Hans Geesink and we had long discussions about consciousness and quantum biology. The discussion stimulated new ideas and this inspired me to write a chapter and article comparing our approaches (see `http://tinyurl.com/lwxdl7y`). Now Hans sent me two prepublications by him and D. K. F. Meijer.

The first preprint "Bio-Soliton Model that predicts Non-Thermal Electromagnetic Radiation Frequency Bands, that either Stabilize or Destabilize Life Conditions" is in arXiv [I18] (see `http://tinyurl.com/zz3ew33`). The abstract reads as:

Solitons, as self-reinforcing solitary waves, interact with complex biological phenomena such as cellular self-organisation. Soliton models are able to describe a spectrum of electromagnetism modalities that can be applied to understand the physical principles of biological effects in living cells, as caused by electromagnetic radiation. A bio-soliton model is proposed, that enables to predict which eigen-frequencies of non-thermal electromagnetic waves are life-sustaining and which are, in contrast, detrimental for living cells. The particular effects are exerted by a range of

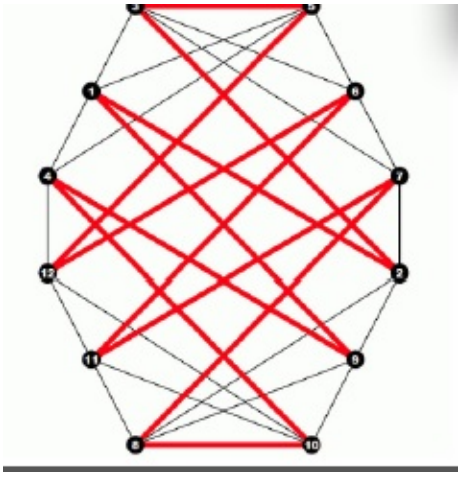

Figure 2.6: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 4 reflection symmetries.

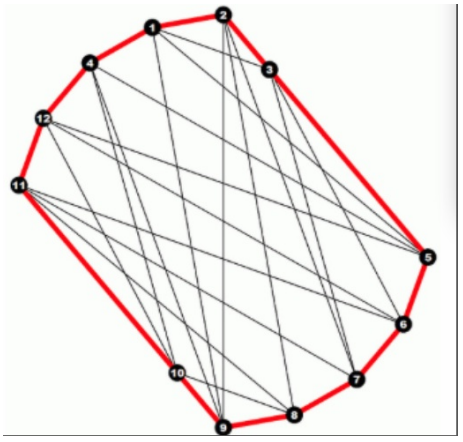

Figure 2.7: $(n_0, n_1, n_2) = (0, 16, 4)$ Hamiltonian cycle with 2-fold rotational symmetry realized as 6-quint shift along the cycle.

electromagnetic wave frequencies of one-tenth of a Hertz till Peta Hertz, that show a pattern of twelve bands, if positioned on an acoustic frequency scale. The model was substantiated by a meta-analysis of 240 published papers of biological radiation experiments, in which a spectrum of non-thermal electromagnetic waves were exposed to living cells and intact organisms.

These data support the concept of coherent quantized electromagnetic states in living organisms and the theories of Davydov, Fröhlich and Pang. A spin-off strategy from our study is discussed in order to design bio-compatibility promoting semi-conducting materials and to counteract potential detrimental effects due to specific types of electromagnetic radiation produced by man-made electromagnetic technologies.

Second preprint "Phonon Guided Biology: Architecture of Life and Conscious Perception are mediated by Toroidal Coupling of Phonon, Photon and Electron Information Fluxes at Eigenfrequencies" is in Research Gate [I19] (see `http://tinyurl.com/j9rsyqd`). The abstract is following.

Recently a novel biological principle, revealing discrete life sustaining electromagnetic (EM) frequencies, was presented and shown to match with a range of frequencies emitted by clay-minerals as a candidate to catalyze RNA synthesis. The spectrum of frequency bands indicate that nature

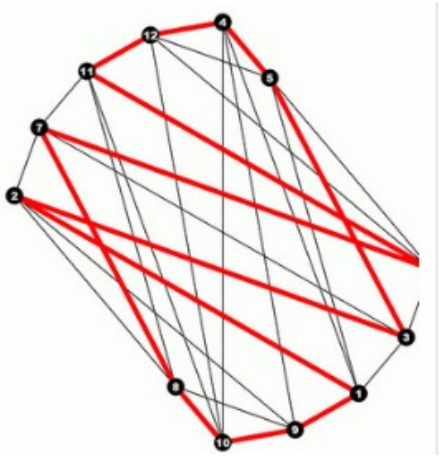

Figure 2.8: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold rotation symmetry.

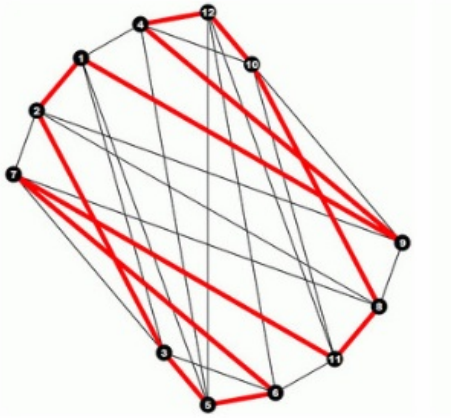

Figure 2.9: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold rotation symmetry.

employs discrete eigen-frequencies that match with an acoustic reference scale, with frequency ratios of 1:2, and closely approximated by 2:3, 3:4, 3:5, 4:5 and higher partials. The present study shows that these patterns strikingly resemble eigen-frequencies of sound induced geometric patterns of the membrane vibration experiments of E. Chladni (1787), and matches with the mathematical calculations of W. Ritz (1909).

We postulate that the spectrum of EM frequencies detected, exert a phonon guided ordering effect on life cells, on the basis of induction of geometric wave patterns. In our brain a toroidal integration of phonon, photon and electron fluxes may guide information messengers such as Ca^{2+}-ions to induce coherent oscillations in cellular macromolecules. The integration of such multiple informational processes is proposed to be organized in a fractal 4-D toroidal geometry, that is proposed to be instrumental in conscious perception. Our finding of an "acoustic life principle" may reflect an aspect of the implicate order, as postulated by David Bohm.

A very concice and very partial summary about the articles would be following.

1. 12-note scale seems to be realized in good approximation as frequency bands (rather than single frequencies) for a membrane like system with the geometry of square obeying four-order partical differential equation studied numerically by Ritz. Since the boundary conditions are periodic this system has effective torus topology. This is rather remarkable experimental fact

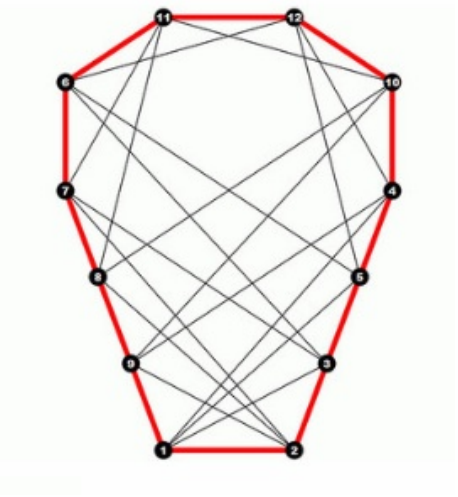

Figure 2.10: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry realized as horizontal reflection

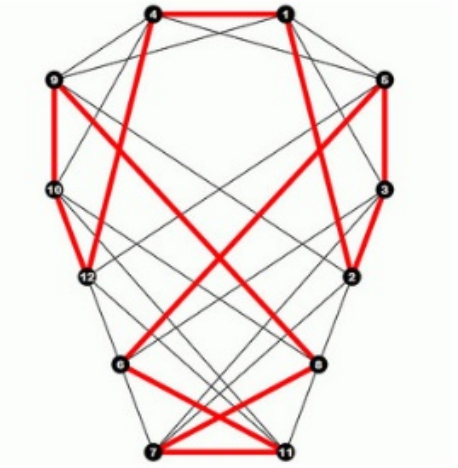

Figure 2.11: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.

and extremely interesting from TGD point of view.

2. The papers also argue that also the octave hierarchy is realized. p-Adic length scale hierarchy indeed predicts that subset of powers of 2, and more generally of $\sqrt{2}$ defines a hierarchy of fundamental p-adic scales with p-adic prime p near to power of two.

In the following I will discuss first the condensed matter realization of 12-note scale and after that considder the significance and realization of 12-note scale from TGD point of view.

2.8.1 Condensed matter realization of 12-note scale in terms of oscillations of square plate

The article discusses a condensed matter physics based realization of 12-note. Acoustic waves are seen as fundamental. Certainly the sound waves are important since they couple to electromagnetic waves. My feeling is however that they provide a secondary realization.

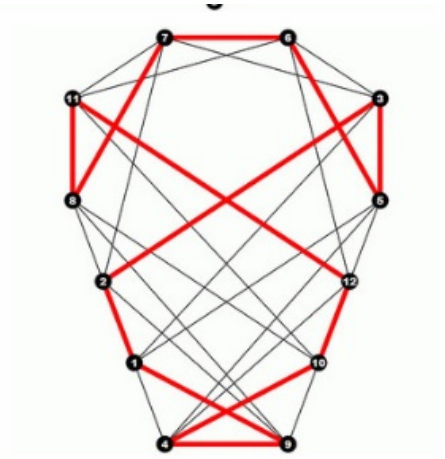

Figure 2.12: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold reflection symmetry.

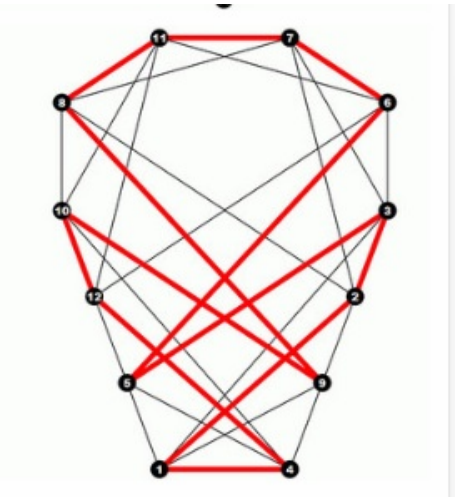

Figure 2.13: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.

1. The realization of 12-note system as 12 bands discussed in the articles is as eigen frequencies of deformations of square plate. Periodic boundary conditions imply that one can regard the system also as a torus. One has bands, not eigenfrequencies. I do not know whether one can pick up from bands frequencies, whose ratio to the fundamental would be rational and same as for Pythagorean scale. Since the system can be treated only numerically, it is difficult to answer this question.

2. So called Chladni patterns (see "An Amazing Resonance Experiment" at `http://tinyurl.com/kcbmrzz`) are associated with vibrating thin square plate and correspond to the node lines of the deformation of the plate in direction orthogonal to the plate. As one adds very small particles at the plate and if the vibrational acceleration is smaller than the gravitational acceleration the particles get to the node lines and form Chladni pattern. Hence the presence of gravitation seems to be essential for the Chladni patterns to occur. These patterns make visible the structure of standing wave eigenmodes of the plate. It is also possible to have patterns assignable to the antinodes at which the deformation is maximum but vibrational acceleration vanishes as in the harmonic oscillator at the maximum value of the amplitude.

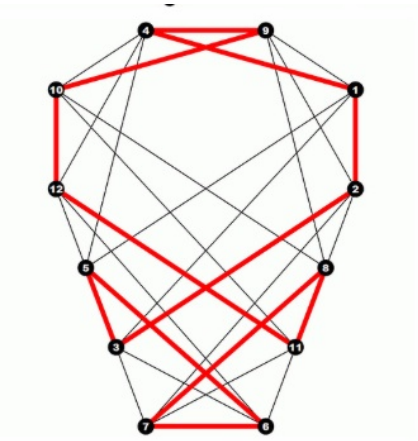

Figure 2.14: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.

3. The vibrations of square plate obey fourth order partial diff equation for the Chladni pattern having the general form

$$\partial_t^2 u = K(\nabla^2)^2 u \ . \tag{2.8.1}$$

Here u is the small deformation in direction orthonormal to the plate. The equation can be deduced from the theory of elasticity about which I do not know much. For standing wave solutions the time dependence is separable to trigonometric factor $sin(\omega t)$ or $cos(\omega t)$, and one obtains eigenvalue equation

$$K(\nabla^2)^2 u = -\omega^2 u \ . \tag{2.8.2}$$

4. The natural basis for the modes is as products of 1-D modes $u_m(x)$ for string satisfying $\partial_x^2 u_m = 0$ at the ends of the string ($x = \{-1, 1\}$) this in both x and y directions. This must express the fact that energy and momentum do not flow out at boundaries.

   The modes satisfy

$$\frac{d^4 u_m}{dx^4} = k_n^4 u_m \ . \tag{2.8.3}$$

Boundary conditions allow modes with both even and odd parity:

$$\begin{aligned} u_m &= \frac{[cos(k_m)cosh(k_m x)+cosh(k_m)cos(k_n x)]}{cosh^2 k_m + cos^2(k_m)} \ , \\ tan(k_m) + tanh(k_m) &= 0 \ , \ m \text{ even} \ . \\ u_m &= \frac{[sin(k_m)sinh(k_m x)+sinh(k_m)sin(k_n x))]}{sinh^2 k_m + sin^2(k_m)} \\ tan(k_m) - tanh(k_m) &= 0 \ , \ m \text{ odd} \ . \end{aligned} \tag{2.8.4}$$

5. The 2-D modes are not products of 1-D modes but sums of products

$$w^{\epsilon}_{mn} = u_m(x)u_n(y) + \epsilon u_m(y)u_n(x) \quad , \quad \epsilon = \pm 1 \quad . \tag{2.8.5}$$

   Modern physicist would notice classical entanglement between x and y degrees of freedom. The first $\epsilon = 1$ mode is analogous symmetric two-boson state and second $\epsilon = -1$ mode to antisymmetric two-fermion state.

6. The variational ansatz of Ritz was superposition of these modes (this variational method was actually discovered by Ritz). Ritz minimized the expectation value of the Hermitian operator $(\nabla^2)^2$ in the ground state and obtained an approximation for the frequencies which holds true with 1 per cent accuracy.

Unfortunately, 4-D geometry does not give rise to this kind of equations: time and space are not in democratic roles. TGD inspired vision would be different. The magnetic flux tubes and even strings could be the fundamental objects concerning biology and consciousness. The acoustic realization of the 12-note scale would be secondary one. Even genetic code would have fundamental realization at the level of dark nuclear physics [L25] and chemical realization of genetic code would be secondary realization.

2.8.2 Why 12-note scale?

Why I am convinced that 12-note scale should be so important?

1. The mysterious fact about music experience is that frequencies whose ratios come as rationals are somehow special concerning music experience. People with absolute pitch prefer the Pythagorean scale with this property as aesthetically pleasing. Pythagorean scale is obtained by forming the 3^k multiples of fundamental and by dividing by a suitable power 2^m of 2 to get a frequency in the basic octave. This scale appears in TGD inspired model for music harmonies [L9] (see `http://tinyurl.com/yad4tqwl`), which as a byproduct led to a model of genetic code predicting correctly the numbers of DNA codons coding for given amino-acid. The appearance of powers of 2 and 3 suggest 3-adicity and 2-adicity. Furthermore, rationals correspond to the lowest evolutionary level defined by the hierarchy of algebraic extensions of rationals.

   This gives excellent reasons to ask whether 12-note scale could be realized as some physical system. One might hope that this system could be somehow universal. Geometric realization in terms of wave equation would be the best that one could have.

2. The model of harmony is realized in terms of Hamilton cycles assignable to icosahedron and tetrahedron. Hamilton cycles at icosahedron are closed paths going through all 12 points of icosahedron and thus can define a geometric representation of the Pythagorean scale. The rule is that curve connects only nearest points of icosahedron and corresponds to scaling of frequency by 3/2 plus reduction to basic octave by dividing by a suitable power of 2. The triangles of the icosahedron define allowed 20 chords for given harmony and one obtains 256 basic harmonies characterized by the symmetries of the cycle: symmetry group can be cyclic group Z_6, Z_4 or Z_2 or reflection group Z_2 acting on icosahedron.

   Bioharmonies are obtained by combining Z_6,Z_4 and Z_2 of either type. One obtains 20+20+20 =60 3-chords defining the bio-harmony. One must add tetrahedral harmony with 4 chords in order to obtain 64 chords. It turns out that it corresponds to genetic code under rather mild assumptions. DNA codons with 3 letters could correspond 3-chords with letter triplets mapped to 3-chords. Amino-acids would correspond to orbits of given codon at icosahedron under one of the symmetry groups involved.

2.8.3 How to realize 12-note scale at fundamental level universally?

How could one realize 12-note scale at the fundamental level - that is in terms of 4-D geometry? The realization should be also universal and its existence should not depend on special properties of physical system. Vibrating strings provide the simplest manner to realize 12-note scale. Harmonics do not however allow its realization. They are in higher octaves and define only the color of the note. There are actually two realizations.

The simplest realization relies on the analogy with piano.

1. The string of piano corresponds to a magnetic flux tube/associated fermionic string and the frequency of the note would be determined by the length of the flux tube. The quantization for the length as certain rational multiples of p-adic length scale gives rise to the 12-note scale. Tensor network would be like piano with the flux tubes of the network with quantized lengths defining the strings of piano.

2. Why the length of the flux tube defining the fundamental frequency would correspond to a frequency of Pythagorean scale? Could this be due to the preferred extremal property realizing SH and posing very strong conditions on allowed space-time surface and 3-surfaces at their ends at boundaries of causal diamonds? If so, 12-note scale would be part of fundamental physics!

   The rational multiples $f(m,n) = (m/n)f_0$, $m = 0, 1, ..n-1$, of the fundamental f_0 with $m/n \leq 2$ (single octave) are in a preferred position mathematically since the superpositions of waves with these frequencies can be represented as superpositions of the suitable harmonics of the scaled down fundamental $f_1 = f_0/n$. For Pythagorean scale $m/n = 3^k/2^l$ the new fundamental is some "inverted" octave $f_1 = f_0/2^{k_{max}}$ of the fundamental and the allowed harmonics are of form $m = 2^r 3^l$.

Second realization would be dynamical and based on the analogy with string instruments.

1. String instruments allow to realize 12-note scale by varying the length of the vibrating string. The note of scale corresponds to the fundamental frequency for the portion of the shortened string, which is picked. Why the lengths of shortened strings should correspond to inverses of frequencies of 12-note scale? One should have powers of 3 divided by powers of 2 to get a frequency in fundamental octave. Could p-adic length scale hypothesis, which generalizes and length scales coming as powers of square roots of small primes help?

2. Strings bring in mind magnetic flux tubes connecting partonic 2-surfaces. They behaving in good approximation like strings and are actually accompanied by genuine fermionic strings and corresponding string world sheets. Flux tubes play a fundamental role in living matter in TGD Universe. Flux tubes carrying dark matter identified as large $h_{eff} = n \times h$ phases would serve as space-time correlates for negentropic entanglement and gives rise to tensor nets with partonic 2-surfaces as nodes and flux tubes connecting them [L28]. Could magnetic flux tubes or associated fermionic strings provide the instruments using Pythagorean scale?

   Partonic 2-surfaces and string world sheets dictate space-time surface by strong form of holography (SH) implied by strong form of general coordinate invariance. It is quite possible that not all configurations of partonic 2-surfaces and string world sheets allow SH that is realization as space-time surface: perhaps only the flux tubes with length corresponding to Pythagorean scale allow it. For p-adic counterparts of space-time surfaces the possibility of p-adic pseudo-constants (failure of strict determinism of field equations) makes this possible: the interpretation is as imagined p-adic space-time surface which cannot be realized as real space-time surface.

   How these flux tubes could behave like strings of guitar? When my finger touching the guitar string it dividing it to two pieces. The analogy for this is the appearance of additional partonic 2-surface between the two existing ones so that one has two flux tubes connecting the original partonic two-surface to the new one. A change of the topology of 3-space would be involved with this stringy music!

   More precisely, the flux tubes would be closed if they carry monopole magnetic flux: they would begin from "upper" wormhole throat of wormhole contact A (partonic 2-surface), go

along "upper" space-time sheet to the throat of wormhole contact B go the "lower" space-time sheet through it, return to the "lower" throat of wormhole contact A and back to the "upper" throat. Shortening of the string would correspond to a formation of wormhole contact at some point of this flux tube structure splitting the flux tube to two pieces.

3. Another realization could be in terms of the quantization of the distance between partonic 2-surfaces connected by flux tubes and associated strings in given p-adic length scale, which by p-adic length scale hypothesis would correspond to power of square root of 2 so that also octaves and possibly also half octaves would be obtained (note that half octave corresponds to tritonus, which was regarded by church as an invention of devil!). Also now the justification in terms of SH.

2.8.4 Could Chladni mechanism allow to realize morphogenesis?

Morphogenesis represents one of the basic unsolved problems of biology. Molecular biology and gene hypothesis have not allowed to understand what is involved. The probable reason is that biochemistry is local approach whereas morphogenesis is a non-local phenomenon. There have been attempts to understand morphogenesis using the catastrophe theory of Thom [A1]. Sheldrake has done highly intersting work with morphogenesis too. Robert Merrick's article harmonic theory of evolution (see `http://tinyurl.com/qda946l`) suggests a connection between the notion of harmony as expressed by 12-note scale and morphogenesis.

The basic building bricks of TGD vision about morphogenesis would be following.

1. Macroscopic quantum coherence is to my view a necessary ingredient of morphogenesis and hierarchy of Planck constants allows to realize it. The notion of magnetic body (MB) is also necessary. MB would guide the morphogenesis. For instance, the replication of living system would be induced by that for MB. The fundamental dynamics takes place at the level of MB and biochemical level is only a shadow of this dynamics. "Topological light rays" ("massless extremals", MEs) is second key element. MB would use MEs to control visible living matter, in particular to guide morphogenesis. The challenge is to understand how MB achieves this.

2. The notion of harmony assignable to various musical scales realized as Hamiltonian cycles at Platonic solids is central. The TGD based model for harmony [L9] was actually inspired by the book of Merrick's theory of music [J86]. The model for harmonies assignable to 12-note scale led to a model for genetic code in terms of so called Hamiltonian cycles on icosahedron and tetra-hedron predicting correctly the numbers of DNA codons coding for given amino-acid and also predicted two additional amino-acids Pyl and Sec appearing in Nature.

3. The fusion of real physics for sensory experience and various p-adic physics for cognition gives rise to adelic physics. In particular, one can speak about adelic variants of space-time surfaces and he notion of monadic geometry emerges. Geometric objects have discrete "spine" for which points have coordinate values in an algebraic extension of rationals for some preferred coordinate system dictated by the symmetries of the embedding space $M^4 \times CP_2$. Space-time surfaces are also locally continuous and smooth so that classical partial differential equations defining space-time surfaces as preferred extremals of Kähler action or its twistor lift make sense.

   Platonic solids represents unique monadic geometries since they correspond to finite discrete subgroups of the 3-D rotation group giving rise to 3-dimensional structures as their geometric representations. Also planar polygons represent this kind of realizations and can be assigned to the inclusion hierarchy of von Neuman algebras knowns hyper-finite factors of type II_1 and very probably also to the analogous fractal hierarchy of sub-algebras of super-symplectic algebra isomorphic to the full algebra.

4. The discrete points realizing monadic geometries could be accompanied by tensor networks having partonic 2-surfaces as notes connected by magnetic flux tubes serving as correlates for negentropic entanglement between the nodes at their ends would serve give rise to the emergence of proprioception - the experience about 3-space. The flux tubes would be analogous to strings of the music instruments with transverse oscillations defining the fundamental

frequencies defining the notes of the scale. Tensor network could be regarded as music instrument having flux tubes as strings.

12-note scale could be by its special mathematical features and by preferred extremal condition fundamental from the point of view of morphogenesis. The lengths of flux tubes are quantized. One can imagine two options. The effective length of given flux tube can be varied as done in guitar or the tensor network would be like piano or harp: the lengths of flux tubes assignable to the tensor network would have quantized lengths coming as rational multiples of fundamental length in such a way that a representation of the 12-note system would be obtained.

The model of music harmony and 12-note scale would be assignable to icosahedron which would aslo define a very natural monadic geometry. This harmony would also related to genetic done. Monadic geometry could in turn emerge naturally in morphogenesis so that genetic code could after all lurk behind morphogonesis but being realized in terms of 3-chords rather than triplets of DNA nucleotides. Morphogenesis could be a realization of genetic code in terms of interfering fields.

How morphogenesis could then be realized 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. 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.

2. The objection is that TGD does not allow single-sheeted realizations of standing waves. 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 trigometric functions - say $sin(\omega t)sin(kz)\epsilon(x)$, $\omega = kc$. The force would vanish at nodal surfaces, which would thus define naturally the shape of a stationary structure defined by molecules.Now these surfaces would be zeros of $sin(kz)$ and $\epsilon(z)$.

   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.

3. 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.

2.9 Bio-catalysis, morphogenesis by generalized Chladni mechanism, and bio-harmonies

In the following I try to relate 3 different ideas inspired by TGD.

1. The first idea is that bio-catalysis relies on the notion of magnetic body (MB) carrying dark matter: reconnections of U-shaped flux tubes giving rise to super-conducting flux tube pairs connecting two systems, and the reduction of their lengths as the value of $h_{eff}/h = n$ is reduced play a key role. The reduction of $h_{eff}/h = n$ for dark atom liberates also energy associated with hydrogen atom like states at flux tubes with energy scaling as $1/h_{eff}^2$. This energy could allow the reactants to overcome the potential wall making the otherwise very slow reaction fast [L29].

   This idea emerged from a model for hydrino atoms proposed by Randell Mills [D2] having scaled up binding energy spectrum manifesting itself as a radiation band in EUV range having no chemical origin. The simplest explanation TGD explanation is that the value of $h_{eff}/h = n$ is $n = 6$ for visible matter and that for hydrino like states it is $m = 1, 2, 3$. This would predict the scaling of the energy spectrum by $(n/m)^2$ and its occurrence would liberate the excess binding energy to be used by reacting molecules.

2. Second idea is that generalized Chladni mechanism [L30] is behind morphogenesis and therefore very probably involved also with catalysis. Charged particles and even charged flux tubes would end up to the nodal surface of electric field to form biological structures. One could speak about dynamics of avoidance and the particles ending up to potential minima provide one example of this dynamics.

   In fact, there are strong mathematical and physical reasons to argue that the dynamics of space-time surface is dynamics of avoidance [L27]. The preferred extremals for the sum of Kähler action and volume term are extremals of both so that one can say that force density defined by Kähler action vanishes and the motion corresponds to a generalization of geodesic line to 4-D minimal surface.

3. The third idea is that genetic code is realized as 3-chords of what I call bio-harmony and represented as dark photon triplets and "massless extremals" (MEs) or "topological light rays" [L9]. This gives also rise to a realization as sounds since living matter consists of electrets transforming light to sound and vice versa. The question is whether the sequence of 3-chords representing gene could provide a basic realization of Chladni mechanism so that morphogenesis could be regarded as "music of blood" (Greg Bear has written a fascinating scifi book with this title).

2.9.1 Catalysis and morphogenesis

I have ended up to a rather general mechanism of catalysis in terms of generalized Chladni mechanism [L30]. The idea is that one has superposition of say em waves and charged particles enter to the surfaces at which electric force vanish. If magnetic forces is parallel to the surface, they state at the surface. If the interfering waves have same frequency the situation is stationary. Also slowly varying frequency can be allowed if the frequency is small as compared to the time scale of the re-organization of charged particles to the nodal surface of electric field.

In TGD framework the superposition of fields is replaced with superposition of corresponding classical forces on charged particles. MEs are carriers of the counterparts of classical fields and one can have analogs of standing waves as MEs carrying the analog of plane wave having fixed frequency. Charged particle in region of $H = M^4 \times CP_2$ containing disjoint union of MEs of this kind touches all MEs and experiences the sum of the forces created by the fields at MEs. Charged particles could be also replaced by magnetic flux tubes carrying charge particles. Using pairs of MEs for which waves propagate in opposite directions one obtains effective standing waves and one can form disjoint unions of these pairs in the same many to obtain more complex nodal surfaces.

Biochemical reactions are central for morphogenesis at molecular level. The general TGD based vision is that MB containing dark matter controls biochemistry. This would explain why biochemical reactions can occur coherently in the scale of cell or even longer scales. One can even ask whether the fundamental dynamics is that of MBs and MEs representing TGD counterparts of radiation fields and whether MB in 4-D sense serves as a template for the biochemical self-organization patterns. The question is whether the generalized Chladni mechanism for MEs [K76] could play a role in bio-catalysis.

Conditions on bio-catalysis

Bio-catalysis is key mechanism of biology and its extreme efficacy remains to be understood. Enzymes are proteins and ribozymes RNA sequences acting as biocatalysts.

What catalysis demands?

1. Catalyst and reactants must find each other. How this could happen is very difficult to understand in standard biochemistry in which living matter is seen as soup of biomolecules. I have already already considered the mechanisms making it possible for the reactants to find each other. For instance, in the translation of mRNA to protein tRNA molecules must find their way to mRNA at ribosome. The proposal is that reconnection allowing U-shaped magnetic flux tubes to reconnect to a pair of flux tube connecting mRNA and tRNA molecule and reduction of the value of $h_{eff} = n \times h$ inducing reduction of the length of magnetic flux tube takes care of this step. This applies also to DNA transcription and DNA replication and bio-chemical reactions in general.

2. Catalyst must provide energy for the reactants (their number is typically two) to overcome the potential wall making the reaction rate very slow for energies around thermal energy. The TGD based model for the hydrino atom having larger binding energy than hydrogen atom claimed by Randell Mills [D2] suggests a solution [L29]. Some hydrogen atom in catalyst goes from (dark) hydrogen atom state to hydrino state (state with smaller h_{eff}/h and liberates the excess binding energy kicking the either reactant over the potential wall so that reaction can process. After the reaction the catalyst returns to the normal state and absorbs the binding energy.

3. In the reaction volume catalyst and reactants must be guided to correct places. The simplest model of catalysis relies on lock-and-key mechanism. The generalized Chladni mechanism forcing the reactants to a two-dimensional closed nodal surface is a natural candidate to consider. There are also additional conditions. For instance, the reactants must have correct orientation. For instance, the reactants must have correct orientation and this could be forced by the interaction with the em field of ME involved with Chladni mechanism.

4. One must have also a coherence of chemical reactions meaning that the reaction can occur in a large volume - say in different cell interiors - simultaneously. Here MB would induce the coherence by using MEs. Chladni mechanism might explain this if there is there is interference of forces caused by periodic standing waves themselves represented as pairs of MEs.

Phase transition reducing the value of $h_{eff}/h = n$ as a basic step in bio-catalysis

Hydrogen atom allows also large $h_{eff}/h = n$ variants with $n > 6$ with the scale of energy spectrum behaving as $(6/n)^2$ if the $n = 4$ holds true for visible matter. The reduction of n as the flux tube contracts would reduce n and liberate binding energy, which could be used to promote the catalysis.

The notion of high energy phosphate bond is somewhat mysterious concept and manifests as the ability provide energy in ATP to ADP transition. There are claims that there is no such bond. I have spent considerable amount of time to ponder this problem. Could phosphate contain (dark) hydrogen atom able to go to the a state with a smaller value of h_{eff}/h¡ and liberate the excess binding energy? Could the phosphorylation of acceptor molecule transfer this dark atom associated with the phosphate of ATP to the acceptor molecule? Could the mysterious high energy phosphate bond correspond to the dark atom state. Metabolic energy would be needed to transform ADP to ATP and would generate dark atom.

Could solar light kick atoms into dark states and in this manner store metabolic energy? Could nutrients carry these dark atoms? Could this energy be liberated as the dark atoms return to ordinary states and be used to drive protons against potential gradient through ATP synthase analogous to a turbine of a power plant transforming ADP to ATP and reproducing the dark atom and thus the "high energy phosphate bond" in ATP? Can one see metabolism as transfer of dark atoms? Could possible negentropic entanglement disappear and emerge again after ADP$\rightarrow$ ATP.

Here it is essential that the energies of the hydrogen atom depend on $\hbar_{eff} = n \times h$ in as $\hbar_{eff}^m$, $m = -2 < 0$. Hydrogen atoms in dimension D have Coulomb potential behaving as $1/r^{D-2}$ from Gauss law and the Schrödinger equation predicts for $D \neq 4$ that the energies satisfy $E_n \propto (h_{eff}/h)^m$, $m = 2+4/(D-4)$. For $D = 4$ the formula breaks since in this case the dependence on $\hbar$ is not given by power law. m is negative only for $D = 3$ and one has $m = -2$. There $D = 3$ would be unique dimension in allowing the hydrino-like states making possible bio-catalysis and life in the proposed scenario.

It is also essential that the flux tubes are radial flux tubes in the Coulomb field of charged particle. This makes sense in many-sheeted space-time: electrons would be associated with a pair formed by flux tube and 3-D atom so that only part of electric flux would interact with the electron touching both space-time sheets. This would give the analog of Schrödinger equation in Coulomb potential restricted to the interior of the flux tube. The dimensional analysis for the 1-D Schrödinger equation with Coulomb potential would give also in this case $1/n^2$ dependence. Same applies to states localized to 2-D sheets with charged ion in the center. This kind of states bring in mind Rydberg states of ordinary atom with large value of n.

The condition that the dark binding energy is above the thermal energy gives a condition on the value of $h_{eff}/h = n$ as $n \leq 32$. The size scale of the dark largest allowed dark atom would be about 100 nm, 10 times the thickness of the cell membrane.

2.9.2 The notion of bio-harmony and morphogenesis as music

For few years ago I constructed a model for harmony in music [L9] [K58]. The idea was that Pythagorean 12-note scale is represented as closed non-self-intersecting curve at icosahedron having 12 vertices and 20 face triangles with subsequent points of curve being nearest neighbors such that the frequencies for them differ by a scaling factor 3/2. This gives slightly more than 7 octaves giving rise to the discrepancy already well-known for Pythagoras. The frequencies were projected to the basic octave by octave equivalence to get 12-note scale.

These closed curves at icosahedron related by icosahedral symmetry are equivalent and one obtains finite number of non-equivalent curves known as Hamiltonian cycles. Only cycles having symmetries were considered. Each would define a harmony with 20 basic 3-chords assignable to the triangular faces of icosahedron. Hamiltonian cycles are classified by their symmetries: symmetry group can be maximal Z_6, Z_4, or Z_2 which can correspond to π rotation or reflection.

The connection with genetic code came as a total surprise.

1. Icosahedron has 20 faces and this led to the question whether they could correspond to the 20 amino-acids. The observation was that 60=20+20+20 DNAs could be interpreted in terms of icosahedral harmonies corresponding to 3 Hamiltonian cycles with symmetry groups Z_6, Z_4 and Z_2. This gives 256 different bio-harmonies.

2. What about missing 4 DNAs? There are also two amino-acids (Pyl and Sec), which are appear in Nature and are coded by a variant of genetic code. Should one add tetrahedron in order to obtain the additional codons and amino-acids and two variants of the code. Also the failure to obtain exactly 7 octaves can be used to argue that one must add tetrahedron as glued to one side of icosahedron. This would give one additional note corresponding to the note going slightly out of the octave scale. The outcome is indeed two slightly different variants of the genetic code. What is so remarkable that the model predicts correctly the numbers of codons coding for a given amino-acid.

How to realize bioharmonies?

1. The proposal was that genetic code is realized as sequences of 3-chords represented in terms of dark photons with frequency ratios determined by the given bio-harmony. Since dark photons can transform to ordinary photons identified as bio-photons, also interaction with visible matter would be possible. The transformation to ordinary sounds is also possible that the connection with music would be very concrete.

2. The dark photons would couple to dark variants of genes proposed to be realized as dark proton sequences [L25]. Remarkably, also this realization of the genetic code predicts the

numbers of codons coding for a given amino-acid correctly. If the notes of the 12-note scale correspond to the cyclotron frequencies assignable to the dark protons, the two realizations would be connected. For dark proton the cyclotron frequency in the endogenous magnetic field of .2 Gauss is 300 Hz so that the "music of blood" would be in the same frequency range as ordinary music. The notes of the scale would correspond to a spectrum of magnetic field strengths as indeed assumed for bio-photons. Large value of $h_{eff} = h_{gr}$ would guarantee that energies are in the range of bio-photon energies and are biologically effective.

3. Musical harmonies would be central in biology and the essence of what it is to be living. The functioning organism is very literally like an orchestra. Various disorders would be analogous to dissonances. There are 256 different harmonies and same DNA sequence could correspond to any of these harmonies. Music is expression of emotions and generates emotions. The natural proposal is that these harmonies provide the molecular realization of emotions and basic building bricks of also our our emotions.

4. This would give rise to a kind of resonance based communication and control system used by MB. For instance, the translation of mRNA sequence to amino-acid sequence would be like playing a piece of music. tRNAs attaching to given mRNA codon would correspond to the same 3-chord. Also amino-acids would correspond to dark DNA codons (dark protons in various states) and corresponding cyclotron frequencies.

This picture provides a different view about genetics. The reductionistic interpretation is that given gene corresponds to a given trait and enormous amount of work is done to deduce correlations between traits and genes. This picture has been challenged. It seems that the reductionism to single gene level simply does not make sense. If it would, it should be possible to predict given trait given gene corresponds: this kind of formula is extremely unfeasible. One must consider the entire genome.

The ability of the collection of genomes to play together to produce music of life would be essential. Disorders would be deviations from harmony and would be also caused by genetic mutations. Already earlier I ended up to a generalization of the notion of genome inspired by the notion of MB. The flux sheets of the MB would go through the DNA and could integrate the genomes of different cells to single coherent whole. One would have hierarchy: coherent gene expression in the scale of organism and even entire population would become possible using collective genome controlled by MB would become possible.

Here a connection with TGD inspired model of morphogenesis [L30] suggests itself strongly. Topological light rays (NEs) are correlates for communications between MB and biological body involving control by MB and sensory input from biological body and EEG is one example ab out these communications.

This inspires a model of morphogenesis based on generalized Chladni mechanism meaning that charged particles or even charged magnetic flux tubes are driven to the nodal surfaces of electric fields representing standing waves. The standing wave are represented as pairs of MEs with opposite direction of momentum (analogs of planewaves). The charged article experiences the sum of the forces assignable to various fields at various space-time sheets so that effectively the fields superpose. Nodal surfaces would correspond to nodal surfaces of this effective field.

The 3-chord sequences could play a crucial in morphogenesis and morphostasis. Since the frequencies of the chord are in general different, the fields representing the members of the code cannot define static nodal surfaces. Hence given 3-chord could define a region of 3-space as union of 3 nodal surfaces. In the case of DNA they would correspond to the 3 letters of the codon. Note that dark codons themselves correspond to the states of dark proton mapped to frequency triplets and do not allow this kind of decomposition.

2.9.3 About Chladni mechanism, bio-harmonies, and genetic code for morphology

I have proposed that generalized Chladni mechanism plays a key role in morphogenesis and morphostasis [L30]. Since the nodal surfaces of field patterns define the shape of structures one can wonder whether Chladni mechanism realizes on 3-chords of bio-harmonies. Could morphogenesis express the music based on bioharmonies? On can consider this idea in more detail.

1. Single ME allows only waves propagating with light velocity and standing waves are impossible. For a pair of MEs carrying analogs of plane waves with opposite spatial directions and same frequency, the nodes at which the em force experienced by charge particle vanishes, correspond to the vanishing of $sin(\omega t)sin(kz)$ at $z = n\pi/k$. Cladni surface is 1-D lattice formed by 2-D cross sections of ME.

2. A region of M^4, where several ME pairs with the same frequency have a non-empty projection, represents an analog of hologram. Now the nodal surfaces correspond to the vanishing of the sum for the electric fields associated with MEs. For single ME there is one condition to be satisfied but for several (at least two) MEs meeting at same region of plane there are two conditions and they allow as a solution 1-D surface in the region where MEs meet. For more than 2 ME pairs, which are not in plane, the nodal surface consists of points.

   If MEs are parallel with magnetic flux tubes the charged particles represented as wormhole contacts connecting ME and flux tube goes to the nodes $z = n\pi/k$. If there are 3 MEs (not in plane) for which the intersection or M^4 projections corresponds to a nodal surface of each then the nodal surface for all of them consists of single point in the intersection.

   The localization to single point might be too strong a condition. Rather, 1-D localization of charges inside flux tubes form a network of flux tubes with nodes at the nodes for all flux tubes that meet might be enough. In this case the frequencies assignable to the flux tubes need not be identical. TGD based model for musical harmony relying on icosahedral and tetrahedral geometries leads also to model for genetic code and suggests strongly the realization of genetic code in terms of 3-chords. The notes of the chord would correspond to 3 different nodal surfaces assignable to DNA nucleotides for instance.

3. With motivations coming from biology I have proposed that magnetic flux tubes and MEs parallel to them form lattice like structures with MEs and flux tubes defining the coordinate lines of a coordinate grid. For plane wave MEs with same frequency in these directions the nodal points are at the nodes of the grid and one obtains a lattice like structure. Also icosahedral quasicrystals can be considered.

   There are good reasons to expect that also curvilinear MEs with the directions of wave vector and polarization vector depending on the position along ME. This would allow also quasi-lattices, which could be important in biology. Chladni mechanism for these structures could allow to catalyze chemical reaction in the nodes of the lattice and achieve the mysterious looking large scale coherence of biochemical reactions. Quasi-lattice could correspond also to the tissue formed by cells, to lipid layer of cell membrane, or to DNA or protein as 1-D lattice.

Consider now the possible connection between genetic code and the geometry of the 3-D lattice like structure.

1. I have also proposed that through each DNA codon there goes 3 approximately orthogonal flux tubes - one tube per nucleotide - connecting it to some other molecules. One flux tube would be roughly parallel to DNA and two orthogonal to it. The molecules associated with the nodes could be other DNA nucleotides. There are many options to consider. The nucleotide of second DNA strand and the corresponding nucleotide in the DNA of second cell can be considered. The genomes of different cells could form a 3-D lattice with lattice points represented by DNAs and flux tube connections between corresponding DNA codon. The model for DNA-cell membrane system as topological quantum computer [K3] leads to ask whether DNA codons not involved with the coding of proteins could be connected with lipids of the lipid layer and define braids essential for topological quantum computation. Now the flux tube pair could be also associated with entire codon.

   Could the number 3 for DNA nucleotides correspond to the dimension of the quasi-lattice involved? Could the flux tubes in three approximately orthogonal directions go through the three nucleotides and connect them to the corresponding DNA nucleotide in another cell? Could this correspondence preserve the linear order or can one imagine braiding but requiring that nucleotide is connected to its conjugate always as in DNA double strand?

This correspondence would give a profound geometric meaning for the number of letters of DNA codon. Only 1-D localization at the vertices of the flux tube is possible. The orientation of molecules entering to the node along 3 flux tubes (also essential for the catalyst action) could be interpreted as catalyst and the orientation of the catalyst and reacting molecules could be determined to a high degree by the interaction with em fields of the flux tube.

2. The lattice constants for the flux tubes connecting nucleotides in different cells should be same but in the simplest picture they would be given by $d_i = a_i = c/\omega_i$. One should require $d = n_i a_i = n_i c/\omega_i$. If the frequencies are in rational ratios as for Pythagorean scale the integers can be chosen in this manner. The number n_i of nodes along ME between different cells proportional to ω_i would code for the frequency geometrically. The special emotional role of Pythagorean scale could reduce to a geometric condition, whose failure would tend to deform DNA!

3. The possibility to have different frequencies for different flux tubes and the fact that the lattice constant defined by the wavelength is given by $a_i = n_i c/\omega$ means that the DNAs of different cells form an orchestra with music consisting of dark photons possibly being able to transform to dark phonons by piezo-electricity. The frequency scale should correspond to the inverse of the cellular distance. It is to be expected that also shorter scales corresponding to UV frequencies in bio-photon spectrum are involved.

To sum up, this picture would mean a long sought for direct connection between genes and the morphology of organism determined by the quasi-lattice like structure.

2.10 Logic, Fermions, And Language

The state basis for the fermionic Fock space has a natural interpretation as a Boolean algebra (fermion number =1/0↔ 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 labeling 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).

2.10.1 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 labeled by the indices labeling 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} of statements consistent with given atomic statement (one bit fixed) as axioms. An interesting possibility is that only these statements 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 the statements consistent with given atomic statement, 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.

2.10.2 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:

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

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

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

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.

2.10.3 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 $A \to B$ with the instances of A and B represented as elements Fock state basis fixed by the diagonalization of the density matrix defined by $M-$-matrix. Hence Boolean consciousness would be basic aspect of zero energy states. Physical states would be more like memes than matter. Note also that the fundamental super-symmetric duality between bosonic degrees of freedom (size and shape of the 3-surface) and fermionic degrees of freedom would correspond to the sensory-cognitive duality.

This would explain why Boolean and temporal causalities are so closely related. Note that zero energy ontology is certainly consistent with the usual positive energy ontology if unitary

process U associated with the quantum jump is more or less trivial in the degrees of freedom usually assigned with the material world. There are arguments suggesting that U is tensor product of of factoring S-matrices associated with 2-D integrable QFT theories [K16]: 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.

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

Matrix logic [A6] emerges naturally when one calculates expectation values of logical functions defined by the zero energy states with positive energy fermionic Fock states interpreted as inputs and corresponding negative energy states interpreted as outputs. Also the non-commutative version of the quantum logic, with spinor components representing amplitudes for truth values replaced with non-commutative operators, emerges naturally. The finite resolution of quantum measurement generalizes to a finite resolution of Boolean cognition and allows description in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of infinite-dimensional Clifford algebras of the world of classical worlds (WCW) identifiable in terms of fermionic oscillator algebras. $\mathcal{N}$ defines the resolution in the sense that quantum measurement and conscious experience does not distinguish between states differing from each other by the action of $\mathcal{N}$.

The finite-dimensional quantum Clifford algebra $\mathcal{M}/\mathcal{N}$ creates the physical states modulo the resolution. This algebra is non-commutative which means that corresponding quantum spinors have non-commutative components. The non-commutativity codes for the that the spinor components are correlated: the quantized fractal dimension for quantum counterparts of 2-spinors satisfying $d = 2cos(\pi/n) \leq 2$ expresses this correlation as a reduction of effective dimension.

The moduli of spinor components however commute and have interpretation as eigenvalues of truth and false operators or probabilities that the statement is true/false. They have quantized spectrum having also interpretation as probabilities for truth values and this spectrum differs from the spectrum $\{1, 0\}$ for the ordinary logic so that fuzzy logic results from the finite resolution of Boolean cognition [K83].

2.10.5 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 [A13] 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 $N(DNA) = (M(n) + 1)/2 = 64$ of statements consistent with given atomic statement at level n regarded as special cases of general theorems. GC corresponds to the mapping $x \to x^{k_{n-1}} = x^6$ 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 $a \to b$ with a and b represented in terms of positive and negative energy parts of the zero energy state. If one has negentropic entanglement this kind of state has interpretation as an abstraction - a "law of physics" - representing as a quantum superposition various instances of a more general law.

The simplest situation corresponds to a CD having only single positive energy fermion and negative energy fermion at its light-like boundaries. The fermion number or spin or isospin of the fermion could represent qubit. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy, when combined with p-adic length scale hypothesis, led to a prediction of order .1 seconds for the duration of the "wake-up" period of sub-self corresponding to the codeword of the memetic code. Since the CD assignable to electron has time scale.1 seconds and the CD assignable to u and d quarks has time scale 1/1.28 milliseconds there is a temptation to proposed that the quark-like sub-CDs of electronic CD give to a realization of memetic code word as a

sequence of 126 quark like sub-CDs. u and d quarks would be assigned to the magnetic flux tubes connecting DNA and the lipids of the cell membrane in the model of DNA as topological quantum computer. Clearly, beautiful connection between new elementary particle physics, genetic code, nerve pulse activity, DNA as topological quantum computer, logical thought, and the basic time scales of speech are suggestive.

This codeword consists of 126 bits represented by quarks such that the two possible magnetization directions correspond to the two values of Boolean statement. This implies that the duration of single bit should 1/1260 seconds. The duration of the nerve pulse is slightly longer than this which might mean that the full memetic code is realized as membrane oscillations rather than nerve pulse patterns. Both hearing and vision have .1 second time scale as a fundamental time scale and sounds are indeed coded to membrane oscillations in ear.

One can consider also the realization of genetic code with six bits of the codon represented by various scaled up versions of quark CD coming as size powers of 2. In this case the ordering of the bits would come from the size of sub-CD whereas in previous example temporal ordering would define the ordering. It is not however clear whether the powers of two can be realized physically.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20.000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-, 5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is.1 seconds. This could be seen as a support for the realization of some degenerate version of the memetic code as nerve pulse patterns.

The model for the memetic code encourages the following conclusions.

1. Membrane oscillation/nerve pulse patterns correspond to temporal sequences of magnetization directions for quarks representing yes/no Boolean statements.

2. The spin polarization of quarks is changed from the standard direction fixed by the spontaneous magnetization in the direction of axon by a ME moving parallel to axon, and inducing membrane oscillation or even a nerve pulse. Nerve pulses could correspond to a degenerate memetic code resulting by frequency coding for which the number of distinguishable code words is 64, and would thus naturally correspond to the reduction of the memetic code to the genetic code.

A very precise correspondence with the basic structures of the genetic code results. mRNA $\rightarrow$ protein translation corresponds to the translation of temporal sequences o magnetization directions to conscious cognitive experiences. Under very natural constraints the mapping to cognitive experiences is not one-to-one and the predicted degeneracy (2^{126} sequences correspond to $(2^{126}-1)/63$ cognitive experiences) can be understood.

One might think that the full memetic code is an evolutionary newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. The full memetic code could be realized for certain regions of brain only. These regions certainly include auditory pathways responsible for the comprehension of speech [K29, K59, K60].

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.

Memetic code, and genetic code as a representation of phonemes?

The average duration of phonemes is about 140 ms, which is by a factor $\sqrt{2}$ longer than the duration.1 seconds of the memetic codon. Durations vary in the range 60-300 ms. Note that the 250-300 Hz rhythm associated with speech organs defines the pitch of speech but phonemes can be recognized even in the absence of the fundamental. The basic pitch of about 250 Hz implies that the number of memetic codons associated single single period is at most 2.

Phonemes can be classified by the vocal tract mechanism generating them and phonemes can be also recognized by their spectral decomposition.

1. Formants [J10, J5] correspond to vowels, approximants (say (r, l) and (j, w)), and nasals (m and n). Only few resonant frequencies are needed to characterize the formant. Lowest formant is below 1 kHz but higher formants above kHz and frequencies up to 3 kHz are possible. It is easy to understand that for vowels the frequency distribution does not depend on time for approximants and nasals it does.

2. Fricatives (hiss, buzz). Fricatives lack the formant structure. Both correspond to a repeated time amplitude peak and frequency distribution involves wide range of frequencies with same intensity.

3. Plosives (such as p, b and t, d) correspond to a single peak in the time domain and constant frequency distribution.

All sensory input might be transformed by a feedback circuit to sequences or notes/memetic codons represented as a modulation of the membrane voltage providing a universal cognitive/emotional representations. Also ordinary phonemes and notes would be represented in this manner.

Also other p-adic codes are possible. Phonemes, the number of which is 41 in American english, could correspond to a sub-code reducing to a genetic code with 64 codons. It is important to notice that the temporal distance between memetic codons does not matter. Other memetic codons could code for recognizable sound patterns not representing phonemes and could have meaning at some other levels of self hierarchy.

One can argue that the representations as "notes" and "phonemes" should carry roughly the same amount of information. For frequency representation as a sequence of "notes" 10 octaves represents upper limit for the modulation frequencies. For high modulating frequencies the representation tends however to fail since slow modulation is not anymore in question. This would mean that the number of distinguishable "notes" is below $10 \times N$, where N is the maximum number of distinguishable frequencies inside octave. $N = 12$, the number of half notes in octave, would give 120 different "notes", which is not far from 127 and corresponds to M_7 allowing $2^7 - 1$ different codons making almost 7 bits with bit duration of 67 ms. Since the first codon in pulse-no pulse representation must be always pulse to tell that the codeword starts, this leaves 6 bits and genetic code. Codons can have varying but long enough pauses between them and the average duration .14 s of phonemes allows this. The association of genetic or memetic codons to characteristic spectrograms of phonemes as a function of time and frequency would result by cortical feedback.

Chapter 3

What Music Could Teach about Consciousness?

3.1 Introduction

Oliver Sacks have written marvellous books giving an overview about neurology not possible to obtain by reading highly specialized articles dealing with highly special problem and producing some statistical correlations and giving very little for anyone who tries to gain overall view.

These books are gems also for those trying to understand consciousness and allow to learn how much is already understood and how vast the variety of strange findings that should be explained by the theories of consciousness is. Sacks's books allow also to get idea about the limitations of neuroscience: it is far from clear that all the reported strange findings can be really explained in the framework of neuroscience. What makes these books so enjoyable is that Sacks communicates his message using stories. It is also heart warming to see Sacks's deep compassion towards his patients and the ability to see them as suffering humans.

Recently I have been reading his book "Musicophilia" [J79] dealing with various aspects of music experience. Humans as a species indeed have a very special relation to music. But is it really genuine characteristic of human consciousness? One can even ask whether consciousness emerges only in higher species or whether it could be in some form a characteric of any living or even inanimate system? I am not the only quantum consciousness theorists forced to consider panpsychism in some form. In this framework one can ask whether music like aspects of conscious experience could be universal and only especially highly developed in humans?

3.1.1 Can One Do Without Music?

According to Sacks, some writers - for instance Pinker [J91] - claim that we could quite well do without music. Most of us would disagree with Pinker on basis of personal experience.

1. Left brain hemisphere dominates as far as functions of brain understood in the framework of neuroscience are considered. It is true, that brain hemispheres could be fighting for metabolic resources and power just as all other life forms and this could lead to suppression of those functions which left hemisphere can take care of.

2. Musician's brain seems to be unique in the sense that its more democratic than average brain. First of all, neurologist can immediately identify musician's brain by visible changes in its anatomy. Corpus callosum connecting the two hemispheres is unusually thick so that left and right brain hemisphere are in much more democratic relationship than usually. Also planum temporale in the auditory area is asymmetric being bigger at the right side. Most of us cannot do without music. Could it be that behind music is something which is vital element of being conscious?

3. One can argue that the dominance of left hemisphere in adults reflects the fact left brain dominated consciousness is optimal for survival. Cognitive representations are abstractions

and require much less bits than sensory representations, which are concrete and extremely detailed. The symbolic character of cognitive representations makes them also much more flexible. To understand what I mean consider the representation of a page of book using bit graphics to that using vector graphics file with letters identified as symbols allowing large number of representation in various fonts and pictures decomposed to basic elements. One might say that cognitive representations are for scientist and sensory representations for artist. But again: we cannot live without art!

4. But why Nature would have built right hemisphere at all if it were useless? Could right brain have hitherto un-identified functions understandable only by widening the scope? EEG has been often often seen as a mere neural noise but it is now known that EEG codes for the contents of consciousness: could it be that EEG relates to the special functions of right hemisphere somehow? It seems useless to code information to EEG if it is not communicated somewhere. Where? And what would distinguish between the EEGs of right and left hemisphere?

5. Interestingly, it is *right* brain hemisphere that dominates for children in fetus. Left brain also develops much more slowly suggesting the development of cognitive abilities characterizing brain hemisphere takes a longer time. Does left hemisphere continue cognitive differentiation from the level, where right hemisphere stopped? Or do both hemispheres have cognitive abilities potentially? These observations serve as important hints as one tries to understand what lies behind right-left dichotomy. How the left hemisphere differs from the right one. Left hemisphere cognizes: how cognition is realized at fundamental level?

On basis of these observations I disagree with Pinker.

3.1.2 Overall View Suggested By *Musicophilia*

In the sequel will I restrict the consideration to those stories of *Musicophilia*, which I find of special interest from the point of view of TGD inspired theory of consciousness. The outcome is a more precise formulation for the general TGD inspired vision about brain based on basic ideas of quantum TGD.

Zero Energy Ontology (ZEO) implies a new view about the relation between geometric and experienced time and allowing to generalize quantum measurement theory to a theory of consciousness.

Strong form of holography implies the analog of AdS/CFT duality between 2-D representation of physics based on string world sheets and partonic 2-surfaces and 4-D space-time representations. This duality is not tautology and this inspires the idea that these two representations correspond to two modes for consciousness motivating "Left brain talks, right brain sings" metaphor.

1. Language and music could relate to two dual representations of conscious information - local and holistic, cognitive and sensory. Discretization of function/its Fourier transform as a collection of its values at discrete set values of time/frequencies would correspond local/holistic approximations of function. In principle any conscious entity - self- could utilize these two representational modes at appropriate quantum criticality.

2. The holistic "musical consciousness" is assignable to right brain hemisphere and according to the stories of Sacks seems to characterized by episodal sensory memories. TGD based view about memories relies on ZEO: the memories would be mental images with sensory input from geometric past, genuine sensory experiences of time reversed sub-selves! This picture simplifies considerably and one can see all memories - sensory, cognitive, or emotional - as analogs of phantom pain, which would be also a sensory memory and even more a genuine sensory experience. It is even possible that our biological bodies are used by two selves: right brain hemisphere sleeps when we are awake and vice versa. Even the experiences of epileptics about having double consciousness could be understood.

3. A more concrete realization of "Left brain talks, right brain sings" metaphor relies on the assumption that "magneto-anatomy" is universal. Only the "magneto-physiology" characterized by the values of h_{eff} characterizing quantum criticality and defining a kind of intelligence quotient dictating the span of long term memory and planned action varies.

   h_{eff} would differ for the magnetic bodies of various brain areas, and the spectrum of h_{eff} for right and left brain would differ and characterize their specializations. For instance, the value of h_{eff} would be large (small) for the cognitive areas of left (right) brain and small (large) for some higher sensory areas of right (left) brain. Magnetic bodies form a fractal hierarchy and one can characterize even individual cells and neurons by the value of h_{eff} associated with them. The spectrum for h_{eff} allows also to distinguish between members of the same species since it defines the skill profile. This obviously goes far beyond the genetic determinism.

3.2 Impressions Created By Stories

The following summary is only a rough sketch about stories of Musicophilia, a clumsy attempt to summarize what I see as especially interesting from my own point of view. My interests are selfish (or better to say, TGDeish): I try to abstract what is interesting from the point of view of quantum consciousness theory and I am eager to see whether these stories might help to develop a deeper vision about TGD inspired theory of consciousness. I strongly encourage the reader to read *Musicophilia* and also other books to get more balanced view: these books are rare gems.

3.2.1 Emergence Of Exceptional Music Abilities

Sacks deals with special music abilities. The exceptional musical talents are often - not always - accompanied by profound cognitive in-abilities and one speaks of idiot savants. Savant abilities involve memory feats suggesting that savants remember differently: one could speak of sensory memories.

Savants can also have exceptional mathematical talents such as ability to "see" the decomposition of integers to primes and the ability to perform complex algebraic operations to numbers. Some mathematicians possess these magic gifts: Ramanujan - certainly not a savant - is the classic example. There are also people having exceptional motor skills - consider only piano virtuosos and athletes who must have holistic control of their entire bodies.

These special gifts often emerge as one loses some cognitive abilities assignable to the left brain. Also sensory defects - say blindness at young age - can be accompanied by these abilities.

Also music training initiated at very early age can lead to the development of this exceptional talents. One can ask whether these sensory talents are necessarily accompanied by cognitive in-abilities and where they are associated with consciousness different from the standard wake-up consciousness.

1. In music these talents include absolute pitch: person "sees" the pitch of heard or imagined note with an accuracy better than one quarter note and can associate with it note or even frequency. The process is completely spontaneous and involves no comparisons.

   An analogy with the perception of visual colors comes in mind. Not only the ratios of frequencies must be rational in good accuracy in order to feel aesthetic but different keys sound different. One example mentioned by Sacks is a finnish scientist Olavi Sotavalta able to tell the frequency of the sound produced by insect with an accuracy better than Hz.

   Absolute pitch can be also a curse for a musician. Since the music piece transformed to different key is not the same piece anymore. Same effect in visual perception is achieved if the colors of painting would be shifted by scaling the frequency in the same manner as the transponation to different key scales the frequencies. This explains why classic compositions are in definite key: this matters for the composer with absolute pitch but for a person without absolute pitch like me this is of course of no significance.

   The ability to name the note or tell even its frequency need not require anything outside standard neuroscience and can be explained as a learned association. One can of course ask what association is at the level of conscious experience.

2. Absolute pitch is more general for musicians than average population and appears more often for musicians who have started at young age. Absolute ear is more general in cultures in which the pitch of speech is important (vietnamise, mandarin) suggesting that it can develop during early age.

Sacks tells stories about musical savants.

1. Musical savant can have absolute sensory memory for music and reproduce the music piece in detail after hearing it just once: as if she would "see" the entire piece. In one case told by Sacks the memory of savant about read text was phonographic rather than photographic. Similar holistic sensory memory but with all the details present is sometimes associated with visual perception. This kind of holism is different from holism based on abstraction sacrificing the details.

   Musical savant can be also highly sensitive to the harmony and the style of the composer and improvise music in this style. This might be understood assuming only that the person has sensory memory about the music and can literally hear it and improvise against this background. If cognition were involved a deep theoretical understanding of music would be required and this is typically lacking.

2. There is a story about people suffering from a congenital disorder known as Williams syndrome and resulting in a strange mixture of intellectual strengths and weakness. Sacks calls these people hypermusical species. They are classified as intellectually retarded (IQ is around 60) but they have unusual command of language, are extremely social and friendly, and have a deep passion for music.

3. Also ordinary persons can have sensory memories or hallucination like states as they fall asleep (hypnagogia) or wake-up (hypnopompia). These experiences seem to be associated with a loss or change of type of consciousness. Could left brain dominance/consciousness transform to right brain dominance/consciousness or vice versa? If so right brain would not be useless at all: we would spend one half of our life in the alternative mode of consciousness!

4. Also visual and auditory hallucinations might have explanation in terms of right brain dominance. For instance, schizophrenics have hallucinations and sensory memories accompanied by cognitive impairing. Schizophrenic consciousness (as also that of children) has been proposed by Jaynes to correspond to bicameral consciousness, which would have preceded the modern left brain dominated cognitive consciousness.

Why the character of right and left brain consciousness would be so different: to my opinion neuroscience does not answer this question.

3.2.2 Phantom Fingers And The Problem Of Time

One fascinating story is about "phantom fingers". The brother of philosopher Wittgenstein was a concert pianist, who lost his second arm in World War I. He however experienced the fingers of his right hand as still existing and "played" with it to develop fingerings to music pieces. He experienced of receiving virtual sensory input from the fingers and also sent motor input to the stump as became clear from the movement of the stump.

The neuroscience explanation is that brain contains sensory maps of body parts and the sensory experience is localizable at this kind of representations in sensory cortex. This view has however an unsolved problem. Neurons or neural circuits in various sensory pathways should be somehow different - neurons for quale "red" should be different from those for note G or sensation of touch - but there seems to be no differences.

naïvely one could argue that maybe the sensory qualia are localized at the level of sensory receptors. Phantom leg is a standard objection against this idea. But could the naïve explanation be correct after all and force to dramatically modify our views about time?

As will be found, TGD based view about the relationship of geometric time and experienced time combined with ZEO indeed allows to consider a different explanation allowing also to understand the sensory memory feats of of idiot savants and providing a general explanation for right-left dichotomy and for why miraculous sensory abilities are often accompanied by cognitive inabilities.

3.2.3 When Music Suddenly Becomes A Passion

Sacks tells real life stories about various fascinating phenomena surrounding music experience: sudden musicophilia - the emergence of special musical talents and deep passion for music; epileptic seizures during which patient hears music with a strange feeling of familiarity; epilepsy induced by music; music imagery allowing to almost hear the imagined music (Beethoven who became deaf is a classic example in this respect); musical hallucinations; etc...

The sudden emergence of musicophilia suggests that right brain consciousness ceases to be inhibited in wake-up state and becomes a dominating part of conscious experience and that sensory memories characteristic for it appear too. This would suggests that right hemisphere is specialized to produce sensory memories.

The dejavu type experiences are of special interest from the point of view of TGD inspired theory of consciousness since they might give a way to test the vision about the relationship between two times and ZEO based view about memory.

3.2.4 Music And Neurological Defects

Sacks tells how music has helped his patients to cope with various brain defects classifiable as sensory, motor, cognitive, emotional, etc... Some examples suggest that music is not at all so useless outcome of evolution as Pinker argues and that musical right brain consciousness can come in rescue when left brain suffers damage.

1. The defects considered are often those of left hemisphere. Say those of frontotemporal regions leading to semantic dementia (`http://tinyurl.com/zscxotc`), non-fluent aphasia, and changes in social behavior and conduct such as poor impulse controls.

2. (Non-fluent) aphasia is motor defect and due to the damage of Broca's area (`http://tinyurl.com/yb8f7fal`) located in promotor area in the left hemisphere and responsible for the production of speech. The victim looses the ability to produce speech although he remembers the meanings of the words. The patient can however to learn to communicate fluently by singing. Singing as a mode of expression is naturally associated with the right brain and one can say that right brain hemisphere comes in rescue.

3. Person can also suffer from fluent aphasia, kind of mirror image of aphasia. Person can produce but t not understand speech speech - in other words cannot assign meaning to the words or sentences that she hears. Fluent aphasia as a receptive defect associated with the damage to the Wernicke's areas in left hemisphere (`http://tinyurl.com/yb8zp5rp`). From neuroscience perspective it is natural to consider the possibility that the patient does not understand what she hears but understands what she says or vice versa. Sacks talks also about "semantic aphasia": I am not quite sure whether he means that the words that the person produces have no meaning to her: this would suggest damage of both Broca and Wernicke areas. What is however remarkable that that the patient can learn to understand communications by singing: right brain again!

4. As opposed to aphasia, amnesia is a defect of right hemisphere. The victim loses completely all episodal memories and becomes a person without past and future: life story can reduce to few seconds and the persons experiences waking up from sleep or re-incarnating again and again and the world is new in every wake-up. Cognitive abilities are not lost and the patient recalls the meanings of words. Sacks tells a moving story about how a victim of amnesia with help of her loving life companion and music gradually manage to rebuild meaning to his life.

5. In some cases the damage to the frontal areas leads to emotional flatness. Person becomes inert, flat, and indifferent -as Sacks expresses it - and loses ability to initiate actions. Sacks tells about a case in which patient seemed to gain back his emotions while singing: impossible by the damage to the frontal lobes if neuroscience view is correct. Episodal memories seem to be characteristic for right brain consciousness. Could temporary right brain consciousness stimulated by singing allow to have episodal memories with emotional content? Could this be an emotional analog of phantom leg.

3.3 TGD Inspired Theory Of Consciousness Very Briefly

The believer in quantum consciousness of course wonders whether these strange findings could be understood in terms of his or her pet theory. First one must try to identify the questions that one must answer if one wants to understand the findings about music and brain described so elegantly by Sacks. My proposal for the list of correct questions if following.

1. What are the quantum physical correlates of mental image? How mental images are born and die? What features are as mental images? What their binding to sensory percepts does mean physically?

2. What is the relationship between geometric time of physicists and the experienced time. What memories are?

3. Do right- and left brain consciousness differ in some fundamental manner and how this is possible taking into account the similar looking neuronal structure? These possibly existing fundamentally different modes of consciousness should have correlates, which belong outside the neuroscience and perhaps even outside the standard physics.

   What are these correlates and how do they relate to EEG? Note that EEG is a poorly understood aspect of neuroscience which until hitherto has been regarded as neural noise but is now know to correlate with contents of consciousness and with the state of brain. The strange effects of ELF em fields on vertebrate were indeed the starting point of the TGD based approach to brain. Bio-photons have been known for long time and are now taken seriously and there might be a relationship.

I can answer these questions only on my own behalf and to do it I must introduce the basic notions and ideas of TGD inspired theory of consciousness. I will not go into details here because I have done this so many times and just suggest that the reading of some basic stuff about TGD inspired theory of consciousness. Suffice it to list just the basic ideas and notions.

3.3.1 Basic Ideas Of TGD Inspired Theory Of Consciousness

1. ZEO and causal diamonds (CDs) and hierarchy of Planck constants assignable to quantum criticality are basic notions. Number theoretic vision is also central. In particular, adelic physics fusing real physics and various p-adic physics as correlates for cognition is also basic building brick.

2. Consciousness theory is generalization of quantum measurement theory constructed to solve the basic problems of ordinary quantum measurement theory: observer becomes self described by physics rather than being outsider of the physical world. Weak form of Negentropy Maximization Principle (NMP) [K41] defines the basic variational principle of consciousness and state that the negentropy gain in state function reduction is maximal.

3. The notion of observe as an outsider to the physical world is replaced by that of self. Self corresponds to a state function reduction sequence to the same boundary of CD. In standard quantum measurement theory this sequence does not change the state but in TGD framework the state at the opposite boundary of CD and even opposite boundary changes. This gives rise to the experience flow of time having the increases of the temporal distance between the tips of CD as a geometric correlate. Self dies as the first reduction to the opposite boundary takes place and re-incarnates at the opposite boundary as its time reversal. Negentropy Maximization Principle forces it to occur sooner or later.

   Self hierarchy is a basic notion in TGD inspired theory of consciousness. Self experiences sub-selves as mental images. The continual birth and death of mental images supports this view if one accepts the idea about hierarchy. One can also consider identification for what the change of the arrow of time means for mental image. The time inversion of mental images about external world generates the mental image at opposite boundary of CD and this suggests interpretation as memory - something so simple that I discovered it only when trying to understand phantom leg.

4. TGD physics is number theoretically universal. This means that real physics is generalized to adelic physics. Besides real number based physics also p-adic physics assignable to p-adic number fields and their algebraic extensions are introduced and identified as physical correlates of cognition: kind of mind stuff of Descartes besides res extensa. Field equations make sense also in p-adic number fields and one can define what preferred extremal of Kähler action mean in p-adic context.

   One can speak also about intersection of realities and p-adicities defined by a particular extension of rational physics. Space-time surfaces are characterized by parameters and if these parameters belong to this extension one can interpreted space-time surfaces either as real or p-adic: the algebra is formally the same. One can algebraically continue the parameters from the extension of rationals to reals and extensions of p-adic numbers and obtains what might be called fundamental sensory and cognitive representations. One can say that fermions localized at string world sheets define the quantum correlates for Boolean cognition and p-adic space-time sheets its space-time correlates.

5. MBs carrying dark matter identified as $h_{eff} = n \times h$ phases of ordinary matter define quantum correlates for selves. Magnetic body (MB) has hierarchical onion-like structure and it communicates with biological body using dark photons propagating along magnetic flux tubes. EEG and its fractal generalization make both communication from/control of biological body to/by MB. Dark matter hierarchy can be reduced to quantum criticality and this in turn has deep roots in the adelic physics.

   MB is and ideal place for the realization of the two basic representation based on pulses *resp.* frequencies behind "Left brain talks, right brain sings" metaphor. 4-D field representations could be realized in terms of massless extremals and pulse representations in terms of supra currents assignable with magnetic flux tubes carrying fermionic strings.

   The completion of organism-environment double to MB-organism-environment triple would be the extension of the ontology of neuroscience needed. Neuroscience alone would not be enough to understand the strange aspects of brain consciousness.

3.3.2 Hierarchy Of Quantum Criticalities And Strong Form Of Holography

The hierarchy of quantum criticalities reduces to strong form of holography in turn implied by strong form of General Coordinate Invariance (GCI).

1. Strong form of holography states that the information about quantum aspects of physics is coded by second quantized induced spinor fields localized at string world sheets and intersecting partonic 2-surfaces at discrete point sets. Collections of string world sheets and partonic 2-surfaces (briefly 2-surfaces) dictate space-time surfaces identified as preferred extremals of so called Kähler action having vanishing Noether charges in a sub-algebra of so called super-symplectic algebra. These conditions effectively eliminate degrees of freedom so that instead of 3-D holograms one has 2-D holograms.

2. The possibility to code space-time surfaces by appropriate boundary conditions at string world sheets (they carry vanishing classical W fields and possibly also Z^0 fields) means that one can reduce to world of classical worlds to a reduced WCW consisting of the collections of these 2-surfaces. This obviously defines the counterpart of AdS/CFT correspondence. Instead of equivalence of QFT at the $n-1$-D Minkowski space defining boundary of AdS^n with string theory in the interior of of 10-D $AdS^n \times S^{10-n}$ one has something which is very near to ordinary holography: the stringy physics at 2-surfaces is dual to the classical physics in the interior of 4-D space-time surface in $M^4 \times CP_2$.

3. This duality is not a tautology! All collections of 2-surfaces need not allow a continuation to a preferred extremal of Kähler action. Continuability implies strong correlations between the 2-surfaces so that one cannot take any collections of 2-surfaces and continue it to preferred extremal.

This is true in real sector. In p-adic sectors the situation is different because p-adic differential equations allow integration constants which have vanishing derivative but are piecewise continuous depending on finite number of pinary digits of the coordinates. This freedom suggests that the continuation to p-adic 4-surface is always possible.

The interpretation would be obvious in consciousness theory. Strong form of holography in the direction $2-D \to 4-D$ corresponds to imagination. Space-time surface can be imagined by continuing the 2-D surfaces to 4-D preferred extremals in p-adic sectors and the imagined space-time surface is not unique. In the real sector this imagination need not be possible in real sector. Imagination is unrealistic!

3.3.3 Selves, Their Time Reversals, And Memories

The notion of self provided by ZEO predicts that selves have time reversals. Could this allow to understand the strange findings about idiot savants?

In this framework the idea about memory recall as communication with the brain of geometric past (time reflection for signals propagating to past) can be formulated more precisely. Memory recall quite generally corresponds to a temporary falling asleep/death of sub-self (mental image) followed by immediate re-incarnation in geometric past and giving rise to mental image located in past.

I have proposed variants of this mechanism such as time like entanglement and emission of signal from the brain of the geometric past back. Time-like entanglement does not seem to be necessary for having sensory memory and signals to geometric future would correspond to a further re-incarnation of sub-self with the original arrow of time. This is possible but does not seem necessary.

Association with the Sacks's stories stimulates fascinating questions.

1. Is memory recall this kind of re-incarnation of sub-self (mental image) in the geometric past? This kind of experience would be just like ordinary experience having both sensory, motor, cognitive, and emotional aspects. Could the sensory memories associated with right brain consciousness explain the memory feats of the idiot savants?

   For instance, the ability to re-experience the music piece heard once would make possible to repeat it by playing together with the second self in past. Combined with absolute pitch this would give powerful music abilities.

   Sacks tells also about epileptic seizures in which one hears music and experiences "double consciousness". Could mental images in right and left hemisphere be simultaneously awake and create this doubling of consciousness?

2. Could the pain in phantom leg be sensory memory that is genuine sensory experience associated with the leg, which still exists in the geometric past? Could all memories be actually conscious experiences of time reversed sub-selves? Could Wittgenstein's brother's phantom fingers exist in the geometric past before World War I and would he "play" piano with the hand of geometric past?

3. Could the patient who had lost emotions and seemed to get it back - not possible according to neuroscience - while singing have emotional counterpart of phantom leg sensations so that he had genuine emotional mental images from the time time before accident? These memories would be analogous to the sensory memories of idiot savants allowing their memory feats and to the sensory memories created by the stimulation of temporal lobes. Why sensory memories are so rare has a simple explanation: their interference with sensory input from recent moment could have disastrous effects. Most memories are non-sensory sine they can be distinguished from the sensory input.

4. Could the sub-selves (mental images) associated with right brain be time reversed with respect to the left brain sub-selves? naïvely left brain dominance means that right brain "sleeps"- or lives in geometric past, remembers in the scale of entire hemisphere. Could it be that when left hemisphere is awake and "remembers geometric future" (precognizes, plans, predicts), right hemisphere is also awake but remembers geometric past. Do the time

directions of right and left selves change during sleep? Are we living two lives? Is the right hemisphere the "Ka" of ancient Egyptians?

5. The feeling that the music heard during during the epileptic seizure is familiar brings in mind dejavu experience. For instance, one can imagine that a cognitive representation about the experience was formed as the original experience occurred and still exists in the geometric "now". Could this create the sensation of familiarity.

6. Sacks tells about a patent with amnesia with time span of autobiographical memory measured in seconds but having usual cognitive abilities assignable to left hemisphere. The simplest explanation is that the region of right brain responsible for autobiographical memories was damaged and the value of h_{eff} associated with the corresponding magnetic body was reduced dramatically.

3.3.4 Hallucinations From The Point Of View Of ZEO

3.3.5 Hallucinations From The Point Of View Of ZEO

Sacks tells also about music hallucinations and emphasizes that is not clear these experiences can be always regarded as hallucinations. The following TGD inspired considerations are not specific to music hallucinations.

1. If one accepts that the feedback from brain or MB to sensory organs as virtual sensory input is possible then imagination differs from hallucinations only in that the virtual sensory input stops before it reaches the sensory organ.

   On the other hand, imagery as a completion of string world sheets and partonic 2-surfaces to - in general non-unique - 4-D surface could be possible in p-adic sectors (p-adic pseudo-constants) whereas in real sector it is possible only partially in the general case. This applies also to virtual sensory inputs: they can be imagined but not necessarily realized.

   The two definitions are consistent if the impossibility of complete continuation to real sector corresponds to the impossibility of the virtual sensory input to reach the sensory organ.

2. The possibility of time reversal for mental images makes possible episodal memories as genuine mental images in geometric past. One cannot speak of hallucinations now, and even talking about memory is somewhat misleading since the event happens for the first time with respect to subjective time. It would be better to talk about multi-time experiences.

   The experiences in which person hears music could be therefore genuine episodal memories/real experiences. Dreams could have both the hallucinatory and sensory memory aspect. My own dreams are often localized to my childhood and youth but cannot be regarded as experiences about real events - the interpretation as time reversed imagery could be considered.

3. I have considered the possibility that some experiences induced by psychedelics - such as experiences of meeting representatives of some exotic life forms - could be real [K70, K75]. The objection that finite light velocity makes these encounters impossible can be circumvented in ZEO since signals can propagate to geometric past and reflect back in time direction. Essentially seeing in time direction would be in question.

   From consciousness theory perspective this could mean simple time reversal of subself so that the sensory mental images are in geometric past. Mechanism wold be same as in the case of long term memory/genuine experience except that the sensory mental image represents representative of distance civilization rather than something generated in own brain. Even in the case of music "hallucinations" it is not clear whether the mental image can be localized in the own brain in past! If the process is a sequence in which the sub-self dies and reincarnates several times it can involve also classical communication and could give rise to memories, which are not sensory ones.

   One can argue that the size of the CD assignable with human as conscious entity poses strong limitations on the distance of the civilization. The naïve first guess is that the size scale of this

CD corresponds to the human light life - less than 100 light years typically. This assumption is however un-necessarily strong. The size scale of personal CD could be considerably longer: in this case however the sensory mental images about body and environment would not be near the boundary of CD but in its interior. The largest value of h_{eff} in the personal hierarchy of sub-selves defines the size of personal CD and at the same time the span of long term memory serving as a kind of IQ. The higher this IQ, the higher the probability of this kind of communications would be.

There are still many unanswered fundamental questions about CDs possibly relevant for the considerations above. Can one assume that space-time surfaces can continue outside the boundaries of CD so that CD could be seen as spotlight of consciousness? Or does CD define its sub-Universe in the sense that it is nothing outside it or that it is impossible to say anything about the situation outside it? How CDs of various size scales interact and can they overlap?

3.4 Two Modes Of Of Consciousness

In the following the idea about two modes of consciousness basically reducing to strong form of holography is developed in more detail.

3.4.1 Conscious Holograms And Two Kinds Of Fundamental Representations

The idea about brain as hologram was introduced in neuroscience long time ago by Karl Prigram [J67] (`http://tinyurl.com/ydyv6ohr`) and there is considerable support for it although it is also clear that at the higher levels of the evolutionary hierarchy brain functions can be localized. Also living matter can be seen as a hologram in the sense that DNA contains the information about the entire organism. I introduced for long time ago the notion of conscious hologram [K11].

Strong form of holography generalizes this notion to a basic law of quantum physics and since consciousness theory reduces to quantum measurement theory in ZEO, of consciousness. The generalized of AdS/CFT realizing strong form of holography is not a tautology since the collections of 2-surfaces do not always define a realizable imagery. This suggests that dual representations give rise to two different fundamental representations of conscious information.

The first representation is in terms of collections of 2-surfaces replacing a naïve discretization of space-time surface by co-dimension 2 discretization dynamical in the sense that physical state itself defines its discretization at both quantum and classical level. String world sheet discretization is a generalization of 4-D discretization in terms of world lines reducing to 3-D discretization using discrete points.

1. Finite measurement resolution is a key notion of quantum TGD. One realization is in terms of string world sheets. At the level of "world of classical worlds" (WCW) its is realized as discretization of general coordinate invariant parameters characterizing the 2-surfaces [K82].

   This allows to avoid problems related to general coordinate invariance and symmetries that plagued the earlier proposal based on cognitive maps of discrete points sets of real space-time surfaces to p-adic ones or vice versa.

   There is no local correspondence between real and p-adic space-time surface by a common points of embedding space in the algebraic extension of rationals as suggested in the earlier proposal [K85]: the p-adic-real connection is global. Real and p-adic preferred extremals share 2-surfaces with parameters in algebraic extension of rationals identifiable as either real or p-adic numbers.

2. The existence of 4-D representation is guaranteed by strong form of holography if additional correlations between 2-surfaces hold true. For generic 2-surfaces continuation is possbile in p-adic sectors but is not unique and can be interpreted in terms of imaginery.

3. Cognitive representations would naturally correspond to this 2-D representation since the reduction of information would be huge. Since the continuation to p-adic space-time surface for obvious reasons is not unique, conceptualization abstracting out the common aspects of

the 4-D representations is necessary and forces the development of cognition and abstraction to see what the correlations between 2-surfaces guaranteeing realizable imagery are. Abstraction allows symbolic representation and imagination.

4. The fundamental representation would be in terms of fermionic strings connecting partonic 2-surfaces, which can have arbitrarily large size (h_{eff} hierarchy). Sound is a phenomenon which is always associated with the relative motion of particles rather than single particle and in this sense differs from elementary particles. The oscillations of these strings could define sound as a fundamental phenomenon, and fermionic strings could be highly analogous to strings of music instrument.

5. At the light-like partonic orbits defining the "lines" of generalized Feynman diagrams (or rather generalized twistor diagrams) the signature of the induced metric changes from Euclidian to Minkowskian. These light-like 3-surfaces correspond to boundaries of physical objects and the ends of strings at them define fermion lines in twistor diagrams [K77]. At partonic 2-surfaces at the boundaries of CDs the discretization consists of a collection points in accordance with naïve expectations.

Second representation would be in terms of 4-D surfaces themselves and corresponds to the sensory representations in real context. 4-D real representation is much more detailed, concrete, and holistic. In some cases the concreteness of the representation makes it superior. Consider only the miraculous feats of mathematician Ramajunan or physicist Tesla, who could see his thoughts. This representation cannot of course not complete and by the huge super-symplectic symmetries the representation should involve only very general characteristics. This representation would be naturally realized at the level of field body (massless extremals and magnetic body).

1. The flux tubes of the MB carrying dark fermions realized at fermionic string world sheets would be part of the 4-D representation. Magnetic flux tubes are indeed in a key role in TGD inspired theory of consciousness and of living matter.

2. Massless extremals (MEs or topological light rays) accompanying magnetic flux tubes and having also tube-like structure are extremals of Kähler action (very probably also preferred ones) represent a propagation of arbitrary radiation pulse to either direction but the superposition of pulses propagating to opposite directions is impossible. The shape of the pulse is not changed during propagation, the signal is precisely targeted, and it propagates with maximal signal velocity. Classic analog of laser beam is in question.

3. Cyclotron frequencies, which are typically determined by lengths of magnetic flux tubes and by the values of magnetic fields at them, would be a natural parameters capturing gross geometric features of space-time surface. Note that also Kähler magnetic field is a geometric notion in TGD framework since classical gauge fields are geometrized in terms of sub-manifold geometry.

   Also the scale of CD determined by the temporal distance between its tips defines a natural resonance frequency spectrum.

3.4.2 How Nerve Pulses And EEG Could Relate To 2-D And 4-D Representations?

How nerve pulses and EEG relate to the 2-D and 4-D fundamental representations? The answer is not straightforward. The description of neuroscience is not based on many-sheeted space-time having fractal hierarchy of space-time sheets, and there are many layers of approximations involved. It also seems that neuroscience misses an important element related to MB - the "motor actions" of MB (hierarchy of them) and MEs, in particular braiding of flux tubes identifiable as braid strands and are accompanied by strings.

1. Resonance frequencies of EEG realized using MEs parallel to flux tubes could relate to frequency representation serving as a correlate for large scale quantum coherence. MB would coordinate the behavior of brain in this manner. alpha band and kHz synchrony would be examples of this.

2. Neuroscience does not provide direct analog of 2-D representation responsible for cognitive memories. In TGD based model for DNA as topological quantum computer [K3, K79] it is assumed that nucleotides or codons are connected by flux tubes to the lipids of the internal lipid layer of the nuclear or even cell membrane. Same can hold true for microtubules and axonal membrane. Also connections between lipid layers and connections of outer lipid layers to lipid layers of other cell membranes are possible.

3. Axonal microtubules are very natural as far as cognitive memory representations are considered. The propagation of nerve pulse induces flow of the 2-D liquid defined by lipids and induces braiding of the flux tubes connecting axonal membrane to microtubules. One has two braidings: time-like braiding analogous to that generated by dancers on the floor and space-like braiding generated if dancers feet are connected to a wall (now DNA strand). Space-like braiding stores time-like braiding to memory. The 2-D representation would be naturally associated with the braid strands idealized as strings. These effectively 2-D braid representations would form a fractal hierarchy and be basic aspect of biology.

4. The value of h_{eff} for the magnetic body part associated with a given brain area defines how long the span of long term memory and planned action for the brain region in question is and can be used to explain also the difference between right and left hemispheres as also difference between individuals without any additional assumptions. Quite generally, the spectrum of h_{eff} would explain the skill profile of individual.

3.4.3 How The Two Representations Could Be Realized At The Level Of MB?

How the two representations could be realized at MB - ME complexes?

1. Effective 2-D representation could involve supra currents propagating along the flux tubes of MB. Supra current is of course practical higher level notion idealizing fermions and Cooper pairs with point like objects. At basic level one has pairs of fermions at different partonic 2-surfaces connected by strings. The string connecting the partonic 2-surfaces of the members of Cooper pair and its oscillations would correspond to the fundamental level.

   A possible realization of effectively 2-D representation in terms of fermion currents or supra currents is discussed in [K57] [L20, L17]. The discussion was inspired by the observation that SmB_6 behaves in "schizophrenic" manner in external magnetic field: it is topological insulator but conducts current in scales of order 10^{-4} m and conduction velocity is million times higher than expected [L20].

   In de Haas-van Alphen effect (`http://tinyurl.com/ych7b9n8`) the magnetization depends periodically as function on the inverse value of the external magnetic field. The effect leads to an explanation of the paradoxical phenomenon. Magnetic flux tubes become carrier of dark electron currents at quantum criticality defined as value of magnetic field at which a new cyclotron orbit emerges at the surface of flux tube with fixed thickness. This flux tube must correspond to electron energy which is very near to the Fermi energy. This indeed requires quantum criticality.

   If electron density (and thus Fermi energy) is kept constant, quantum criticality is realized only for discrete values of magnetic field strength allowing the generation of quantum critical cyclotron orbit carrying dark electrons (say). If electron density can vary and magnetic field strength is fixed, then certain values of electron density allow quantum criticality and dark electron current along flux tube. The variation of electron density could be the natural control variable in the case of nerve pulses. Part of electron current would leak out to MB as dark current.

2. Frequency representation could be realized in terms classical em fields (MEs) assignable to EEG and its variants and having as quantum counterparts dark photons assignable to flux tubes. EEG resonance frequencies should correspond to cyclotron frequencies. Flux tube thickness determining the value of magnetic field is at criticality must be such that the cyclotron frequencies correspond to generalized Josephson frequencies in order to make

possible the communication of the variations of membrane potential to the MB. In both cases quantum criticality making possible the presence of dark matter at flux tubes is necessary and makes possibly transformation of electrons to dark matter phase with $h_{eff}/n = n$.

3.4.4 What The Specialization Of The Brain Hemisphere To 2-D Or 4-D Representation Could Mean?

"Right brain signs, left brain talks" metaphor should have concrete content and the 2-D and 4-D representations could could provide this content. The challenge is to understand how this specialization might be realized.

The specialization to a particular representation cannot take place at the level of neuro-anatomy. The specialization should therefore occur at the level of MB.

1. Could the magneto-anatomies of the left- and right MBs differ? Or is the magneto-anatomy universal and differentiation leads to different magneto-physiologies. The latter option looks more feasible. Differentiation would select the available quantum criticalities in turn selecting which representation is used. This option is certainly the most flexible one.

2. Also the values of h_{eff} involved characterizing the size of MB matter: the larger the value of MB, the higher the magnetic IQ. This would suggests that magnetic bodies are present but the time scale of corresponding long term memories and planned actions depends on the value of h_{eff}. The growth of magnetic body would be intellectual development.

3. In left hemisphere only cognitive areas (including frontal lobes) could have access go MB with large h_{eff} or access to it (ability to generate the needed quantum criticality) making possible long term cognitive memories. In right hemisphere only sensory areas could have access MB with large h_{eff}.

4. The universality of magneto-anatomy is also consistent with the enormous flexibility of brain. For instance, for patients with very bad epileptic seizures brain hemispherectomy (`http://tinyurl.com/ycszpb5k`) can be the only possible treatment. Usually this operation is carried out at age below four years since at this age brain is still developing and at higher age complications appear (I do not know whether there exists detailed data about the character of these complications). Surprisingly, the operation has no apparent effect on personality or memory (`http://tinyurl.com/nppk9vc`)! In particular, entire left or right hemisphere can be removed.

5. The most flexible and still metabolically feasible (by $E = h_{eff}f$ large h_{eff} photons are metabolically very costly!) option is that the magneto-anatomy of all cells is same and that the character of quantum criticality available determines, which option can be used. The specialization would be at the level of magneto-physiology fixing what control knobs are available and large h_{eff} photons would be generated only when needed.

   This option would be minimun option conforming with "right brain sings, left brain talks" metaphor. Even if the access is possible at both sides, metabolic economy would favor specialization meaning that left hemisphere develops cognitive long term memories and skills and right hemisphere their sensory counterparts. The observation that he damage for the left hemisphere causes cognitive defects can be understood: right brain hemisphere comes in rescue but it has generated only long term sensory memories with large h_{eff} whereas cognitive memories are short term memories and cognitive skills are much weaker. Also the loss of autobiographical memory in the damage of right hemisphere can be understood if right brain is specialized to produce this kind of episodal memories.

   This option also allows to understand the magic mathematical skills if these skills are associated with some region of the right hemisphere. The skill in question would be more analogous to sensory perception rather than cognition. For instance, a possible explanation for the miraculous ability to "see" the decomposition of an integer to primes is that it is a visual representation for the dark phase transition in which a phase characterized by $h_{eff}/h = n_1 n_2$ transforms to a phase characterized by $h_{eff}/h = n_i$, $i = 1$ or 2.

$(k, k+2)$	$(137, 139)$	$(149, 151)$	$(167, 169 = 13^2)$	$(179, 181)$
$L_e(k)$	.78 A	5 nm	$2.5\mu m$	.16 mm
$(k, k+2)$	$(191, 193)$,	$(197, 199)$		
$L_e(k)$	1 cm	8 cm		

Table 3.1: Twin primes define especially interesting candidates for double membrane like structures defining Josephson junctions. Also included the pair $(167, 13^2 = 169)$ although $k = 169$ is not prime. The two largest scales could relate to structures appearing in brain. Note that the primes $k = 151, 157, 163, 167$ correspond to Gaussian Mersennes. The appearance of so many Gaussian Mersennes in the length scale interval between cell membrane thickness and the size of cell nucleus is a number theoretical miracle.

3.4.5 Fractal Hierarchy Of Binary Structures And Realization Of Two Kinds Of Representations

Many basic structures of living matter serving as basic units of consciousness have binary structure and this has already earlier led to the idea that one has fractal hierarchy of binary structures analogous to pairs of brain hemispheres. It seems natural to assume that pulse and frequency representations are realized and the right-left asymmetry suggests that second member of pair produces frequency representation and second member the pulse representation.

Twin primes are pairs $(k, k+2)$ of primes and seems to be of special importance. As **Table 3.1** below demonstrates, there is large number of these pairs in biologically relevant length scales and they might correspond to twin structure forming a fractal hierarchy especially interesting from the point of view of consciousness. The members of first few twin primes are of form $n \pm 1$ for $n = 4, 6, 12, 18, 30, 42, 60,\ 72, 102, 108, 138,\ 150, 180, 192,\ 198, 228, 240, 270, 282, ...$

In particular, twin primes abundant in the p-adic length scale range assignable to living matter could define double layered structures acting as Josephson junctions.

In the following only few examples are considered.

1. DNA double strand has binary structure: one strand is active and second one passive as far as transcription is considered. There are also portions for which the two strands are identical: these correspond to palindromic sequences of DNA. These palindromes serve as control units initiating transcription of gene.

   An analogous symmetric structure in brain is pineal gland, which Descartes identified as seat of soul. One might think that MB controls gene expression through the palindromes and MB of the entire brain via the pineal gland. There are also other glands performing hormone control, and they could also serve as lower level relay stations controlling brain hemispheres rather than entire brain.

2. Nuclear and cell membranes consist of two lipid layers and correspond to *primary* p-adic length scales $k = 149$ and $k = 151$ (both integers are primes): the latter corresponds to Gaussian Mersenne. I have proposed that this double layer has the structure of generalized Josephson junction [K59]. Similar Josephson junction structure could be associated with DNA double strand. The generalized Josephson frequencies would give rise to EEG in terms of large h_{eff} dark photons with energies in visible and UV range characterizing bio-photons.

   Frequency modulation of generalized Josephson frequencies by nerve pulse patterns would assign to the nerve pulse representation at axons the frequency representation communicated to the MB. This leads to ask whether the Josephson currents between brain hemispheres possibly running through corpus callosum define give rise to an analog of EEG at low frequencies? This Josephson junction would be of special importance for the music consciousness.

3. Twin primes could define binary pairs forming both kinds of sensory representations. The pair (179,181) corresponds to primary p-adic scales (.16-.32) mm perhaps assignable to epithelial sheets, which are double cell layers appearing in skin. The pair (191,193) corresponds to primary scales (1.0,2.0) cm perhaps assignable to the basic structural units of cortex. The

pair (197,199) corresponds to primary length scales (9, 18) cm naturally assignable to brain hemispheres.

4. There are also several highly interesting primary p-adic length scales associated with twin primes and Gaussian Mersennes possibly having relevance as size scales of structures relevant for biosphere but these will not be discussed here.

The *secondary* p-adic time scales associated with Gaussian Mersennes and twin primes $(k, k+2)$ might be interesting from the point of view of memory long.

1. Consider first Gaussian Mersennes. For $k = 127$ associated with electron the secondary time scale is .1 seconds defining the fundamental biorhythm and this time scale defines the duration of sensory mental image. For $k = 151$ associated with Gaussian Mersenne the secondary time cale is by a factor $2^{151-127} = 2^{24}$ longer and roughly 1.6×10^6 seconds, about 18 days. For $k = 157$ the time scale is 64 times longer - 10^8 seconds, roughly 3 years. For $k = 163$ the time scale is 64 times longer and about 200 years. Could these time scales define preferred size scales for MBs and time scales of long term memory? Note that the scales is of order Earth circumference already for $k = 127$.

2. The twin pair $(137, 139)$ could correspond to time scales 3.2 sec and 6.4 sec perhaps assignable to short term memory. The twin pair $(149, 151)$ would correspond to time scales of 9 days and 18 days.

3.4.6 Absolute Pitch

Absolute pitch can be seen as right brain aspect of consciousness. Sensory memories are involved and I have already discussed the TGD based model for them. Sensory memories allow to literally hear the piece of music repeatedly and build associations to note, piano key, or even to frequency.

That rational frequency ratios (in Pythagorean scale coming as powers $(3/2)^k$ reduced to the lowest octave by octave equivalence are preferred might relate to the number theoretic vision about evolution as emergence of higher dimensional algebraic extensions of rationals. The lowest level would correspond to rational numbers.

Absolute scale does not only mean that the ratios of frequencies that a person with absolute pitch prefers are rational. It means also that there is indeed absolute scale and music in other scales is different and in some cases even non-recognizable as same music piece.

Interestingly, the range of visible frequencies is one octave suggesting that there might be a deep connection between music and vision. Sacks tells that already Newton considered the possibility that the 8 notes correspond to some colors of light. TGD inspired mode geometric model for harmony [K58] [L12, L9] leads to analogous correspondence.

1. I have considered this connection in detail in the geometric model of harmony providing also a model of genetic code [K58]. The first observation is that 12-note scale has as many notes as there are vertices at icosahedron, one of the Platonic solids. Second observation is that icosahedron has 20 triangles as faces and that also the number of amino-acids is 20.

   This inspires the idea that given harmony corresponds to so called Hamiltonian cycle, which is a closed (by octave equivalence) non-self-intersecting curve connecting neighboring vertices at icosahedron and going through all vertices. Single step between neighboring points of the curve correspond to single quint (scaling of frequency by factor 3/2): the idea is that notes differing by quint are 3-adically near to each other. Each Hamiltonian cycle defines one particular harmony with 3-chords defined by the 20 triangles. There are 17 different harmonies and 11 of them have symmetries.

2. The surprise is that one can understand the degeneracies of the genetic code defined as numbers of DNAs coding for given amino-acid for 60 DNAs in terms of the symmetries of Hamiltonian cycles. 4 DNAs are however lacking. There is also second problem: 12 quints corresponds to slightly more than 7 octaves so that projection to the same octave gives 13 rather than 12 notes with two notes very near to each other: this problem was familiar already for Pythagoras.

The handling of these problem requires addition of tetrahedron bringing in also 4 additional DNAs and 2 additional amino-acids known to be coded in some circumstances by DNA in all organisms (Pyl and Sec). One obtains actually two slightly different genetic codes, and can ask whether the two DNA strands speak different dialects of the same language.

3. The model maps genetic codons consisting of 3 nucleotides to triangles to 3-chords and the allowed 64 chords define what I call bio-harmony. 256 different bioharmonies consistent with genetic code are predicted. These harmonies have as buildingbricks harmonies consisting of 20 allowed 3-chords.

4. The model leads to the proposal that the fundamental realization of the genetic code could be in terms of dark photons with frequencies, which could be in the range of audible frequencies. Also the representation in terms of dark photons is suggestive and since living matter is piezoelectric it could allow to transform dark phonons to dark photons and vice versa.

If the last step of this argument is accepted, the problem of understanding absolute scale reduces to the physical identification of the special dark cyclotron frequency - call it f_0. It could correspond to note C (say). Neuroscientist would explain this special frequency as a resonance frequency of some neural circuit - for instance, thalamocortical resonance frequency around 40 Hz is assumed to result in this manner. In TGD framework the presence of MB changes the situation.

1. The first step is to accept that the identification of gravitational Planck constant $\hbar_{gr} = GMm/v_0$ with $\hbar_{eff} = n \times \hbar$ [K52, **?**] (M and m are masses connected by magnetic flux tube mediating the gravitational interaction and v_0 is velocity parameter [K67, **?**, K52]). This fixes the value of $h_{eff}/h = n$ and implies that the spectrum of cyclotron energies does not depend on the mass of charged particle and depending on the magnetic field strength only. Bio-photon energy spectrum corresponds to the spectrum of magnetic field strengths. The condition that the energy spectrum is in the scale of bio-photon energies belonging to the range of excitations energies of biomolecules (visible and UV range) fixes the value of n if the value of magnetic field and mass of charged particle is fixed to.

2. An interesting - perhaps too science fictive - possibility giving a justification for 12-note scale at fundamental level would be that the octave spanned by visible photon energies corresponds to 12-note scale realized as powers of 3/2 modulo 2 for this magnetic field strength, call it B_0. In this case different ions would correspond to scaled variants of basic spectrum with scaling factor given the ratio q_0A_i/q_iA_0 of mass numbers, where A_0 is the mass number of the reference ion and q_0 is its charge, say H^+. One would obtain preferred keys related by these scalings. This is of course only one possibility.

   Some bio-molecular transition energy fixes the basic frequency and therefore the value of B_0 and perhaps also other frequencies. DNA absorbs UV light at wavelength of 260 nm and energy 4.8 eV: the highest energy of visible photon energy is around 3.2 eV and correspond to wavelength of 390 nm. The ratio of this energies is 3/2 - one quint! Maybe this is not a pure accident.

   $B_0 = .2$ Gauss is suggested as the preferred value of endogenous magnetic field by the original observations that ELF em fields have quantal looking effects on verterbrate brain [K51, K24]. If this value is accepted, one can deduce the value of $h_{eff}/h = n$ for reference ion. The optimal choice is to take the reference ion as H^+ since the masses are in a good approximation integer multiples of proton so that the values of h_{eff} are approximately $n_i(ion) = A_i \times n_i(proton)$ and thus integer valued. For $B_0 = .2$ Gauss proton cyclotron frequency is 300 Hz. Ion frequencies are in EEG spectrum. The higher powers of 3/2 give higher octaves and frequencies in audible range. 10 actaves would give audible range.

3. The two kinds of representations are possible if the quantum criticality condition for cyclotron resonance in case of frequency representation or for the generation of electronic supra currents in the case of pulse representation is satisfied. This would fix the value of the magnetic field strength B_0 for H^+.

Chapter 4

TGD View about Language

4.1 Introduction

This chapter has been written together with Reza Rastmanesh, who proposed the topics of the article leading to this chapter. Human languages differ dramatically from their analogs for animals. Animal languages consist mainly of simple signals, warnings and threats for instance; emotional expression dominates and grammar is lacking. Birds can have impressive repertoire of different song patterns and monkeys have gesture language.

There is a huge variety of human languages: speech and written language, sign languages based on gestures, the language of mathematics and computer languages in which emotional expression is absent. One can also regard music as a kind language expressing emotions and creating them. Also pictures define linguistic representations. Children and animals learn language by mimicry and also learn the grammar and syntax without conscious efforts. Adults can learn a foreign language by learning the vocabulary and the rules of grammar. Human language is also special in that it involves conceptualization, metaphors, and analogies representing abstract concepts in terms of objects and actions of the external world.

One might understand the semantic aspect of language in terms of association and conditioning. Language acquisition involves showing the object and saying the word describing it. This suggests that conditioning and association happens so that mere word generates an imagined percept of the object. Conditioning and formation of associations is a very general form of learning assumed to relate to the increase of synaptic strengths leading to a generation of association pathways. In computer science pattern recognition and completion models it mathematically. One one can ask whether the learning of language and language understanding is something more than this.

For more detailed approaches of language theories, interested readers may be referred to references [J73, J82, J78, J96]. The article of Kempe and Brooks [J94] and the review article "From Molecule to Metaphor: A neural theory of language" about the language theory of Jerome A. Feldman by Stefan Frank [J90] gives a deeper perspective to language theories. The notion of embodiment is in key role in these theories and will be in a key role also in the proposal to be discussed.

4.1.1 About language genes

Forkhead box protein P2 (FOXP2) encodes a transcription factor involved in language acquisition and speech [J34]. In addition to FOXP2 a limited number of genes are involved in speaking [J50]. All vertebrates possess FOXP2, however it is estimated that some 120,000-200,000 thousand years ago, some mutations occurred only in humans which aided humans to start initial forms of speaking [J73]. Animals have their own primitive language; both voices and gestures with meaning make communications possible. They mainly recognize each other and communicate with pheromones. As for vocabulary, a short review of the Old Testament, cuneiform writings, glossary of old books, and hieroglyphs clearly shows that the number of entries was quite limited in the past. Therefore, a further progression of language could be almost a matter of cultural communications and technological advances.

However, today it is clear that crucial mutations occurred in the non-coding part of the genome controlling the expression of genes coding for proteins [J50] which lead to language evolution. Therefore, the evolutionary step was associated with control of existing genes. Humans are also distinguished from animals by their learning abilities.

Language acquisition must rely on conditioning/associations between language expressions and experiences. It seems that embodiment is the mechanism, which associates to a linguistic expression an imagined sensory perceipt and/or motor action making the emergence of meaning. What is needed is long term memory and also some kind of standardization of percepts so that they consist of standardized mental images. Pattern recognition and completion could give this standardization.

Since sensory and motor imagination could be seen as almost sensory experiences and almost motor actions, this suggests that new communications between auditory organs and sensory and motor areas emerged. Even more generally, this kind of communication could have emerged quite generally. This would be essentially a new form of conditioning and the same mechanism could apply to all kinds of conditionings.

4.1.2 How the mutation of only a few genes led to cultural evolution?

Amazingly, only a few mutations for relatively few genes seems so have led to human languages. Why few point mutations of relatively few genes could have transformed biological evolution to cultural evolution? What happened for these genes? In the biochemistry framework it is difficult to imagine an answer to this question. Here TGD could come in rescue.

Number theoretic physics is part of quantum TGD and essential for understanding evolution as an increase of algebraic complexity. Evolutionary hierarchies would correspond to hierarchies of algebraic extensions of rationals. The dimension n of extension defines effective Planck constant $h_{eff}/h_0 = n$, the larger the dimension, the larger the scale of quantum coherence at corresponding level of magnetic body (MB) associated with the system. One can also say that n is analog of IQ. One can assign a value of h_{eff} characterizing their evolutionary level also to genes. The genes with larger h_{eff} would serve as control genes. The increase of h_{eff} for genes would mean an evolutionary step. Perhaps a dramatic increase of h_{eff} occurred to FOXP2 and some other genes as human language emerged.

Second mechanism could be energy resonance in the coupling of the analogs of DNA, RNA, tRNA, and amino acids consisting of dark proton triplet with their chemical counterparts. The coupling would be between the entire gene and its dark analog and codon sequence would play a role of address. In both cases small changes of the gene could spoil or produce an energy resonance. This sensitivity would make genes an ideal control tool but would also serve as a general mechanism also for genetic diseases. The increase of h_{eff} accompanied by a small mutation to guarantee energy resonance could be the mechanism explaining the importance of FOXP2 and similar control genes.

Note: This chapter was prepared in collaboration with Dr Reza Rastmanesh who provided a lot of biological and neurosscientific knowhow and made inspiring questions.

4.2 Number theoretical aspects of quantum biology

The basic ideas about consciousness and life are discussed in Appendix. Here the aspects relevant for the recent work are discussed.

Fig. 4.1 summarises the role of number theory in the TGD inspired vision concerning consciousness, cognition, and quantum biology and **Fig. 4.2** the role of dark matter in TGD inspired quantum biology.

4.2.1 Dark proton representation of genetic code

Fig. 4.3 summarizes the TGD based vision about genetic codes.

Codons as dark nucleons?

The model for codons of genetic code emerged from the attempts to understand water memory [**?**] The outcome was a totally unexpected finding [**?**] the states of dark nucleons formed from three

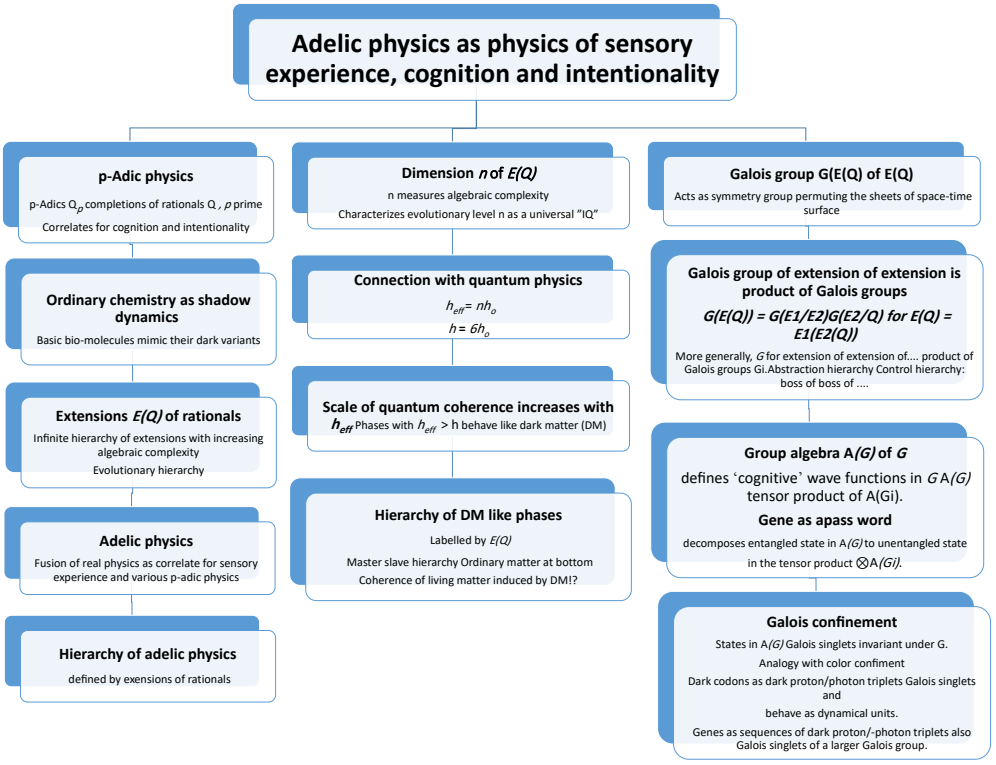

Figure 4.1: Adelic physics as physics of sensory experience, cognition and intentionality

quarks connected by color bonds can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAs, 20 amino acids, and tRNA and there is natural mapping of DNA and RNA type states to amino acid type states such that the numbers of DNAs/RNAs mapped to given amino acid are same as for the vertebrate genetic code.

The basic idea is simple. The basic difference from the model of free nucleon is that the nucleons in question - maybe also nuclear nucleons - consist of 3 linearly ordered quarks - just as DNA codons consist of three nucleotides. One might therefore ask whether codons could correspond to dark nucleons obtained as open strings with 3 quarks connected by two color flux tubes or as closed triangles connected by 3 color flux tubes. Only the first option works without additional assumptions. The codons in turn would be connected by color flux tubes having quantum numbers of pion or η.

This representation of the genetic would be based on entanglement rather than letter sequences. Could dark nucleons constructed as a string of 3 quarks using color flux tubes realize 64 DNA codons? Could 20 amino acids be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner? The codons would not be separable to letters but entangled states of 3 quarks anymore.

Genetic code would be defined by projecting DNA codons with the same total quark and color bond spin projections to the amino acid with the same (or opposite) spin projections. The attractive force between parallel vortices rotating in opposite directions serves as a metaphor for the idea. This hypothesis allows immediately the calculation of the degeneracies of various spin states. The code projects the states in $(4 \oplus 2 \oplus 2) \otimes (5 \oplus 3)$ to the states of 4×5 with the same or opposite spin projection. This would give the degeneracies $D(k)$ as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies $D = 1, 2, 3, 4, 6$ are predicted. The numbers $N(k)$ of amino acids coded by D codons would be

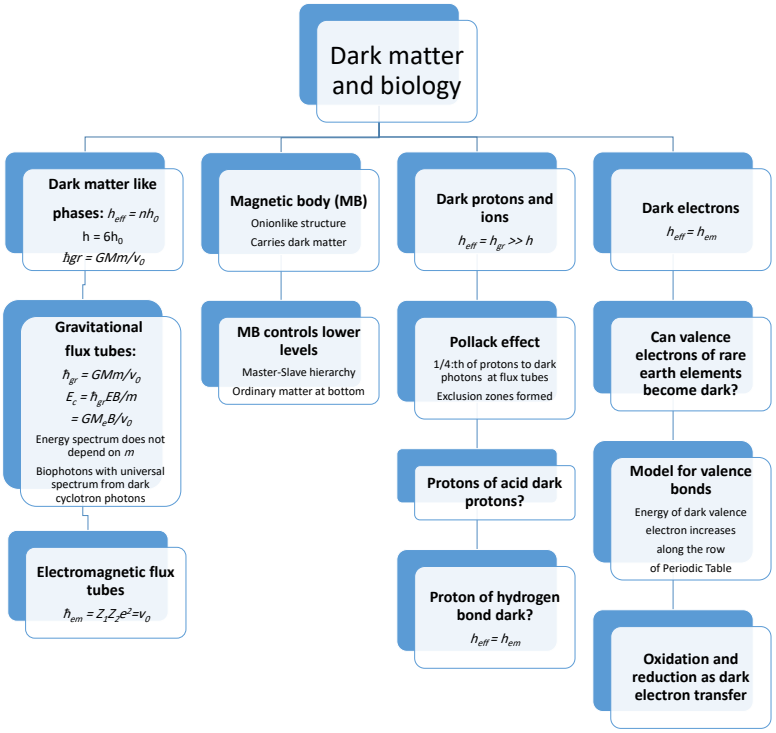

Figure 4.2: Dark matter in TGD inspired quantum biology

$$[N(1), N(2), N(3), N(4), N(6)] = [2, 7, 2, 6, 3] \quad .$$

The correct numbers for vertebrate nuclear code are $(N(1), N(2), N(3), N(4), N(6)) = (2, 9, 1, 5, 3)$. Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in the second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result $(2, 9, 1, 5, 3)$!

Codons as dark proton triplets?

The model of codon as dark nucleon predicts analogs Δ resonances whose masses differ from those of nucleons.

The hint comes from the fact that DNA nucleotides have a negative charge, which is problematic from the point of view of DNA stability. This suggests that dark codons should have a charge of 3 units screenng the charge of the ordinary DNA codon. Pollack effect [**?**]eans formation of negatively charged exclusion zones as protons are transferred to dark protons at magnetic flux tubes. Could DNA be formed by Pollack effect? Could codons be represented as dark proton triplets?

The problem is that protons however have only 2 spin states: 4 states would be needed as in the case of quarks having also color. Where could the counterparts of spin and color come from?

One could consider adding a neural pion-like and/or ρ_0 meson-like bond connecting neighboring protons. Since ρ_0 has spin 1, this would give 1+3=4 states per bond. However, 2 states are enough and one must get rid of 2 states. The string-like structure of the proton triplet

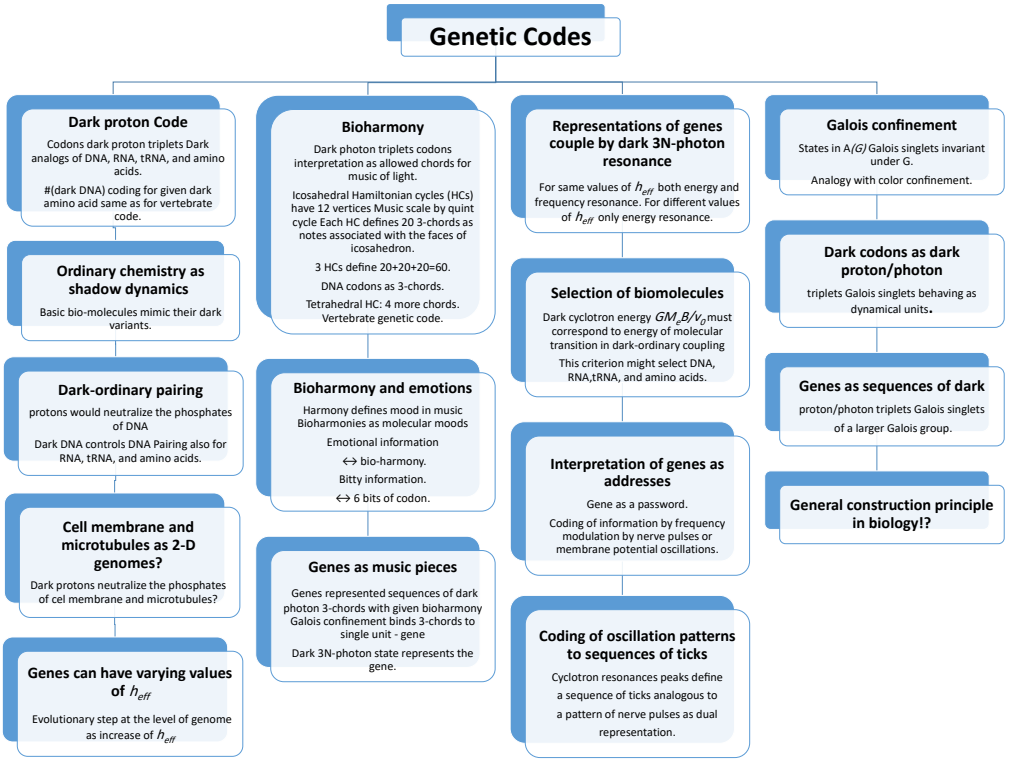

Figure 4.3: Genetic codes in TGD framework

suggests that the rotation group reduces to $SO(2) \subset SO(3)$ so that ρ meson states split into singlets with helicities 0,1,-1. The doublet (-1,1) would serve as the analog of the isospin doublet (u,d) for baryons and enough to achieve a correct effective number $N = 4$ of states per single DNA codon. Helicity would replace isospin and the tensor product states could be constructed effectively as tensor products of 3 representations $2 \otimes 2$.

There is also an issue related to the fermionic statistics. Protons are fermions and the total wave function for them must be antisymmetric. For baryons color singlet property allows this. Can one require statistics in the ordinary sense also now? Or could the effective 1-dimensionality of the magnetic flux tube allow braid statistics?

The following variant gives good hopes about the ordinary statistics.

1. Adelic physics [**?**]rings in additional discrete degrees of freedom assignable to the group algebra of Galois group of extension of rationals inducing the extensions of p-adic number fields appearing in the adele [**?**]

2. Galois group acts on the space of space-time surfaces, and one can say that one has wave function at the orbit of the Galois group consisting of space-time sheets. At quantum level quantum states correspond to wave functions in the group algebra of Galois group of extension.

3. The role of color degrees of freedom in helping to achieve correct statistics in the case of baryon could be taken by Galois degrees of freedom. One can even consider the notion of Galois confinement as a generalization of color confinement [**?**]inding codons as dark proton triplets to dynamical units. Codons should be antisymmetric under exchange of dark

protons in Galois degrees of freedom. Also genes as sequences of codons could be bound to dynamical units as Galois singlets. Could this allow ordinary statistics.

If this picture is correct, genetic code would be realized already at the level of dark nuclear physics or even at the level of ordinary nuclear physics if the nuclei of ordinary nuclear physics are nuclear strings. Chemical realization of genetic code would be induced from the fundamental realization in terms of dark nucleon sequences and vertebrate code would be the most perfect one. Chemistry would be a kind of shadow of the dynamics of positively charged dark nucleon strings accompanying the DNA strands and this could explain the stability of the DNA strand having 2 units of negative charge per nucleotide. Biochemistry might be controlled by the dark matter at flux tubes.

4.2.2 Bio-harmony as a realization of genetic code

TGD leads to a notion of bio-harmony in terms of icosahedral and tetrahedral geometries and 3-chords made of light assigned to the triangular faces of icosahedron and tetrahedron [L15, L16, L77]. The surprise was that vertebrate genetic code emerged as a prediction: the numbers of DNA codons coding for a given amino acid are predicted correctly. DNA codons correspond to triangular faces and the orbit of a given triangle under the symmetries of the bio-harmony in question corresponds to DNA codons coding for the amino acid assigned with the orbit.

Codon corresponds to 6 bits: this is information in the usual computational sense. Bio-harmony codes for mood: emotional information related to emotional intelligence as ability to get to the same mood allowing to receive this information. Bio-harmony would be a fundamental representation of information realized already at molecular level and speech, hearing and other expressions of information would be based on it. For emotional expression at RNA level possibly involved with conditioning at synaptic level see [L49].

Does the generation of nerve pulse patterns by a gene mean at the cell membrane from dark DNA to dark protein map to dark protein (it could be also dark RNA or dark DNA even) associated with the cell membrane. What about communications with RNA and enzymes involved with transcription and translation. Do all basic biocatalytic processes involve them.

What about a generalization of Josephson currents? Dark ions certainly define them but could also dark proton triplets and their sequences associated with proteins give rise to oscillating Josephson currents through cell membrane and therefore to dark Josephson radiation with 3N dark photon units! Proteins themselves need not move much!

The universal language could be restricted to the genetic code which would be realized by dark proton triplets. The 64 codons are formed from 3 20-chord harmonies associated with icosahedron and the unique 4-chord harmony associated with tetrahedron. Bio-harmonies are associated with the so-called Hamiltonian cycles ,which go through every vertex of Platonic solid once. For icosahedron the number of vertices is 12, the number of notes in 12-note scale.

Also tetrahedron, cube, octahedron and dodecahedron are possible and one can consider the possibility that they also define harmonies in terms of Hamiltonian cycles. Dodecahedron would have 5-chords (pentagons as faces) as basic chords and there is only single harmony. Same mood always, very eastern and enlightened as also the fact that scale would have 20 notes.

Also octahedron gives 3-chords (triangular faces) whereas cube gives 4-chords (squares as faces). One can of course speculate with the idea that DNA could also represent this kind of harmonies: sometimes the 3N rule is indeed broken, for instance for introns.

Galois confinement [L85] allows the possibility to interpret dark genes as sequences of N dark proton triplets as higher level structures behaving like a single quantal unit. This would be true also for the corresponding dark photon sequences consisting of 3N dark photons representing the gene in bio-harmony as an analog of a music piece consisting of 3-chords and played by transcribing it to mRNA.

The picture can be viewed even more generally. Any discrete structure, defining graph, in particular cognitive representation providing a unique finite discretization of space-time surface as points with the coordinates of the 8-D embedding space coordinates in the extension of rationals, defines harmonies in terms of Hamiltonian cycles. Could also these harmonies make sense? The restrictions of the cognitive representations to 2-D partonic 2-surfaces would define something

analogous to bio-harmony as Hamiltonian cycle of 2-D graph (Platonic surfaces solids can be regarded as 2-D graphs). The interpretation as representations of Galois groups and the notion of Galois confinement is possible although one loses the symmetries of the Platonic solids allowing to identify genetic code.

About the details of the genetic code based on bio-harmony

TGD suggests several realizations of music harmonies in terms of Hamiltonian cycles representing the notes of music scale, most naturally 12-note scale represented as vertices of the graph used. The most plausible realization of the harmony is as icosahedral harmony [L9] (see `http://tinyurl.com/yad4tqwl` and `http://tinyurl.com/yyjpm25r`).

1. Icosahedron (see `http://tinyurl.com/l5sphzz`) has 12 vertices and Hamiltonian cycle as a representation of 12-note scale would go through all vertices such that two nearest vertices along the cycle would differ by quint (frequency scaling by factor 3/2 modulo octave equivalence). Icosahedron allows a large number of inequivalent Hamiltonian cycles and thus harmonies characterized by the subgroup of the icosahedral group leaving the cycle invariant. This group can be Z_6, Z_4, or Z_2 which acts either as a reflection group or corresponds to a rotation by π.

2. The fusion of 3 icosahedral harmonies with symmetry groups Z_6, Z_4 and Z_2 gives 20+20+20=60 3-chords and 3+1 + 5 + 10 =19 orbits of these under symmetry group and almost vertebrate genetic code when 3-chords are identified as analogs of DNA codons and their orbits as amino acids. One obtains counterparts of 60 DNA codons and 3+1 + 5 + 10 =19 amino acids so that 4 DNA codons and 1 amino acid are missing.

3. The problem disappears if one adds tetrahedral harmony with 4 codons as faces of tetrahedron and 1 amino acid as the orbit of the face of tetrahedron. One obtains 64 analogs of DNA codons and 20 analogs of amino acids: this harmony was coined as bio-harmony in [L15, L16]. The predicted number of DNA codons coding for given amino acid is the number of triangles at the orbit of a given triangle and the numbers are those for genetic code.

4. How to realize the fusion of harmonies? Perhaps the simplest realization found hitherto is based on the union of a tetrahedron of 3 icosahedrons obtained by gluing tetrahedron to icosahedron along its face which is a triangle. The precise geometric interpretation of this realization has been however missing and some possibilities have been considered. The model could explain the two additional amino acids Pyl and Sec appearing in Nature [L15, L16] as being related to different variant for the chemical counterparts of the bio-harmony.

   There is also a slight breaking of symmetries: ile 4-plet breaks into ile triplet and met singlet and trp double breaks into stop and trp also leu 4-plet can break in leu triplet and ser singlet (see `http://tinyurl.com/puw82x8`). This symmetry breaking should be understood.

Cell membrane and microtubules as a higher level representation of genetic code?

Also the representation of genetic code at the level of cell membrane can be considered [L58]. This kind of proposal have been made with different motivations by Okecukwu Nwamba [I23]. The motivation for the current proposal is that the lipids have at their ends negatively charged phosphates just as DNA nucleotides have. The generalization of DNA as a 1-D lattice like structure to a 2-D cylindrical lattice containing nucleotide like units - letters - possibly assignable to lipids and realized as dark protons. Single lipid could be in the role of ribose+nucleotide unit and accompanied by a neutralizing and stabilizing dark proton. For axons one would have cylindrical lattice dark DNA lattice. The two lipid layers could correspond to two DNA strands: the analogs of the passive and active strand.

The finding is that membrane affects protein's behavior. This would be understandable in the proposed pictures 2-D analog of 1-D nucleotides sequences with codons replaced with counterparts of genes as basic units. That lipids are accompanied by phosphates with charge -1 gives the hint. Phosphate charge is neutralized by a dark proton as an analog of a nucleotide.

The notion of Galois confinement identifying genes as units consisting of N dark proton triplets representing genetic codons suggests that genes possibly assignable to the lipid layers of

the cell membrane could communicate using dark $3N$-photon sequences with the proteins, genome, RNA and DNA. Dark variants of the control genes could initiate a nerve pulse pattern. An interesting possibility is that ganglions, nucleus like structures assignable to sensory organs and appearing as basal ganglia in brain [I14] (`https://cutt.ly/zfWoBFt`) could communicate with genes.

Also microtubules have GTPs with charge -3 bound to tubulins. In dynamical instability known as treadmilling the transformation of GTP$\rightarrow GDP$ bound to β tubulin by hydrolysis induces the shortening of the microtubule at minus end whereas the addition of tubulins bound to GTP induces the growth at plus end. Also actin molecules bound to ATP show a similar behavior. Could they be accompanied by dark DNA codons? Are all codons allowed or does the absence of XTP, X= T,C,G mean that only codons of type GGG would be present?

For the dark codons for the cell membrane the p-adic length scale $L(151) \simeq 10^{-8}$ m would correspond to the lipid's transversal size scale and would be the distance between the dark protons. The scale of dark nuclear energy would be proportional to $1/L(151)$ and scaled down by factor $\sim 10^{-3}$ from that for DNA. The energy scale should be above the thermal energy at room temperature about .025 eV. If the energy scale is 2.5 eV (energy of visible photon) for DNA, the condition is satisfied. Note that 2.5 eV is in the bio-photon energy range. For p-adic large scales longer than $L(151)$ thermal instability becomes a problem.

It is interesting to compare the number of codons per unit length for ordinary genetic code (and its dark variant) and for various membranes and microtubules.

- For the ordinary genetic code there are 10 codons per 10 nm defining p-adic length scale $L(151)$. This gives a codon density $dn/dl = 10^3/\mu m$ in absence of coiling. The total number of codons in human DNA with a total length $L \sim 1$ meter is of order $N \sim 10^9$ codons. The packing fraction of DNA due to coiling is therefore huge: of order 10^6.

- If each lipid phosphate is accompanied by a dark proton and if lipid correspond to square at axonal cylinder with side of length $d = L(151)$ and the radius R of axon corresponds to the p-adic length scale $L(167) = 2.5\mu$ m (also of the same order as nucleus size), there are about $dn/dl = 2\pi(R/d)^2 \sim (2\pi/3) \times 10^4 \sim 1.3 \times 10^5/\mu m$. Axon should have length $L \sim 1$ cm to contain the entire genome.

  The same rough estimate applies to microtubules except that there would be one codon per GTP so that the estimate would be 3 times higher if GTP corresponds to length scale $L(151)$ of tubulin molecule. It has been proposed that genetic code is realized at the microtubular level.

- The nuclear membrane assumed to have a radius about $L(167) = 2.5\mu$m could represent $N \sim (4/3)R^2/d^2 \sim .8 \times 10^5$ codons. This is a fraction 10^{-5} about the total number of codons. For a neuronal membrane with radius $R \sim 10^{-4}$ meters assignable to a large neuron the fraction would be roughly 10^{-1}. The fraction of dark codons associated with membranes could correspond to genes involved with the control and communication with genome and other cell membranes. Note that the non-coding intronic portion dominates in the genome of higher vertebrates. One can ask whether the chromosome structure is somehow visible in the membrane genome and microtubular genome.

4.2.3 Galois group of space-time surface as new discrete degrees of freedom

Galois confinemenent

The problem is to understand how dark photon triplets occur as asymptotic states - one would expect many-photon states with a single photon as a basic unit. The explanation would be completely analogous to that for the appearance of 3-quark states as asymptotic states in hadron physics - the analog of color confinement [L88]. Dark photons would form Z_3 triplets under the Z_3 subgroup of the Galois group associated with corresponding space-time surface, and only Z_3 singlets realized as 3-photon states would be possible.

The invariance under $Gal(F)$ would correspond to a special case of Galois confinement, a notion introduced in [L84] with physical motivations coming partially from the TGD based model of genetic code based on dark photon triplets.

Cognitive measurement cascades

Quantum states form Galois group algebra - wave functions in Galois group of extension E. E has in general decomposition of extension E_1 as extension of E_2 as extension of ... to a series . Galois group of E has decomposition to product of $Gal(E) = Gal(E/E_1)Gal(E_1)$ and same decomposition holds true for $Gal(E_1)$ so that one has hierarchy of normal subgroups corresponding extension of extension of...hierarchy defined by a composite polynomial $P(x) == P_1(P_2(x))$ with P_2 having similar representation. P defines in M^8 picture the space-time surface. This maps a tensor product composition for group algebra and the factors of group algebra entangle. SSFR corresponds to a quantum measurement cascade: SSFR in $Gal(E/E_1)$, SSFR in $Gal(E_1/E_2)$ etc.

Could this cascade relate to the parsing of a linguistic expression? It would certainly correspond to a sentence S_1 about a sentence S_2 about ... such that one substitutes a concrete sentence for S_1 first, then to S_2, etc.... The sentences in the sequence indeed have h_{eff} which decreases. This is the case in the cascade of SSFRs since $h_{eff}/h_0 = n$ is the dimension of E_n.

I also mentioned the number theoretic measurement cascades for purely number theoretic Galois degrees of freedom. `http://tgdtheory.fi/public_html/articles/SSFRGalois.pdf`.

Could cascade of flux tubes decaying to smaller flux tubes with smaller value of h_{eff} should correspond to this hierarchy. Certainly this is linguistics but the sentence as argument could correspond to several sub-sentences - different flux tubes. Could a neural pathway defined by the branching axon correspond to a concretization of this kind statement about statement (or multistatement, perhaps nerve pulse pattern generated by nerve pulse patterns arriving to a given neuron) about...

4.2.4 Energy and frequency resonance as basic elements of dark photon communications

Dark photon realization of genetic code leads to a view about fundamental linguistic communication based on resonance and we will write a separate paper connecting TGD with language soon. Two systems can be in communication when there is resonance. $E = h_{eff}f$ and energy conservation implies

$$h_{eff,1}f_1 = h_{eff,2}f_2 \quad .$$

For $h_{eff,1} = h_{eff,2}$, energy conservation implies that both energies and frequencies are identical:$E_1 = E_2$ and $f_2 = f_2$. Both energy and frequency resonances in question.

In the general case one has $f_1/f_2 = h_{eff,2}/h_{eff,1}$ and frequency scaling takes place. The studies of water memory lead to the observation that this kind of phenomenon indeed occurs [I5]. The communications of dark matter with ordinary matter and those between different values of h_{eff} involve only energy resonance. Frequency and wavelength scaling makes it possible for long scales to control short scales. Dark photons with EEG frequencies associated with the big part of MB transform to bio photons with a wavelength of say cell size scale and control dynamics in these short scales: for instance, induce molecular transitions. This is impossible in standard physics.

The resonance condition becomes even stronger if it is required there is a large number of biomolecules in resonance with dark matter realized as dark variants of biomolecules and dark ions. Cyclotron resonance energies are proportional to $\hbar_{eff}$ characterizing magnetic flux tubes and to the valued of the magnetic field strength dictated by the quantization of the monopole flux quantization by the thickness of the flux tube which can be do some degree varied by varying the thickness of the flux tube giving rise to frequency modulation.

The findings of Blackman *et al* [J24] suggest that $B_{end} = 0.2$ Gauss defines an important value in the spectrum of B_{end} values. It could correspond to the field strength for the monopole flux part of the Earth's magnetic field: besides this there would be a non-monopole flux part allowed also in the Maxwellian theory.

There are however indications that the value B_{end} is quantized and is proportional to the inverse of a biologically important p-adic length scale and thus would be quantized in octaves.

This could relate directly to the octave equivalence phenomenon in music experience. The model of bio-harmony [L15, L16, L77] suggests a further quantization of the octave to Pythagorean 12-note scale of music. This would not be only essential for the music experience but communications of emotions and molecular level using the music of light.

Selection of basic biomolecules by energy resonance

The dark particles must have energy resonance with bio-molecules in order to induce their transitions. This seems to pose extremely strong conditions possibly selecting the bio-molecules able to form interacting networks with dark matter and with each other. One expects that only some amino acids and DNA type molecules survive.

Nottale's hypothesis provides a partial solution to these conditions. Nottale proposed the notion of gravitational Planck constant

$$\hbar_{gr} = GMm/v_0$$

assignable in TGD to gravitational flux tubes connecting large mass M and small mass m and v_0 is velocity parameter. The gravitational flux tube presumably carries no monopole flux. The TGD based additional hypothesis that one has equals to

$$hbar_{gr} = h_{eff} = nh_0 \ .$$

This implies that the cyclotron energy spectrum

$$E_c = n\hbar_{gr}\frac{eB}{m} = n\frac{GM}{v_0}eB$$

of the charged particle does not depend at all on its m. Therefore in a given magnetic field, say B_{end}, the cyclotron resonance spectrum is independent of the particle.

The energy resonance condition reduces to the condition that the charged ion or molecule has some cyclotron energy coming as a multiple of fundamental in its spectrum in the spectrum of its transition energies. Even this condition is very strong since the energy scale for cyclotron energy in B_{end} is in the bio-photon energy range containing energies in visible and UV. The fact that bio-photons have a quasi-continuous spectrum strongly suggests that B_{end} has a spectrum. The model of bio-harmony [L9, L65] suggests that the values of B_{end} correspond to Pythagorean scaling constructible by quint cycle.

The above simplified picture is formulated for single dark photon communications. The dark proton and dark photon realizations of the genetic code requires 3-resonance that is a simultaneous energy resonance for the 3 members of dark photon triplet. In dark-dark pairing also frequency resonance is possible. In dark-ordinary pairing frequency increases and couples long scales with short scales. Also resonant communications between genes with N codons involving $3N$ dark photon frequencies must be possible. This requires new physics provided by number theoretical vision.

What happens in the cyclotron resonance?

3 cyclotron energies for flux tubes characterize dark 3-proton triplet and Nottale's hypothesis predicts that they depend on the values of B_{end} for the flux tubes only. Bio-harmony suggests that the spectrum of frequencies and thus B_{end} corresponds to Pythagorean 12-note scale for a given octave. The allowed chords of bioharmy would characterize the emotional state at the molecular level and correspond to the holistic emotional aspects of the communication beside the binary information.

The resonance would require that the dark cyclotron energy changes are equal to corresponding energies in molecular transitions. Galois confinement [L84] makes possible also 3-N resonance. The resonance condition would select basic biomolecules and the ability of dark analogs of biomolecules to simultaneously resonate with several biomolecules would give additional conditions. In particular this would select DNAs and amino acids.

An open question is whether the coupling to ordinary biomolecules involves a transformation of a dark photon triplet or an N-plet to a single ordinary photon. For instance, does the sum of

the 3 cyclotron excitation energies appear in the coupling of dark 3-proton state to amino acid in protein? This would have an analog as 4-wave coupling in laser physics allowing in biology the transformation of dark photon triplet to single biophoton/or 3 bio-photons or vice versa. 6-wave coupling of laser physics would be analogous to the coupling of ordinary 3-photon state to dark 3-photon and back to ordinary 3-photon state.

The resonance itself would mean a process in which dark 3-proton cyclotron excitation returns to the ground state and generates dark 3-photon transforming transforming to ordinary photon (or 3-photon) and absorbed by the ordinary codon or amino acid excitation to hither energy state. This state would in turn emit an ordinary photon transforming to dark 3-photon absorbed by dark codon. This mechanism generalizes to 3N-proton states representing genes or dark proteins.

4.3 TGD based view about brain

4.3.1 A new view about the role of nerve pulses in sensory perception

Sensory perception would in TGD generate sensory mental images at sensory organs: this would solve a basic problem of neuroscience due to the similarity of neural tissue in various sensory areas. The new view about time and memory implied by ZEO solves the problem caused by the phantom limb. The pain in the phantom limb is a sensory memory of pain.

The stimulation of temporal lobes indeed generates sensory memories, and people with a cognitive impairment are known for memory feats such as being able to draw a building seen in the past with every detail or to learn music pieces with single listening. These feats can be understood if the memories correspond to "seeing" in time direction with a beam of dark photons travelling to the past reflected back. ZEO allows this.

Since perception involves a lot of processing this would require forth-and back signaling between brain and sensory organs. There would be virtual sensory input from the brain or via the brain. Sensory percept would be an artwork, standardized mental image, resulting as pattern recognition assigning to sensory input standardized mental image nearest to the input.

1. Nerve pulses would not mediate information inside the brain. They would only build short connections between existing flux tube connections parallel to axons. Same happens in an old fashioned telephone network by relays: it would be energy consuming to keep the connections on all the time.

   The velocity of nerve pulse conduction is quite too slow to realize the iteration leading to a standardized sensory mental image. If the signal velocity is light velocity, duration of order 1 ms for nerve pulse also for 10 cm neural pathway about 10^6 forth and back travels between sensory cortex and retina.

   Communications would occur by dark photons signals with $h_{eff}/h = n$ and with maximal signal velocity allowing for an iteration leading to standardized perceptions as near as possible to the sensory input and representing only the essential features. Dark photons could transform in an energy conserving manner to biophotons with energies in visible and UV range (at least) and thus above thermal energy and therefore having effects not masked by thermal radiation. Brain is known to emit biophotons and they are also associated with axons [K14, K9].

2. All information molecules (neural transmitters, hormones, messengers) would be connection builders so that the view of neuroscience would be badly wrong here. I have discussed this idea earlier but in a slightly different form: the proposal was that information molecules are attached to the end of a flux tube getting longer as the molecule travels to its target. This is possible but unnecessary since it is enough to build just the bridge between existing connections. **Remark:** The view of neuroscience might be very different if information technologies would have been known for a century ago. Same applies to homeopathy and water memory [K31], which still remains curse words in mainstream science, although a lot about the mechanisms involved is known.

   The standard view about learning as strengthening of synaptic connections would translate to a gradual build-up of permanent flux tube connections so that communications with dark

photon signals would be possible all the time. This would lead to fusion of sender and receiver to a single quantum entangled system.

If the meridians of acupuncture network correspond to this kind of permanent network, they would not require nerve pulses, transmitters, nor information molecules.

3. Nerve pulse patterns would however generate Josephson radiation at EEG frequencies propagating from the brain to its MB from axonal membranes serving as Josephson junctions. EEG would code the nerve pulse patterns as frequency modulated Josephson radiation [K24].

The view about sensory perception and function of nerve pulse transmission differs from the standard view. Nerve pulse transition would not be communication between parts of CNS but building of the communication line for dark photons making possible communications with maximal signal velocity [L32] [K59].

1. This would allow generation of sensory mental images at sensory organs by an iteration involving virtual sensory input from brain to sensory organs. Pattern recognition would be realized as a build-up of an artwork representing standardized mental image as near as possible to the original sensory input.

2. Neurotransmitters and all information molecules would be bridges needed to construct connected communication lines. Learning as formation of permanent synaptic connections would be generation of permanent bridges of this kind.

3. Cell membrane and perhaps also other structures serve as generalized Josephson junctions [K24]. The (generalized) Josephson radiation generated by nerve pulses would give rise to EEG (and perhaps also to its fractal counterparts) as communication of neural information from brain to MB via Josephson frequency modulation. The size scale of the layer of MB would be rather large, of the order $1/f_c$, of the order Earth size in alpha band ($f_c \simeq 10$ Hz).

This view allows to understand imagination as virtual sensory inputs *resp.* motor actions from MB via brain which do not reach actual sensory organs . muscles but virtual sensory organs inside brain for which a good candidates are basal ganglia - ganglions are also associated a with sensory receptors. Dreams (REM), hallucinations, and psychedelic experiences (motor activities during sleep) could be understood as virtual sensory input reaching the sensory organs (muscles).

Also memory recall could involve virtual (real in the case of sensory memories) sensory input from MB at which memory mental images are realized [L96] [L68].

4.3.2 Binaural beat as a support for TGD view about brain

The phenomenon known as binaural beat [J43] provides support for the TGD view about the brain. Binaural beat occurs when sound waves with slightly different frequencies arrive in both ears. The beat can be understood as interference due to the time-varying phase difference of the waves. What is heard is the difference frequency, even when it is below 20 Hz - for instance 10 Hz-, and therefore not audible. The amplitude modulation with 10 Hz would be perceived, not the 10 Hz frequency. Strangely, the binaural beat occurs also when the signals arrive only to separated ears so that interference is not possible.

The TGD based explanation could be that the sound waves generate dark photon signals propagating along flux tubes and having classical em waves as correlates. The waves from different ears would interfere if the flux tubes meet at some point in the brain located at auditory areas perhaps. The first option is that this interference gives rise to the experience of the binaural beat and superposes with the sensory input assigned to ears (one cannot exclude the possibility that the sensory qualia are assigned to virtual sensory organs in the brain). Second option is that the virtual sensory input as feedback sent back to ears as dark photons superpose to the sensory input from ears.

4.3.3 The roles of nerve pulses and oscillations of neuronal membrane in the TGD picture

1. Nerve pulses - or more precisely, the transmitters emitted at synaptics contacts - connect flux tubes to longer pathways along which dark photons signals travel. Biophotons are dark photons transformed to ordinary so that there is empirical basis for this. Dark photons are an optimal tool for communications: light velocity and coherence.

   This allows the build of percepts as standardized sensory mental images by feedback. Nanosecond is the time scale for a single feedback loop so that there is a lot of time for this. This also explains dreams as virtual sensory input from the brain of MB to sensory organs in particular eyes (REM).

   Imagination can be understood as virtual sensory input which does not reach sensory organs or muscles but stops before it. Imagination is almost sensory experience with input from MB or brain. The notion of virtual sensory input is central for understanding speech comprehension and also inner speech.

2. Nerve pulses patterns modulate generalized Josephson frequencies for the membrane proteins (ion channels and pumps, etc...) and Josephson radiation to big bart of MB codes for the sensory input.

   Motor output is from MB in reverse time direction induced by BSFRs. A good guess is that it is via genes and induces gene expression by producing proteins but possible are also other forms of gene expression such as as dark photon signals to cell/neuronal membrane inducing nerve pulse patterns building connected wave guides for motor output as dark photons signals to propagate

4.3.4 Memories

To understand what memories and memory recall could be in ZEO one must specify what the geometrical correlate of subjective "Now" have?

1. The first proposal was that it corresponds to the active boundary of causal diamond (CD). It however turned out that the subjective "Now" could more naturally correspond to the $t = T$ slice of CD with maximal size located in the middle of the CD. Here t corresponds to a linear Minkowski time axis connecting the tips of the CD. If one accepts $M^8 - H$ duality [L79], this picture can be made precise.

   The moments "Now" would correspond to "special moments in the life of self" [L79, L95] identifiable as intersections of 6-spheres, which are brane-like entities (branes are encountered in M-theory) appearing as universal special solutions of algebraic equations determining the space-time surfaces in M^8_c. The values of T correspond to the roots of the real polynomial defining the space-time surface so that the values of "Now" are quantized.

2. During the sequence of state function reductions the active boundary of CD would shift towards the geometric future and the size of CD would increase (in statistical sense). The sub-CDs accompanying sensory and other mental images would shift to the direction of geometric future as CD increases and become potential memory mental images suffering BSFRs in a shorter time scale.

   The self would experience a memory mental image as a sub-self in memory recall to be discussed below. The time=constant snap-shots at the upper half of CD assignable to the memory mental images are ordered with respect to the Minkowski time t but the order is opposite to that for the subjective experiences. This was a great surprise to me. They would correspond to subselves to which memory recall builds a connection by entanglement quantally or by sending a signal, which is reflected back in BSFR for the memory mental images.

   What about recall of episodic memories in ZEO?

1. Spontaneous memory recall could correspond to a death of a memory mental image with an opposite arrow of time and re-incarnation with the same arrow of time as self. This could be accompanied by emission of a past directed "negative energy" signal received by self associated with the moment "Now". The interpretation would be in terms of extraction of metabolic energy: memory recall indeed requires metabolic energy. Active memory recall could correspond to a receival of future directed "positive energy" signal coming from "Now" having interpretation as metabolic energy feed. Energy conservation would force the memory mental image to change the arrow of time.

2. The prediction would be that in active memory recall by a "positive energy" signal received by the memory sub-CDs, the order of recalled memories is opposite to that for the real experiences. There is evidence for this kind of change [J71] (see also the popular article "*The human brain works backwards to retrieve memories*" at `http://tinyurl.com/y7hbqmug`).

4.3.5 Associations at quantum level

How associations could be formed at quantum level? Certainly memories and memory recall are involved and ZEO provides a universal model of memories.

1. In contrast to the naïve expectations, in ZEO the memory mental images would be sub-selves and would comove with the active boundary of causal diamond (CD identified as an intersection of future and past directed light-cones) and shift to the direction of the geometric future after their creation at $t = T$ hyper-plane of CD at which upper and lower light-cones of CD are glued to together. This is the largest time slice of CD and assumed to define the geometric correlate for the subjective moment "Now".

   Memory mental image (associated with sub-CD) continues its Karma's cycle having as basic unit a birth in BSFR, a life consisting of a sequence of analogs of unitary time evolutions followed by SSFRs, death in BSFR and living a life with opposite arrow of time. Memory mental images can live in the brain of the geometry future being connected to the brain "Now" by long flux tubes.

2. Memory recall wakes up the memory mental images by sending a message using dark photons received by the memory mental image. The universal model of language suggests that the signal is biological system coded genes serving also as addresses.

3. Conditioning in its simplest form should associate two mental images. The classical example about conditioning is a dog, which learns to expect food after it hears the sound of a bell. The primary experience involves both the sound of the bell and getting the food. After the conditioning the mere sound of the bell stimulates activities like salivation. Positive or negative emotions facilitate conditioning. In ZEO framework the learning of the conditioned response would involve two mental images: imagined experience about obtaining the food and the sound of a bell.

   They should fuse to a composite mental image, perhaps by entanglement. These primary memory mental images and their almost copies produced later and involving only the bell and the imagined food would form a population of memory mental images in the geometric future shifting farther away. As the dog hears the sound of the bell, a message to the memory mental images in the geometric future is sent. It is realized as frequency modulated dark Josephson radiation from say basal ganglia of sensory organs.

4. A naïve guess is that the modulated Josephson frequencies correspond to a period larger than the temporal distance of the memory mental image from "Now" and defining its age. Rather low frequencies are involved for long term memories and the values of h_{eff} must be scaled correspondingly. The longer the time span of the memory, the larger the value of h_{eff}. The emergence of language is therefore accompanied by the emergence of long term memory. The memory mental images about expectation of food +sound of bell have however a shorter time span. These signals wake-up the memory mental images but they are however not conscious to self - and as they die they send a signal back to the brain inducing an imagined mental image involving also the promise of food.

5. In some cases the signal can reach the sensory organs and a sensory memory mental image is generated. This picture applies also to the acquisition of the language. The larger value of h_{eff} associated with language genes (the value of h_{eff} could vary for a given language gene) meaning larger layers of MBs and a possible fusion of MBs of he communicators, and therefore the ability to remember the associations of the words to sensory mental images for a long time. Hearing of the linguistic expression would also generate internal speech as a particular virtual motor action.

4.4 A TGD inspired vision about language

4.4.1 The role of MB

The proposal is that new layer of MB assignable to larger part of MB outside body was involved with the emergence of language. There are several arguments in favor of this proposal.

1. The model for how mutation of few genes like FOXP2 lead the evolution of human languages to be discussed relies on the idea that the value of h_{eff} assignable to dark variants of language genes increases. This means the emergence of new layer of MB having onion-like structure. What emerged was grammatics and syntax as hierarchical structures represented as many-sheeted space-time structures distinguishing humans from other animals could have emerged: these tructures can be assigned to MB and they have also interpretaton in terms of extension of rationals leading to n-sheeted structures. The new level of hierarchy would have emerged at the level of the MB including also dark gene first: flux tubes inside flux tubes inside labelled by values of h_{eff}.

2. The development of language led to a cultural evolution and could have been a quantum leap in the evolution of collective levels of consciousness: emergence of new levels in the hierarchy of extensions of rationals. Maybe the emergence of gene with large h_{eff} meant that it receives control commands from this collective level of consciousness possibly assgnable to communications, social group, or even larger structure. Recall that the size scale of MB assignable to EEG frequencies is of order Earth size. The basic structure of language are indeed very "social". Subjects, objects, verbs expressing what they do to each other, relations between these entities, attributes (adjectives) characterizing their states. Also the notions of plural and singular.

3. One can also ask how it is possible to distinguish between sensory input created by living beings and having meaning from that produced to dead matter. Also humans give emotional meaning to bird's song and vocal signals and gestures of animals but not to the sounds of dead Nature. For autists this ability might be very weakly developed. The natural answer to the queston is that all communications are also communications between magnetic bodies, quite concrete touching, makes it possible to distinguish natural sounds from speech and signals with represent communications. Communications require attention and the flux tube connections between communicators would be correlates for the attention.

   Mere mimicry does not require interpretation of the signal as communications. Some birds can mimic the sound of even a car. I remember my astonishment when finnish bird "talitiainen" mimicked the fate motif of Beethoven's symphony No. 5. My neighbours listened to classical music!

   There should be also a fundamental difference between the communications of ordinary sounds and speech to brain. The communications of speech could be via the large part of MB outside body whereas ordinary sensory data would be communicated via small part of MB to brain.

4. In language acquisition the role of parents, in particular mother, is crucial. One might of course argue that just mimicry and rewards are enough. But how the child knows that mother is trying to teach her that the word "apple" corresponds to the object that the mother is holding at ther hand. Is the fusion and entanglement of MBs needed?

The acquisition of language by child might also involve the MBs of child and Mother at least fusing to a larger structure. This might help the child to understand that the purpose is to learn to reproduce the word associated with the object that word describes. It could also make possible to learn the grammatics and syntax by becoming a part of larger self already learned these notions.

5. Speech communications happen magically in a good company when people are friendly and benevolent. As a young man I was extremely shy in a company of people who were not my friends. When I had intention to say something, I tried to form sentences in my mind as internal speech before possibly getting courage to talk but found it extremely difficult and I remained usually silent. In a company of good friends I realized that it was not so difficult at all: someone talked through me using me as an instrument.

4.4.2 Genes and language

What is the role of FOXP2 and other control genes?

The question that led to the writing of this article was whether the mutation of the genome leading to FOXP2 gene and other similar genes responsible for control of the genome did lead to the evolution of human language. How? The above mechanism does not distinguish in no manner between linguistic and ordinary associations. What happened?

Evolution in TGD framework means the increase of number the increase of the complexity of extension of rationals and thus increase of its dimension $h_{eff}/h_0 = n$ defining a universal measure of intelligence and also a measure for the temporal and spatial scale of quantum coherence. A possibly dramatic increase of h_{eff} for FOXP2 gene and other key genes is a natural hypothesis explaining why the complexity of the language evolved and led from signals to sentences requiring longer time scale of quantum coherence and also the emergence of complex hierarchical structures naturally assignable to the new extension as extension of the original one.

The larger the value of h_{eff}, the larger the scale of the layer of MB. This suggests that a new level of collective consciousness essential for communications emerged. This layer would be associated with the system formed by the systems communicating using language. This would explain the ability to distinguish between sounds produced by inanimate systems and sounds produced by living systems and having meaning.

The emergence of this new level would have meant emergence of many new things: of speech, of longer time scales of memory and planned action, of a new level of cognition, of imagination in longer time scales, and of cultural evolution.

Second mechanism related to the emergence of FOXP2 and other similar control genes could be energy resonance in the coupling of the analogs of DNA, RNA, tRNA, and amino acids. The coupling would be between the entire gene and its dark analog. Whether the energy resonance occurs for all cyclotron energies of codons separately or for their sum remains an open question. For both scenarios small changes of the gene can spoil or produce an energy resonance. This sensitivity would make genes an ideal control tool but would also serve as a general mechanism also for genetic diseases. The increase of h_{eff} accompanied by a small mutation to guarantee energy resonance could be the mechanism explaining the importance of FOXP2 and similar genes.

What about the development of speech organs and brain areas related to speech?

The development of speech required development of speech organs and brain areas for understanding of language and language production. How important was their role or was the mutation of certain genes responsible for language control enough to initiate the evolution leading to the development of speech organs and needed brain areas?

One can consider the emerge of a layer of MB with a considerably longer scale perhaps assignable to some collective level of consciousness - perhaps even the entire species. MB as a TGD counterpart for magnetic fields in Maxwellian theory indeed has layers or order of Earth size and even much larger. The proposed emergence of a big layer of MB with a large value of h_{eff} could relate closely to Sheldrake's proposal [I29] about learning at the level of species. How this new layer could have affected the evolution of speech organs and new brain regions.

1. MB is the key player in TGD. The TGD Universe allows conscious entities and they tend to have ideas as we know. Did MB at some level of hierarchy get an idea about expression of information using temporal sound patterns coupling to dark photons with specific frequencies? That would be a representation of bio-harmony in a new much longer spatial and time scale: did this evolutionary step correspond to the emergence of a new even larger value of h_{eff} to the dark matter hierarchy. Maybe the realization of this new faculty would have been a fractally scaled up variant of earlier realizations making this easier. Did MB make a plan which was eventually realized after a lot of trials and errors?

2. What this plan could correspond to? Here p-adic physics enters into the game. p-Adic dynamics for p-adic variants of space-time sheets obeys the same field equations as real space-time sheets. It however allows breaking of a strict determinism of real number based field equations: this non-determinism would correspond to the freedom of imagination.

   p-Adic data could give rise to full space-time surface as dynamical patterns but they could correspond only to a piece of its real counterpart. Imagination would be non-realistic. Imagined motor actions and sensory inputs would correspond to this kind of partially fulfilled entions: signals would not reach sensory organs or muscles.

3. How this would apply to MB's plan to create sound producing organs? This plan could proceed by trial and error to become more realistic and gradually find a complete realization. The reduction of the planning to trial and error at dark gene level - would be an enormous simplification and could have meant mutations increasing the value of h_{eff} bringing in larger layers of MB related to the brain areas and speech organs.

4.4.3 Meaning from embodiment in the TGD framework

The notion of embodiment is central for the understanding of how speech gets its meaning. The simplest sentences represent sensory inputs or motor actions. But also very abstract expressions have metaphoric representations in terms of subject and objects and verbs representing actions. Embodiment means that language expressions are transformed to virtual sensory inputs and virtual motor actions creating imaginations of the real ones. This requires formation of associations as generation of sensory and motor mental images.

For instance, the sentence "A does something to B" creates virtual sensory and motor mental images in which A indeed does something to B. Mental images representing A and B and "does something" are generated and could correspond to interaction between two mental images. Basically remembering sensory percept in which A does something to B is enough to provide the meaning and the linguistic decomposition is a model. For instance, the heard speech generates internal speech helping in understanding.

The experience or imagined experience as virtual almost experience with input from MB rather than environment is associated with the expression of language. When the language has been learned, a mere language expression generates memory mental images about the experience associated with the expression. The mechanism is naturally pattern recognition and completion as a general mechanism of association and conditioning also in neuroscience and artificial pattern recognition.

Questions

In the TGD framework the questions are the following ones.

1. How memories are represented and how they give rise to conscious memory mental images? ZEO leads to a general proposal for how memory mental images are represented. First communication of sensory input to the part of MB containing a subself representing memory mental image, call it M. M receives the signals and experiences BSFR analogous to motor action involving a signal to the direction of geometric past to subself representing "Me Now". This signal is transformed to a nerve pulse pattern generating a virtual almost sensory mental image.

The general proposal is that in biology at cellular level motor actions are generated as time reversed signals from MB to dark genome inducing neural activity by a signal to cell membrane. The signal from MB to genome would take place by dark photon representation of genetic code and induce BSFR. This mechanism would be quite general.

Genes with N codons must be represented as a dark 3N-photon signal behaving like a single particle like entity. This is not possible in standard physics but adelic physics relying on number theory makes this possible. The notion of Galois confinement [L88] allows dark photon 3N-plets representing genes as sequences of N 3-chords of bio-harmony - kind of music pieces - serving as dynamical units analogous to baryons as color confined units formed from 3 quarks and thus behaving as dynamical units.

The signal would generate a sequence cyclotron resonance peaks at the genome giving rise to a sequence of ticks at dark genome. They must in turn generate a signal to the cell membrane received as a sequence of ticks inducing the sequence of nerve pulses. This seems to require realization of genetic code at the level of the cell membrane level proposed [L46]. The general principle would be the same as in computer language LISP manipulating lists: only identical genes serving as addresses can be in communications by cyclotron resonance. Not only the notion of cyclotrotron radiation but also the notion of generalized Josephson radiation [L13] must be further generalized: dark Josephson photons are replaced with dark 3N-photons.

2. Where the sensory signal to MB is generated? Its generation at neuronal or cell membranes as generalized Josephson radiation is not plausible since the time scales do not fit together. The modulation of Josephson radiation by nerve pulses patterns produces ripples rather than slow frequency modulation. A more plausible proposal is that the sensory signal to MB is generated at the basal ganglia of sensory organs as a generalized Josephson radiation with frequency modulation generated by the sensory input.

3. What is the basic quantum mechanism of association of the memory mental image B to a sensory input A? In the neuroscience framework it would happen in the associative regions of the brain by new pulse patterns and by learning based on changes in synaptic contacts. Now this would take place at analogous regions of MB to which sensory input is sent as a signal and induced cyclotron resonance for 3N-chords.

   A pattern recognition at the level of MB would be in question. This involves a completion of the sinput pattern - sensory mental image - to a pattern representing memory mental image associated with it. This requires a generalization of the existing view about pattern recognition to quantum level. Also this step could involve resonance leading to a fusion of the associated mental images by entanglement. This fused pair of mental images would generate a dark 3N-photon signal propagating to the brain as a generalized cyclotron radiation.

Association to memory mental images gives meaning to linguistic expressions

Association of the auditory input to memory mental images would provide linguistic expressions with meaning.

1. Association is a way to assign meaning to linguistic expressions by embodiment. Language expression is associated with an imagined sensory experience or motor activity. Also internal speech is imagined speech as imagined motor activity and generated by written text.

   Association requires wake-up of memory mental image by the speech signal, which in turn generates a virtual sensory brain or lower level of layers of MB . In ZEO memory mental images are in the geometric future of "me Now" so that BSFR must take place: the memory self "dies" when it sends the message as a dark photon signal. The signal eventually arrives in the brain and generates a nerve pulse pattern needed by dark photon communications generating the virtual sensory to virtual sensory organs.

   Memory mental images at MB are woken up in ordinary memory recall presumably taking place at the hippocampus [J25]. The frequencies involved are theta frequencies suggesting that the layers involved of MB have the size scale of Earth. In the case of speech the frequencies are in the range 150-300 Hz which suggests that layers corresponding to these

frequencies are involved. Also longer time scales such as minute time scale are involved and much bigger layers of MB could be involved.

2. The signals could be sent to the MB from sensory organs:

   (a) Ganglions associated with sensory organs are analogous to brain nuclei and would be the primary receivers of the sensory input. Nerve pulses are generated by neurons above then. Ganglions must play an important role in the generation of sensory experience and motor activities. Ganglions in the brain are called basal ganglia. They could serve as receivers of virtual sensory input and motor output from the brain.

   The neuron structures above ganglions also generate nerve pulses and these give rise to communications to the brain along flux tubes associated with neural pathways by dark photons signals. These communications would represent ordinary sensory communications, in particular sounds as mere sounds without meaning. They would also give rise to language acquisition via association.

   (b) The view about communications to MB as Josephson radiation modulated by membrane voltage variations suggests that the frequency modulations of membrane potential at frequencies of speech are involved. The earlier proposal that nerve pulse patterns could induce this modulation. They however would correspond to ripples of long wavelength waves. Of course, also axonal membranes involve oscillations of the membrane potential inducing the modulation but this modulation of generalized Josephson energy involving also difference of cyclotron energies is much smaller than that caused by nerve pulses.

   The oscillations ganglion membrane potential induced by sound waves could be involved. Frequency modulated Josephson radiation modulated by sounds would propagate to some part of MB. One can consider even the possibility that dark genes such as FOXP2 generate dark 3N-photon radiation. These dark genes could be also realized at the level of cell membrane.

   What could be the radiation in the case of dark genes. Could it be generalized Josephson radiation assignable to an array of Josephson junctions defined by dark genes and their conjugates. Sound waves could induce frequency modulations of oscillations of the voltage between the dark genes just by putting them into motion. Does the distance matter.

   (c) The signals would be received by frequency resonance by some layer of MB responsible for memories representing word-sensory/motor associations. What this layer of MB is and where it is located? The flux tubes should allow 3-N dark photon sequences. Their realization outside the biological body does not look realistic. This suggests that the part of MB can be assigned with the brain of the geometric future. Magnetic loops would return back to the brain of the geometric future. The longer the time scale of the memory, the longer the loop. The realization of sensory or in part of MB analogous to associative cortex. What happens in the part of the MB of the future brain representing the memory about association. The analogy of pattern completion of incoming sound signal to sensory input should take place and generate a virtual sensory input to the geometric past as a response along flux loops arriving at the virtual basal ganglia defining virtual sensory organs. Two long loops would be involved. From sensory basal ganglia to the highest motor and sensory areas? And from these to virtual sensory and motor organs.

   (d) The branching of axons suggests a branching of corresponding flux tubes. What could happen in this process? In branching the value of h_{eff} could be reduced for dark photons - for instance by frequency doubling. Frequency doubling would transform audible frequencies to patterns of nerve pulses with much higher frequencies. From long to short scales. h_{eff} hierarchy would be essential.

   A possible interpretation as a cognitive quantum measurement is possible. Cognitive quantum measurement as a cascade of measurements in the group algebra of the Galois

group of extension would give rise to a gradual reduction of effective Planck constants for the factors of the tensor product.

This cascade could correspond to the branching of axons leading to the reduction of biophoton energy in visible or UV to energy above thermal energy and assignable to cell membrane. What happens in branching of the flux tube? Is energy shared to that of n dark photons with the same frequency and smaller h_{eff}. Or does a localization to a single branch occur. h_{eff} would be reduced and f would increase. E would be conserved. Also both processes can occur. Division into n dark photons with $h_{eff} --> h_{eff}/n$ with f preserved plus a reduction $h_{eff}/n \to h_{eff}/nm$ and increase $f \to mf$ increasing by factor m.

(e) The communication via long flux loops to the small part of MB at the brain cannot correspond to this kind of process since the value of h_{eff} assignable to FOXP2 genes should be preserved. The communication could be to dark control genes such as dark FOXP2 generating signal to neuronal membrane - perhaps dark control gene also there - giving rise to nerve pulse pattern generating virtual almost sensory experience at the virtual sensory organs defined by basal ganglia.

This feedback should have been present already before the emergence of language but in shorter scales and leading to lower layers in the hierarchical structure of the brain ordered by evolution. They would correspond to a hierarchy of increasing values of h_{eff} realized at the level of genome.

These long feedback loops could end also at lower layers inside the brain and also the hierarchy of cortical layers could relate to this kind of feedback hierarchy. The virtual sensory input to the basal ganglia inside the brain would give rise to imagined sensory perceptions and motor actions.

(f) The interpretation as analog of Fourier transform [A2] is suggestive. The cyclotron resonance peaks would generate a sequence of ticks analogous to a Fourier transform of the incoming waves. Music-speech dichotomy suggests itself strongly. Speech could be analogous to a sequence of SFRs - ticks - and singing to superpositions of classical time evolutions connecting them. It is said that the right brain sings and the left brain talks. Could some brain regions sing in the sense that they receive or send the signal as dark cyclotron radiation and could some brain regions talk in the sense that this radiation would induce or be induced by internal speech as virtual motor action.

A holistic representation in terms of frequencies would be transformed to "reductionistic" representation as time series. The correlation function for ticks would have the frequencies in its Fourier transform: stochastic resonance or its analog. Eventually this association to a sequence of ticks could generate a nerve pulse pattern creating a neural pathway making possible virtual sensory input in various sensory areas.

Given language expression corresponds to a huge number sensory percepts and one could argue that this requires a huge number of associations. In the computationalistic framework this would mean a huge amount of computer storage. The model for the generation of mental images predicts that the sensory mental images are standardized mental images generated by a feedback loop giving rise to a pattern recognition. Standard mental images allow also abstraction and conceptualization. One can even consider a quantum counterpart of the classical notion of concept. Concept as the set of its instances would be replaced by wave function in the set of instances giving a large number of different views about the concept.

4.4.4 Bio-harmony as a universal language

Bio-harmony [L9, L65] realizing genetic code for communications is an ideal candidate for a universal language: codon would represent 6 bits and the allowed 64 chords would represent mood at molecular level. There is quite a large number of fundamental moods. Both dark codons and 3-chords bound to units by Galois confinement [L84] can be combined to dark genes by Galois confinement. This language would be minimal. The contents of the message would be minimal - the

address of the receiver same as that of sender - so that LISP like language would be in question. The communications would be based on 3N-resonance. U-shaped flux tubes from receiver and sender forming bridges by reconnection would be the topological aspect of the communications.

The space-time surface associated with n:th order polynomial in M^8 defining the extension of rationals has n sheets corresponding to the roots of the polynomial [L70, L68]. These many-sheeted structures would give rise to a geometric representation of hierarchical linguistic structures.

There is also an abstraction hierarchy defined by the functional composition of polynomials giving rise to representation of the Galois group of extension in terms of inclusion hierarchy of normal subgroups. Flux tubes within flux tubes within.... are possible. For extension of extension of ... with extensions having dimensions $n_1, n_2, ...$ one would have n_1-sheeted structure with sheets replaced with n_2 sheeted structures replaced with..... Substitution of x in $P_{n_1}(x)$ with $P_{n_2}(x)$ with x replaced with....would correspond to this replacement.

Cascades of quantum measurements for the states of the Galois group algebra to a product state in the tensor product of Galois group algebras of the hierarchy of normal subgroups would define cognitive measurements which could be crucial for understanding of language by analysis [L85].

Speech is only one form of communication of binary and emotional information

Concerning production and understanding of speech, one must see the situation more generally in TGD framework.

1. Speech is only one form to communicate information and emotions. Also gestures define a language being based on motor expression. An interesting test is how complex gestures developed before speech and whether FoxP2 has anything to do with sign language. Does sign language have grammatics and syntax characterizing formal languages?

2. Music and singing is the second form of language and expresses emotions rather than bits. Here harmony is an essential notion. Some basic chords define the harmony expressing the mood. Bits/words do not matter, only the chords used.

   This leads in TGD to the model of bioharmony in terms of icosahedral and tetrahedral geometries and 3-chords made of light assigned to the triangular faces of icosahedron and tetrahedron. The surprise was that vertebrate genetic code emerged as a prediction: the numbers of DNA codons coding for a given amino-acid is predicted correctly. DNA codons correspond to triangular faces and the orbit of a given triangle under the symmetries of the bioharmony in question corresponds to DNA codons coding for the amino-acid assigned with the orbit.

   Codon corresponds to 6 bits: this is information in the usual computational sense. Bioharmony codes for mood: emotional information related to emotional intelligence as ability to get to the same mood allowing to receive this information. Bioharmony would be a fundamental representation of information realized already at molecular level and speech, hearing and other expressions of information would be based on it.

   The surprising findings that RNA is central in conditioning [**?**]uggest that RNA somehow represents emotions crucial for conditioning [**?**] Dark DNA and bioharmony for which emotions would be realized at molecular level would make it possible.

What does Universality mean?

There are two views about language: Universality (or computationalism involving only grammar and syntax) concentrates on the formal aspects whereas connectionism concentrates language as a conditioning. For the first option one speaks of language learning as learning of formal rules and this applies to written language and language of mathematics. For the latter option one speaks of language acquisition as an almost unconscious process of imitation. These two views would be fused together in TGD view.

1. There would be only one universal language at the fundamental level. For communications it would be defined by genetic code realized as 3-chords of dark photons forming in turn

3N-frequency composites serving also as units. This code has both the bitty aspect: codon corresponds to 6 bits and the emotional aspect defined by given bio-harmony characterizing that is by the 3-chords defining the bio-harmony and in this manner mood. Genome would define genotype of language and specific languages would be phenotypes.

This code is used in communications between various levels of the hierarchy. At least in control commands arriving from MB to genome. The analog of Josephson radiation from cell membrane mediating sensory data to MB would consist of a sequence of notes but if cell membrane realizes genetic code, also Josephson radiation could consist of 3N-frequency dark photon composites representing genes. Note that the notion of tick makes sense also for 3N-chords. The message would be sent as Josephson radiation or cyclotron radiation and received as ticks corresponding to state function reductions.

Of course, one cannot exclude the single note option - mere temporal pattern of ticks with varying time separations - for the messages to the genome could be the case of speech having constant pitch. For singing and speech mediating emotions the situation melody or sequence of 3-chords would be needed.

Since the language would be realized at DNA level, even plants could communicate using it. Plants are known to communicate and there is evidence that plants can cognize and even count [I8](`https://cutt.ly/ffRYXH8`). In TGD framework also hormonal communications thought to be chemical would take place by biophotons: the hormones connected by flux tube to molecule in say hypothalamus would build the waveguides to second molecule in body for dark photons to propagate.

The basic new physics building bricks in this picture would be 3N-frequency cyclotron resonance transforming the oscillating signal from basal ganglia membranes to a sequence of ticks in turn inducing a sequence of nerve pulses generating the virtual sensory experience using stochastic resonance coding the frequencies of original signal to peaks in the frequency spectrum of the correlation function for the sequences of nerve pulses. Also dark 3N-photon Josephson radiation assignable to genes represented also at cell membrane level would emerge as a new concept.

2. The universal aspects of the language would be realized as a basic expression of dark genes realized in terms of 3N dark photon composites propagating along flux tubes. The content of the packet is the address to which it sent! This would be just like in computer language LISP. This would be the genotype of language, the universal language based on 3N-frequency-resonance between sender and receiver genes.

   This would completely separate the meaning of language expressions from the basic communication mechanism. This is of course true also for kinds of communications. The sender and receiver provide the meaning for language expressions by sensory perceiving them. Understanding of how the meaning is generated is the key problem. This requires theory of consciousness and a new view about the conscious brain.

3. TGD view is based on dark 3N-photon resonance communications between genomes and possibly also the genomes associated with the cell membranes and microtubules realizing the genetic code. The sensory input together with the language expression would provide the primary sensory percept - just as in learning by example. When communicated to the brain and even MB a secondary virtual almost sensory percept and virtual almost motor action would be generated as imagined sensory inputs.

   This would be the fundamental association giving meaning to the language. Conditioning would occur and when the mere linguistic input is received, the virtual sensory precept and motor output are generated. Does this require anything new: for instance, does it require that the associations are remembered in some sense or are the associations realized as in neuroscience in terms of synaptic strengths? One would have memory as a learned behavior.

   First the sensory input generated by linguistic expression is communicated from the basal ganglia of sensory organ or virtual sensory organ to the sensory and motor cortices by using dark 3N-photon resonance. After this the virtual sensory input and almost imagined) perception is generated. How?: as dark 3N-photon signals propagating in opposite spatial

direction to sensory organs. The fact that nerve pulse conduction is in a single direction only suggests that also time reversal occurs in BSFR.

4. This general picture applies to the formation of associations and conditioning quite generally. This would be also the mechanism of imagination, which also sharply distinguishes humans from animals. The special ability of the humans to imagine would have emerged at the same time as the complex language. This could be due to the mutations of certain language genes like FOXP2 acting as genes for which the 3N-photon resonance is realized and one must understand how this could be the case.

The proposed notion of universality is not in conflict with the fact there exist large number of languages. The development of different languages is actually easy to understand as reflecting the fact that there is underlying universal language which is minimal in the sense that the content of the message is the address of the receiver. Language acquisition is a conditioning process associating sensory inputs and motor outputs to language expressions at a more fundamental level and the words are just labels for them. This is like general coordinate invariance in general relativity. Points of space-time can have infinite manner of different labelings in terms of numbers (now words).

4.4.5 Geometrization and topologization of the grammar and syntax in terms of many-sheeted space-time

These aspects of speech make understanding of speech acquisition possible but what about intentional learning of speech involving learning of grammar and syntax, which have nothing to do with contents of speech? In computer languages and mathematics as language this aspect would dominate.

Fractal flux tubes networks and structures of language

The TGD proposal is that magnetic flux tube networks - possibly trees in case of speech and associated with nerve pulse patterns are in an essential role. Flux tubes are effectively 1-D and have orientation which corresponds to temporal direction of speech and spatial direction of written language. There are flux tubes inside flux tubes flux tubes giving rise to hierarchical structures corresponding to the parsing of language expressions. MB would as many-sheeted structure would geometrize/topologize grammar and syntax.

There are aso 2-D and even 3-D flux tube networks but not accompanied by neural networks. These would be essential for the geometric and holistic aspects of cognition: visual cognition in particular. The meridian system of Eastern medicine could be associated with the MB. These flux tube networks would have been present before the emergence of the neural system and would be possessed even by plants. TGD could reduce the structures of language to purely geometric structures. Sentences would correspond to many-sheeted space-time surfaces with their topology representing the parsing structure. Basic space-time sheets would represent words, and the gluing of them to larger space-time sheets by topological sum operation would build sentences. Topological sum of surfaces A and A_0 essentially means that A is inside A_0. Also the ordering of the words matters: AB and BA are not the same thing. When A and B are inside an effectively 1-D magnetic flux tube A_0, the ordering of the positions inside the flux tube makes it possible to tell whether A is before B or vice versa.

Non-associativity forcing use of brackets in mathematical expressions would be also important ($(A+B)C \neq A+BC$). For instance, $(AB)C$ would correspond to the structure formed from a pair A_0C of flux tubes by putting AB inside flux tube A_0. $A(BC)$ would be obtained from the AA_0 by putting BC inside A_0. Putting inside brackets means gluing at a larger space-time sheet. The reader is encouraged to imagine what these examples look like when represented in terms of flux tubes within flux tubes.

The hierarchy of extensions of rationals realized in terms of functional composition of polynomials defining space-time surfaces in M^8 as n-sheeted structures provides a number theoretical view about linguistic structures [L79]. The functional decomposition $P_1 \to P_1 \circ P_2(x)$ replaces each space-time sheet of the n_1-sheeted structure with an n_2-sheeted structure associated with P_2. This is like fractal zoom each sheet to n_2 sheets.

This is due to the fundamental theorem of algebra stating that a polynomial P_n of complex argument with degree n obtains all its values n times. The argument $y = P_{n_2}(x)$ of $z = P_{n_1}(y)$ has the same value for n_2 points x_k. This gives n_2 sheets at y. The value z in turned obtained for n_1 points. Therefore n_1 sheets decompose to n_2 sheets.

How the structural elements of language can be understood?

One must understand what is behind the notions of subject, object, verb. How tense, case, singular and plural , pronouns, adverbs, etc. are expressed: at the level of genetic code or of conscious experience as contents of imagined sensory experience and motor activity associated with the experience? Are they coded already by the oscillation pattern of the basal ganglia membrane giving rise to imagined experience beside genuine sensory experience? This would be the most elegant option.

The same FoxP2 gene or its analogs could be involved. Consider tense as an example. How the tense would be coded to the oscillations of the ganglia membrane or to the position of these membranes in the brain - to what subself they represent. Who is talking and about what and when!

- "I see" would correspond to a real sensory perception.
- "I saw" corresponds to immediate personal memory: could this be a virtual almost percept produced by a memory and realized at different places as virtual sensory percept. Basal ganglia associated with a level higher than sensory organs responsible for imaginations and inner speech..
- "I will see" would correspond to sensory percept, precognitions in reversed arrow of time.
- "I have done" seems to refer to a remote past: different time scale and perhaps different value of h_{eff}.
- "I had done" is talk of another self above or parallel me in self hierarchy about me as sub-self as an outsider. Now the basal ganglia would be at some part of the brain containing mental images representing some outsiders, say community as sub-self.

One should also understand what makes the sentence a question or command. In written language formal tools to express whether the sentence represents a question, command or something else have emerged. The many-sheeted structure of space-time should express these aspects of language using fixed words as vocabulary at the basic level. For instance, the building bricks for "Did you do this?" and "Do this!" should have the same "genotype" but different "phenotypes" if the reduction to dark genetic code makes sense. The context represented by a mental image containing the standard mental images representing the words of the sentence would determine "phenotype" allowing to differentiate between the two cases. The geometric representation would be based on flux tubes. Context - the larger flux tube - would be associated with the mental image "I do not know" for "Did you do this?" and "I am the boss" for "Do this!": this context would determine the phenotype just like the environment affects the phenotype in ordinary genetics.

4.5 Appendix: Living matter, biochemistry, and consciousness

The model for living matter relies heavily on the notions of MB carrying $h_{eff} > h$ phases behaving like dark matter and ZEO.

4.5.1 ZEO based quantum measurement theory extends to a theory of consciousness

ZEO based quantum measurement theory [L96] leads to a quantum theory of consciousness (see **Fig. 4.4**)by lifting the observer from an outsider to part of physical system. In particular, the theory predicts that the arrow of time changes in "big" (ordinary) state function reductions

(BSFRs) as opposed to "small" SFRs (SSFRs) as the counterparts of weak measurements (see **Fig. 4.5**).

This suggests that self-organization in all scales reduces to dissipation with reversed arrow of time. The energies of states increase with h_{eff} and h_{eff} tends to be reduced spontaneously. This means that energy feed is needed to preserved the distribution for h_{eff}: in biology this corresponds to metabolic energy feed. The energy feed necessary for self-organization would reduce to dissipation of self-organizing system in reversed time direction. Dark matter at MB of the system would serve as a master controlling the ordinary matter serving in the role of slave. Note that there would be master-slave hierarchy of MBs ordered by h_{eff}.

This would happen at magnetic and have dramatic implications. Time reversed dissipation looks like energy feed from the environment to system. Self-organization involves always energy feed and generation of structures rather than their disappearance in apparent conflict with second law. Self-organization would correspond to dissipation in reversed time direction implied by generalized second law. No specific mechanisms would be required and only metabolic energy storages- systems able to receive the energy dissipated in reversed time direction - are enough. Obviously this provides a totally new vision about energy technology.

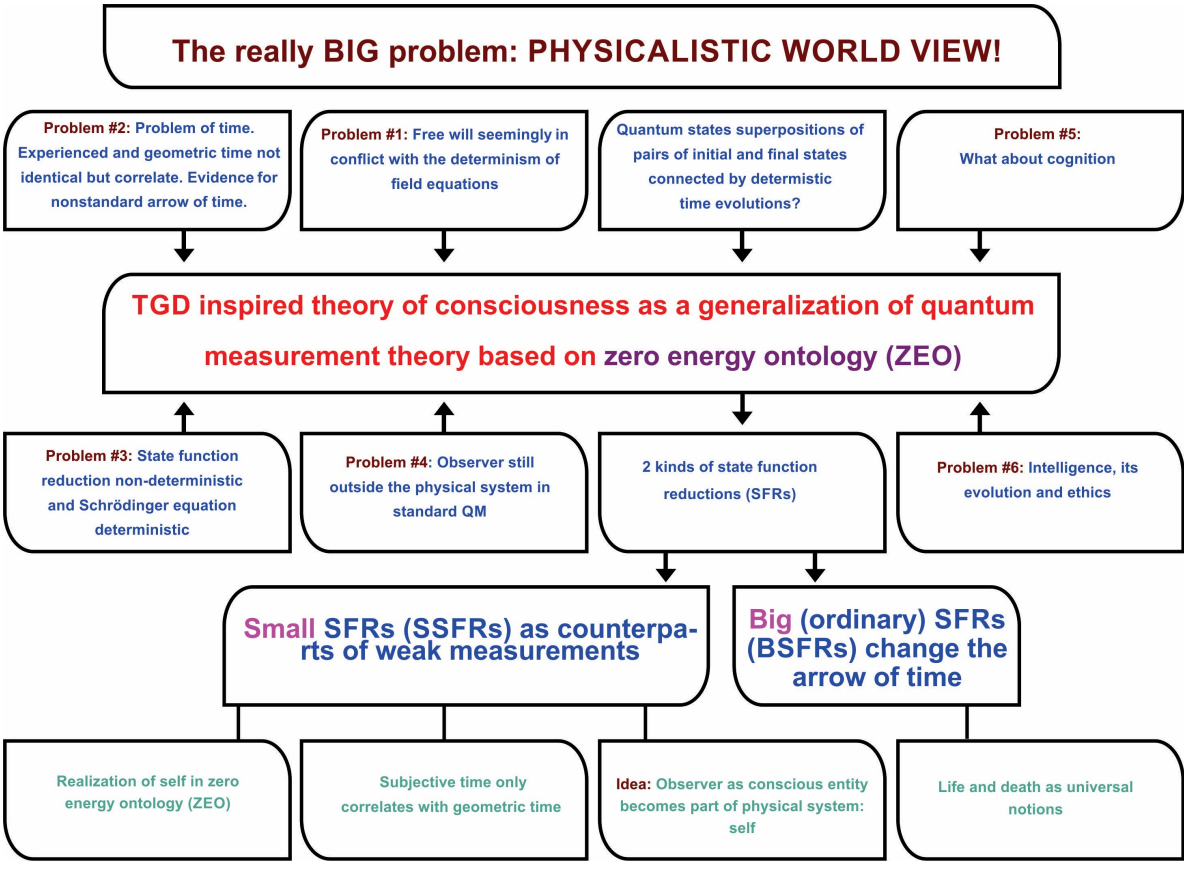

Figure 4.4: Consciousness theory from quantum measurement theory

4.5.2 p-Adic physics as a correlate of intention and cognition

One of the earlier ideas about the arrow of subjective time was that it corresponds to a phase transition front representing a transformation of intentions to actions and propagating towards the geometric future quantum jump by quantum jump. The assumption about this front is unnecessary in the recent view inspired by ZEO. Intentions should relate to active aspects of conscious

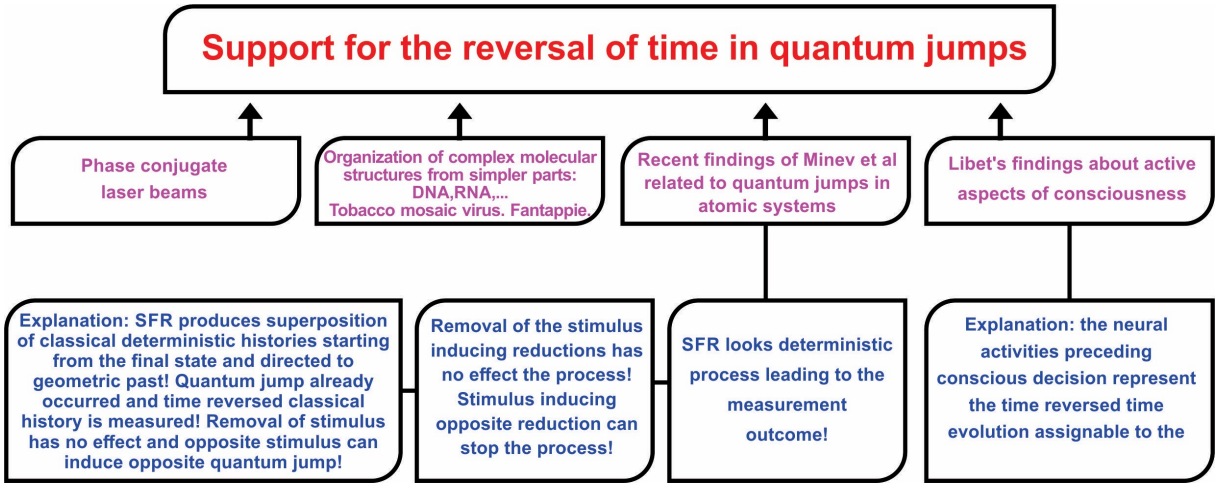

Figure 4.5: Time reversal occurs in BSFR

experience. The question is what the quantum physical correlates of intentions are and what happens in the transformation of intention to action.

1. The old proposal is that p-adic-to-real transition could correspond to a realization of intention as action. One can even consider the possibility that the sequence of state function reductions decomposes to pairs real-to-padic and p-adic-to-real transitions. This picture does not explain why and how intention gradually evolves increasingly stronger, and is finally realized. The identification of p-adic space-time sheets as correlates of cognition is however natural.

2. The newer proposal, which might be called adelic, is that real and p-adic space-time sheets form a larger sensory-cognitive structure: cognitive and sensory aspects would be simultaneously present. Real and p-adic space- time surfaces would form a single coherent whole which could be called adelic space-time. All p-adic manifolds could be present and define kind of chart maps about real preferred extremals so that they would not be independent entities as for the first option. The first objection is that the separate assignment of fermions to every Cartesian factor of the adelic space-time does not make sense. This objection is circumvented if fermions belong to the intersection of realities and p-adicities.

   This makes sense if string world sheets carrying the induced spinor fields- define seats of cognitive representations in the intersection of reality and p-adicities. Cognition would be still associated with the p-adic space- time sheets and sensory experience with real ones. What can be sensed and cognized would be represented by the intersection.

   Intention would be however something different for the adelic option. The intention to perform quantum jump at the opposite boundary would develop during the sequence of state

function reductions at fixed boundary and eventually Negentropy Maximization Principle (NMP) [K41] [L31] (stating that in given state function reduction negentropy gain is in some sense maximized) would force the transformation of intention to action as first state function reduction at opposite boundary. NMP would guarantee that the urge to do something develops so strong that eventually something is done.

Intention involves two aspects: The plan for achieving something which corresponds to cognition and the will to achieve something which corresponds to emotional state. These aspects could correspond to p-adic andreal aspects of intentionality.

The recent view relying strongly on $M^8 - H$ duality lead to ask whether the picture could be made more precise.This picture forces also to challenge the above picture.

1. The basic idea is that p-adic integration constants of the differential equation are pseudo-constants having a vanishing derivative but depending on finite number of pinary digits-rational numbers satisfy this condition. In M^8 picture a real polynomial with rational (or possibly algebraic) coefficients determines the space-time surface. The roots of this polynomial as a function of radial light-coordinate r at light-like boundary of CD determine this polynomial. When pseudo constant are allowed, the coefficients become pseudo constants, which are constants at the interval $[0;T]$ divided to sub-intervals $I_1 = [0;t_1]$, $I_2 = [t_1;t_2]$, ...,$I_N = [t_{N-1};t_N]$ by the division $0 < t_1 < t_2 < ...t_N = T$.

2. Could the division to the intervals be unique by some argument? The roots of P are identified as moments for which SSFRs occur. Could tk correspond to a root of the polynomial P_k defined in the interva lI_k. Could the "very special moments in the life of self" as roots of a polynomial correspond to introduction of new pseudo constants as a p-adic correlate for the state function reduction? Each interval has it own polynomial P_k and the allowed roots r_{k_i} become to the interval $[t_k;t_{k+1}]$ and their number is usually smaller than the degree n of the polynomial. Assume that each polynomial restricted to its own range defines a 4-surface inside the same CD. One would have m separate p-adic space-time surfaces. These surfaces would serve as correlates for intentions or dreams.

How could the real space-time surface as a realized intention relate to these surfaces?

1. Each of the 4-surfaces with genuinely constant coefficients of P_k has its own cognitive representation as points common to real and all p-adic variants. If the number of points t_k is finite one indeed has p-adic pseudo-constants for any prime p.

2. The realization of intention should be a quantum jump, state function reduction, or action of free will. Does this state function reduction have the selection of one of the polynomials P_k as a real polynomial defining the real space-time surface as a geometric correlate.

3. Could one generalize this to fermionic degrees of freedom. In [L73] its is proposed that one could super-symmetrize TGD and quark spinors as embedding space spinors by replacing embedding space coordinates with super fields with components expressible as hermitian composites of second quantized quark and antiquark oscillator operators. Analogous generalization would be made for the second quantized quark field.

   In the M^8 picture the real polynomial would be replaced with a polynomial of super coordinate algebraically continued to super-octonionic coordinate. Solutions of the algebraic equations defining space-time surface would be now super-space-time surfaces which are unions of components assignable with the fermionic super coefficients of the super-polynomial.

   The rational coefficients of this polynomial could be replaced with pseudo- constants and the above picture seems to generalize. The spinor super-field would be a restriction of the M^8 spinor super-field to the p-adic branches of the p-adic space-time surface. Could the above picture about intentional act as a choice of the real branch generalize.

The next important step is to understand intentional action at quantum level.

1. The most general vision is that intention corresponds to a superposition of p-adic spacetime surfaces with coefficients of polynomials which are genuine pseudo constants and by number theoretic universality same in all p-adic sectors. These superpositions would represent intentions and dreams. One could also speak of a dreamy CD containing a dreamy quantum Universe. Since cognitive representations are considered, everything would reduce to an extension of rationals, and the quantum dynamics by SSFRs and BSFRs would not formally differ from that for the real space-time surface and one could speak about transition amplitudes between dreams.

2. The realization of an intentional action would correspond to an SFR in which the pseudo constants become genuine constants. The simplest model is that one of the polynomials P_k is selected and be extended to a polynomial in the entire CD associated with P. The origin of CD is in a unique role in M^8 picture and $P(0) = 0$ makes possible hierarchies of extensions and conservation of number theoretical data as roots of P in the composition of polynomials realized for space-time surfaces.

   If $P_k(0)$ is required also for $k > 1$, any P_k can be selected. One can however challenge the idea that intentional action involves a selection. If $P_k(0) = 0$ for $k > 1$ is not assumed, P_1 associated with the interval $[0, t_1]$ must be chosen and CD corresponds to its size cale. One can talk about a partial realization of the intention in accordance with the intuitive expectations. For instance, imagined sensory percepts and motor actions could correspond to this kind of partial realizations.

3. If motor action corresponds to BSFR, intentional action can be realized only for BSFR. SSFR could not allow a realization of intention if the sequence of SSFRs corresponds to a functional composition of polynomials or even iteration of a single polynomial: I have considered these options for the sequence of SSFRs in [L82].

4. This picture is in accordance with the conservation laws in ZEO and allows the creation of Universes as from nothing. CDs do not pop up from vacuum but dream-CDs transform to real ones.

It is difficult to avoid the question of whether the notion of state function reduction could be reduced to a classical choice selecting one P_k: quantum jump as choice between dreams to be realized. This option would lead to purely classical probability theory and it would be however very difficult to understand what determines the transition probabilities.

4.5.3 The notion of magnetic body

Magnetic body (MB) would carrying dark matter would serve as the boss controlling ordinary matter at flux tubes.

1. MB has as building bricks magnetic flux quanta. Typically flux tubes and flux sheets. It consists of two kinds of flux quanta. Flux can be vanishing, which corresponds to Maxwellian case. The flux can be also non-vanishing and quantized and corresponds to monopole flux. In monopole case magnetic field requires no current to create it. This option is not possible in Maxwellian world. These flux tubes play a key role in TGD Universe in all scales.

2. Also Earth's magnetic field with nominal value $B_E = .5$ Gauss would have these two parts. Monopole part corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss explaining strange effects of ELF em radiation to the physiology and behavior of vertebrates [J24]. The presence of this part identifiable as monopole flux explains why Earth has magnetic field: this field should have decayed long time ago in Maxwellian world since it requires currents to generate it and they disappear. Magnetic fields of permanent magnets could have a monopole part consisting of flux quanta. Electromagnets would not have it.

3. MB would carry dark matter as $h_{eff} = n \times h_0$ phases and act as a "boss" controlling ordinary matter [L78]. Communication to and control of biological body (ordinary matter) would be based on dark photons, which can transform to ordinary photons and vice versa. Molecular transitions would be one form of control.

4. Dark photons with large h_{eff} serve as as communication and control tools. Josephson frequencies would be involved with the communication of sensory data to MB and cyclotron frequencies with control by MB. Dark photons are assumed to transform to bio-photons [L7, L6] with energies covering visible and UV associated with the transitions of bio-molecules. The control by MB which layers having size even larger than that of Earth means that remote mental interactions are routine in living matter. EEG would be a particular example of these communications: without MB it is difficult to understand why brain would use such large amounts of energy to send signals to outer space.

5. The experiments of Blackman and others led originally to the notion of h_{eff} hierarchy. The large effects of radiation at ELF frequencies could be understood iin terms of cyclotron transitions in $B_{end} = .2$ Gauss if the value of h in $E = hf$ is replaced with h_{eff}, which would be rather large and possibly assignable to gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$.

   MB would control BB by cyclotron radiation - possibly via genome accompanied by dark genome at flux tubes parallel to the DNA strands. Cyclotron Bose-Einstein condensates of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear in living matter and $h_{eff} = h_{gr}$ hypothesis predicts universal energy spectrum in the range of bio-photon energies.

   Cell membrane could act as generalized Josephson junction generating dark Jophson radiation with energies given by the sum for ordinary Josephson energy and of the difference of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential would induce variation of the Josephson frequency and code the sensory information at cell membrane to a dark photon signal sent to MB.

6. In ZEO field body and MB correspond to 4-D rather than 3-D field patterns. Quantum states are replaced by quantum counterparts of behaviors and biological functions. The basic mechanism used by MB would be generation of conscious holograms by using dark photon reference beams from MB and their reading. In ZEO also the time reversals of these processes are possible and make possible to understand memory as communications with geometric past. Sensory perception and memory recall would be time reversals of each other and correspond to sequences of SSRs. Motor action would correspond to BSRs.

4.5.4 Life is not mere chemistry

The dogma about biology as mere bio-chemistry is given up in TGD framework.

1. Bio-catalysis remains a mystery in bio-chemical approach. MB carrying dark matter could provide the needed mechanisms.

   According to TGD view about catalysis, the U-shaped flux tubes associated with the MBs of reactants reconnect to a pair of flux tubes connecting the molecules [L62]. This happens if there is cyclotron resonance for dark cyclotron radiation assignable to massless extremals (MEs) associated with U-shaped flux tubes. This requires that the flux tubes have same strength of magnetic field and therefore same thickness by flux quantization. The same value of h_{eff} guarantees resonance. The next step is the shortening of the flux tubes by a reduction of h_{eff} and liberating energy kicking the reactants over the potential wall making the process extremely slow otherwise.

2. Also valence bonds and hydrogen bonds could correspond to magnetic flux tubes characterized by $h_{eff} = h_{em} = n \times h_0$, where n is now rather small number ($h = 6h_0$). This leads to a model for valence bond energies of atom with n increasing as one moves to right along the row of the periodic table providing insights to the biological roles of various molecules in biology [L44]. For instance, the molecules involving atoms towards right end of the periodic table would be natural carriers of metabolic energy whereas at the left end of row would be naturally involved with biocontrol via cyclotron frequencies.

3. The physics of water is full of anomalies [I33]. TGD suggests an explanation [L45] in terms of flux tubes assignable to hydrogen bonds [L45, L61]. These flux tubes could correspond

also to values of $h_{eff} > h$ so that these flux tube could be long and give rise to long range quantal correlations. Water could be seen as a manyphase system. The MBs assignable to water molecule clusters could mimick the cyclotron frequency spectrum of invader molecules and make possible water memory and primitive immune system based on reconnections of U-shaped flux tubes of water cluster and invader molecule [L88]. In this framework water would represent a primitive life form.

In Pollack effect [I27] exclusion zones (EZs) are induced at the boundary between gel phase and water by energy feed such as IR radiation. The negative charge of EZs is explained as a formation of flux tubes carrying dark protons having interpretation as dark nuclei. A simple model for linear dark proton triplets predicts their states to be in 1-1 correspondence with DNA, RNA, tRNA, and amino-acids and the numbers of codons coding for given amino-acid are predicted to be same as for vertebrate genetic code [L58, L77]. The model thus predicts deep connections between nuclear physics, condensed matter physics, chemistry, and biology usually thought to be rather disjoin disciplines.

EZs are able remove impurities from interior in conflict with second law. TGD based explanation of the mystery is change of the arrow of time induced by TGD counterpart of ordinary state function reduction in ZEO) [L96]: self-organization would be dissipation with reversed arrow of time at at the magnetic body (MB) of system acting as master and forcing time reversed evolution at the level of ordinary bio-matter serving as a slave.

DNA has one negative charge per nucleotide, microtubules are negatively charged, also cell is negatively charged, ATP carries 3 units of negative charge. This together with ZEO suggests that Pollack effect plays a key role in bio-control and macroscopic SFRs play a key role in living matter.

Chapter 5

Is Non-associative Physics and Language Possible only in Many-Sheeted Space-time?

5.1 Introduction

In Thinking Allowed Original (see https://www.facebook.com/groups/thinkallowed/) there was very interesting link added by Ulla about the possibility of non-associative quantum mechanics (see http://phys.org/news/2015-12-physicists-unusual-quantum-mechanics.html#jCp).

Also I have been forced to consider this possibility.

1. The 8-D embedding space of TGD has octonionic tangent space structure and octonions are non-associative. Octonionic quantum theory however has serious mathematical difficulties since the operators of Hilbert space are by definition associative. The representation of say octonionic multiplication table by matrices is possible but is not faithful since it misses the associativity. More concretely, so called associators associated with triplets of representation matrices vanish. One should somehow transcend the standard quantum theory if one wants non-associative physics.

2. Associativity seems to be fundamental in quantum theory as we understand it recently. Associativity is a fundamental and highly non-trivial constraint on the correlation functions of conformal field theories. It could be however broken in weak sense: as a matter of fact, Drinfeld's associator emerges in conformal field theory context. In TGD framework classical physics is an exact part of quantum theory so that quantum classical correspondence suggests that associativity could play a highly non-trivial role in classical TGD. The conjecture is that associativity requirement fixes the dynamics of space-time sheets - preferred extremals of Kähler action - more or less uniquely. One can endow the tangent space of 8-D imbedding $H = M^4 \times CP_2$ space at given point with octonionic structure: the 8 tangent vectors of the tangent space basis obey octonionic multiplication table.

   Space-time realized as n-D surface in 8-D H must be either associative or co-associative: this depending on whether the tangent space basis or normal space basis is associative. The maximal dimension of space-time surface is predicted to be the observed dimension $D = 4$ and tangent space or normal space allows a quaternionic basis.

3. There are also other conjectures [K77] about what the preferred extremals of Kähler action defining space-time surfaces are.

   (a) A very general conjecture states that strong form of holography allows to determine space-time surfaces from the knowledge of partonic 2-surfaces and 2-D string world sheets.

(b) Second conjecture involves quaternion analyticity and generalization of complex structure to quaternionic structure involving generalization of Cauchy-Riemann conditions.

(c) $M^8 - M^4 \times CP_2$ duality stating that space-time surfaces can be regarded as surfaces in either M^8 or $M^4 \times CP_2$ is a further conjecture.

(d) Twistorial considerations select $M^4 \times CP_2$ as a completely unique choice since M^4 and CP_2 are the only spaces allowing twistor space with Kähler structure. The conjecture is that preferred extremals can be identified as base spaces of 6-D sub-manifolds of the product $CP_3 \times SU(3)/U(1) \times U(1)$ of twistor spaces associated with M^4 and CP_2 having the property that it makes sense to speak about induced twistor structure.

The "super(optimistic)" conjecture is that all these conjectures are equivalent.

The motivation for what follows emerged from the observation that language is an essentially non-associative structure as the necessity to parse linguistic expressions essential also for computation using the hierarchy of brackets makes obvious. Hilbert space operators are however associative so that non-associative quantum physics does not seem plausible without an extension of what one means with physics. Associativity of the classical physics at the level of *single* space-time sheet in the sense that tangent or normal spaces of space-time sheets are associative as sub-spaces of the octonionic tangent space of 8-D embedding space $M^4 \times CP_2$ is one of the key conjectures of TGD.

But what about many-sheeted space-time? The sheets of the many-sheeted space-time form hierarchies labelled by p-adic primes and values of Planck constants $h_{eff} = n \times h$. Could these hierarchies provide space-time correlates for the parsing hierarchies of language and music, which in TGD framework can be seen as kind of dual for the spoken language? For instance, could the braided flux tubes inside larger braided flux tubes inside... realize the parsing hierarchies of language, in particular topological quantum computer programs? And could the great differences between organisms at very different levels of evolution but having very similar genomes be understood in terms of widely different numbers of levels in the parsing hierarchy of braided flux tubes-that is in terms of magnetic bodies as indeed proposed. If the intronic portions of DNA connected by magnetic flux tubes to the lipids of lipid layers of nuclear and cellular membranes make them topological quantum computers, the parsing hierarchy could be realized at the level of braided magnetic bodies of DNA.

Fortunately the mathematics needed to describe the breaking of associativity at fundamental level seems to exist. The hierarchy of braid group algebras forming an operad combined with the notions of quasi-bialgebra and quasi-Hopf algebra discovered by Drinfeld are highly suggestive concerning the realization of weak breaking of associativity. With good luck this breaking of associativity is all that is needed. With not so good luck this breaking of associativity takes place already at the level of single space-time sheets and something else is needed in many-sheeted space-time.

5.2 Is Non-associative Physics Possible In Many-sheeted Space-time?

The key question in the sequel is whether non-associative physics could emerge in TGD via *many-sheeted* space-time as an outcome of many-sheetedness and therefore distinguishing TGD from GRT and various QFTs.

5.2.1 What Does Non-associativity Mean?

To answer this question one must first understand what non-associativity could mean.

1. In non-associative situation brackets matter. $A(BC)$ is different from $(AB)C$. Here AB need not be restricted to a product or sum: it can be anything depending on A and B. From schooldays or at least from the first year calculus course one recalls the algorithm: when calculating the expression involving brackets one first finds the innermost brackets and calculates what is inside them, then proceed to the next innermost brackets, etc... In

computer programs the realization of the command sequences involving brackets is called parsing and compilers perform it. Parsing involves decomposition of program to modules calling modules calling.... Quite generally, the analysis of linguistic expressions involves parsing. Bells start to ring as one realizes that parsings form a hierarchy as also do the space-time sheets!

2. More concretely, there is hierarchy of brackets and there is also a hierarchy of space-time sheets labelled by p-adic primes and perhaps also by Planck constants $h_{eff} = n \times h$. B and C inside brackets form (BC), something analogous to a bound state or chemical compound. In TGD this something could correspond to a "glueing" space-time sheets B and C at the same larger space-time sheet. More concretely, (BC) could correspond to braided pair of flux tubes B and C inside larger flux tube, whose presence is expressed as brackets (..). As one forms $A(BC)$ one puts flux tube A and flux tube (BC) containing braided flux tubes B and C inside larger flux tube. For $(AB)C$ flux one puts tube (AB) containing braided flux tubes A and B and tube C inside larger flux tube. The outcomes are obviously different.

3. Non-associativity in this sense would be a key signature of many-sheeted space-time. It could show itself in say molecular chemistry, where putting on same sheet could mean formation of chemical compound AB from A and B. Another highly interesting possibility is hierarchy of braids formed from flux tubes: braids can form braids, which in turn can form braids,... Flux tubes inside flux tubes inside... Maybe this more refined breaking of associativity could underly the possible non-associativity of biochemistry: biomolecules looking exactly the same would differ in subtle manner.

4. What about quantum theory level? Non-associativity at the level of quantum theory could correspond to the breaking of associativity for the correlation functions of n fields if the fields are not associated with the same space-time sheet but to space-time sheets labelled by different p-adic primes. At QFT limit of TGD giving standard model and GRT the sheets are lumped together to single piece of Minkowski space and all physical effects making possible non-associativity in the proposed sense are lost. Language would be thus possible only in TGD Universe!

5.2.2 Language And Many-sheeted Physics?

Non-associativity is an essentially linguistic phenomenon and relates therefore to cognition. p-Adic physics labelled by p-adic primes fusing with real physics to form adelic physics are identified as the physics of cognition in TGD framework.

1. Could many-sheeted space-time of TGD provides the geometric realization of language like structures? Could sentences and more complex structures have many-sheeted space-time structures as geometrical correlates? p-Adic physics as physics of cognition would suggest that p-adic primes label the sheets in the parsing hierarchy. Could bio-chemistry with the hierarchy of magnetic flux tubes added, realize the parsing hierarchies?

2. DNA is a language and might provide a key example about parsing hierarchy. The mystery is that human DNA and DNAs of most simplest creatures do not differ much. Our cousins have almost identical DNA with us. Why do we differ so much? Could the number of parsing levels be the reason- p-adic primes labelling space-time sheets? Could our DNA language be much more structured than that of our cousins. At the level of concrete language the linguistic expressions of our cousin are indeed simple signals rather than extremely complex sentences of old-fashioned German professor forming a single lecture each. Could these parsing hierarchies realize themselves as braiding hierarchies of magnetic flux tubes physically and - more abstractly - as analos of parsing hierarchies for social structures. Indeed, I have proposed that the presence of collective levels of consciousness having the hierarchy of magnetic bodies as a space-time correlates distinguishes us from our cousins so that this explanation is consistent with more quantitative one relying on language.

3. I have also proposed that intronic portion of DNA is crucial for understanding why we differ so much from our cousins [K3, K79]. How does this view relate to the above proposal? In the

simplest model for DNA as topological quantum computer introns would be connected by flux tubes to the lipids of nuclear and cell membranes. This would make possible topological quantum computations with the braiding of flux tubes defining the topological quantum computer program.

Ordinary computer programs rely on computer language. Same should be true about quantum computer programs realized as braidings. Now the hierarchical structure of parsings would correspond to that of braidings: one would have braids, braids of braids, etc... This kind of structure is also directly visible as the multiply coiled structure of DNA. The braids beginning from the intronic portion of DNA would form braided flux tubes inside larger braided flux tubes inside.... defining the parsing of the topological quantum computer program. The higher the number of parsing levels, the higher the position in the evolutionary hierarchy. Each braiding would define one particular fundamental program module and taking this kind of braided flux tubes and braiding them would give a program calling these programs as sub-programs.

4. The phonemes of language have no meaning to us (at our level of self hierarchy) but the words formed by phonemes and involving at basic level the braiding of "phoneme flux tubes" would have. Sentences and their substructures would in turn involve braiding of "word flux tubes". Spoken language would correspond to temporal sequences of braidings of flux tubes at various hierarchy levels.

5. The difference between us and our cousins (or other organisms) would not be at the level of visible DNA but at the level of magnetic body. Magnetic bodies would serve as correlates also for social structures and associated collective levels of consciousness. The degree of braiding would define the level in the evolutionary hierarchy. This is of course the basic vision of TGD inspired quantum biology and quantum bio-chemistry in which the double formed by organism and environment is completed to a triple by adding the magnetic body.

5.2.3 What About The Hierarchy Of Planck Constants?

p-Adic hierarchy is not the only hierarchy in TGD Universe: there is also the hierarchy of Planck constants $h_{eff} = n \times h$ giving rise to a hierarchy of intelligences. What is the relationship between these hierarchies?

1. I have proposed that speech and music are fundamental aspects of conscious intelligence and that DNA realizes what I call bio-harmonies in quite concrete sense [L9] [K58]: DNA codons would correspond to 3-chords. DNA would both talk and sing. Both language and music are highly structured. Could the relation of h_{eff} hierarchy to language be same as the relation of music to speech?

2. Are both musical and linguistic parsing hierarchies present? Are they somehow dual? What does parsing mean for music? How musical heard sounds could give rise to the analog of braided strands? Depending on the situation we hear music both as separate notes and as chords as separate notes fuse in our mind to a larger unit like phonemes fuse to a word. Could chords played by single instrument correspond to braidings of flux tubes at the same level? Could the duality between linguistic and musical intelligence (analogous to that between function and its Fourier transform) be very concrete and detailed and reflect itself also as the possibility to interpret DNA codons both as three letter words and as 3-chords [L9]?

5.3 Braiding Hierarchy Mathematically

More precise formulation of the braided flux tube hierarchy leads naturally to the notions of braid group and operad that I have considered earlier. They have a close relationship with quantum groups - more precisely, bialgebras and Hopf algebras and their generalizations quasi-bialgebras and quasi-Hopf algebras, which in turn allow to characterize what might be called minimal breaking of associativity in terms of Drinfeld associator. These notions are already familiar from conformal field theories and string theories them so that there are good hopes that no completely new mathematics is not needed.

It must be made clear that I am not a mathematician and the following is just a modest attempt to understand what the problem is. I try to identify the algebraic structure possibly allowing to realize the big vision and gather some results about these structures from Wikipedia: I confess that I do not understand the formulas at the deeper level and my goal is to find their physical interpretation in TGD framework.

5.3.1 How To Represent The Hierarchy Of Braids?

Before going to web to see how modern mathematics could help in the problem, try first to formulate the situation more concretely. One must consider a more detailed representation for braids and for their hierarchy.

Consider first rough physical geometric view about braids of braids represented in terms of flux tubes.

1. Braid strands have two ends: one can label them as "lower" and "upper". Flux tubes can be labelled by p-adic prime p and $h_{eff} = n \times h$. Magnetic flux tubes can carry monopole flux and this could be crucial for the breaking of associativity - at least it is so in the proposed model (see `http://tinyurl.com/y7oom5kh`). The possibility of apparent magnetic monopoles in TGD framework indeed involves many-sheetedness in an essential manner: monopole flux flows from space-time sheet to another one through wormhole contact. This can be taken as one possible hint about the concrete physics involved.

2. One can get more precise picture by using formulas. One has labelling of flux tubes by primes p and Planck constants h_{eff}: to be short call this label $a, b, c, ...$ Since the values of p and h_{eff} are graded one could also speak of grading. The states for given value of a assignable to braid strands are labelled by the quantum states $A, B, ...$ associated with them and analogous to algebra elements. One must however consider all possible situations so that has operators $A_a, B_a, ...$ analogous to algebra elements of a graded algebra about which Clifford algebras and super-algebras are familiar examples.

3. Consider now the physical interpretation for the breaking of associativity. For ordinary associative algebra one considers $A(BC) = (AB)C$. This condition as such make sense if $A(BC)$ and $(AB)C$ are inside same flux tube and perhaps also that the strands A, B, C are not braids. In the general case one must must add the labels a, b, c, d and a, b_1, c_1, d_1 and one obtains $((A_d B_d)_c) C_b)_a$ and $(A_{b_1}(B_{d_1} C_{d_1}))_{c_1})_a$. Obviously, these two states need not identical unless one has $a = b = c = d = b_1 = c_1 = d_1$, which is also possible and means that all strands are at the same flux tube labelled by a. The challenge is to combine various almost copies of algebraic structure defined by braidings and labelled by $a, b, ..$ to larger algebraic structure and formulate the breaking of associativity for this structure.

5.3.2 Braid Groups As Coverings Of Permutation Groups

Consider next the definition of braid group.

1. The notion of braiding can be algebraized using the notion of braid group B_n of n strands, which is covering of the permutation group S_n. For ordinary permutations generating permutations are exchanges of P_i two neighboring elements in the ordered set $(a_1, ..., a_n)$: $(a_i, a_{i+1}) \to (a_{i+1}, a_i)$. Obviously one has P_i^2 so that permutation is analogous to reflection. For braid group permutation is replaced to twisting of neighboring braid strand. It looks like permutation if one looks at the ends of strands only. If one looks entire strands, there is no reason to have $P_i^2 = 1$ except possibly for the representation of braid group. For arbitrarily large n that one has $P_i^n \neq 1$. 2-D braid group B_n can be represented as a homotopies of 2-D plane with n punctures identifiable as ends of braid strands defined by their non-intersecting orbits.

2. At the level of quantum description one must allow quantum superpositions of different braidings and must describe the quantum state of braid as wave function in braid group: one has element of group algebra of braid group. To each element of braid group one can assign unitary matrix representing the braiding and this unitary matrix would define a "topological

time evolution" defined by braiding transforming the initial state at the lower end of braid to the state at upper end of braid. Hence it seems that braid group algebra is the proper mathematical notion. One has quantum superposition of topological time evolutions: something rather abstract.

5.3.3 Braid Having Braids As Strands

Many-sheeted space-time makes possible fractal hierarchy of braids. Braid group in above sense would act on flux tubes at the same space-time sheets or space-time of QFT and GRT. Braids can have as strands braids so that there is hierarchy of braiding levels. The hierarchy of coilings of DNA provides a simple example (very simple having not much to do with the hierarchy of braidings for flux tubes).

1. Suppose that one has only two levels in the hierarchy. One has n braid strands/flux tubes altogether and there are k larger flux tubes containing n_i, $i = 1, .., k$ flux tubes so that one has $\sum_{i=1}^{k} n_i = n$. One can imagine a coloring of the braid strands inside given flux tube characterizing it. Only braid strands inside same flux tube - with the same color - can be braided. The full braid group B_n braiding freely all n braid strands is restricted to a subgbroup $B_{n_1} \times .... \times B_{n_2}$. This group can be regarded as subgroup of B_n so that permutations of B_{n_i} have a well-defined outcome, which seems however to be trivial classically. In quantum situation the exchange of the factors B_{n_i} however corresponds to braiding and for non-trivial quantum deformations its action is non-trivial. One has braided commutativity instead of commutativity.

2. Besides this there are braidings for the k braids of braids and this gives braid group B_k acting at upper level of hierarchy. Clearly the higher level braids b_i, $i = 1, ..., k$ and lower level braids b_{ij}, $j = 1, ..., n_i$ form a two-levelled entity. The braid groups B_k and B_{n_i} form an algebraic entity such that B_k acts by permuting the entities. Same holds true for the braid group algebras. This structure generalizes to an entire hierarchy of braid groups and their group algebras.

The hierarchy of braid group algebras seems to closely relate to a very general notion known as operad (see `http://tinyurl.com/yavyhcsk`). The key motivation of the operad theory is to model the computational trees resulting from parsing. The action of permutations/braidings on the basic objects is central notion and one indeed has hierarchy of symmetric groups/braid groups such that the symmetric/braid group at $n + 1$:th level permutes/braids the objects at n:th level. Now the objects would be braids whose strands are braided. The braids can be strands of higher level braids and these strands can be braided. The action of braidings extends to that on braid group algebras defining candidates for wave functions.

5.4 General Formulation For The Breaking Of Associativity In The Case Of Operads

The formulas characterizing weak form of associativity by Drinfeld and others look rather mysterious without understanding of their origins. This understanding emerges from very simple but general basic arguments. Instead of studying given algebra one transcends to a higher abstraction level and studies - not the results of algebraic expressions - but the very process how the algebraic expression is evaluated and what kind of rules one can pose on it. The rules can be abstracted to what is called algebraic coherence.

The evaluation process - parsing - starts from inner most brackets and proceeds outwards so that eventually all brackets have disappeared and one has the value for the expression. This process can be regarded as a tree which starts from n inputs which are algebra elements, in the recent case they could be braid group algebra elements.

For instance, $(AB)C$ corresponds to an tree in which A, B, C are the branches. As one comes downwards, A and B fuse in the upper node and AB and C in the lower node. One manner to see this is as particle reaction proceeding backwards in time. For $A(BC)$ B and C fuse to BC in the upper node and A and BC at the lower node. Associativity says that the two trees give the same

result. "Braided associativity" would say that these trees give results differing by an isomorphism just as braided commutativity says that AB and BA give results differing by isomorphism.

One can formulate this more concretely by denoting algebra decomposition $A \otimes B \in V \otimes V \to AB \in V$ by θ. In associativity condition one has 3 inputs so that 3-linear map $V \otimes V \otimes V \to V$ is in question. $(AB)C$ corresponds to $\theta \circ (\theta, 1)$ applied to $(A \otimes B \otimes C)$. Indeed, $(\theta, 1)$ gives $(AB, C) \in V \otimes V$. Second step $\theta\circ$ applied to this gives $(AB)C$. In the same manner, $A(BC)$ corresponds to $(\theta \circ (1, \theta)$ and associativity condition can be expressed as

$$\theta \circ (\theta, 1) = \theta \circ (1, \theta) \quad .$$

An important delicacy should be mentioned. Although operations can be non-associative, the composition of operations is assumed to be associative. One can imagine obtaining $((ab)c)d$ either by $\theta \circ (\theta, 1) \circ (\theta, 1, 1))$ or by $(\theta \circ (\theta, 1)) \circ (\theta, 1, 1))$. The condition that these expressions are identical is completely analogous to the associativity for the composition of functions $f \circ (g \circ h) = (f \circ g) \circ h$ and this axiom looks obvious becomes one is used to *define* $f \circ g$ using this formula (starting from rightmost brackets). One could however imagine starting the evaluation of the composition of operators also from leftmost brackets. This makes sense if the composition can be done without the substitution of the value of argument.

5.4.1 How Associativity Could Be Broken?

How to obtain the breaking of associativity? The first thing is to get some idea about what (weak) breaking of associativity could mean.

Breaking of associativity at the level of algebras

Basic examples about breaking of associativity might help in the attempts to understand how many-sheetedness could induce the breaking of associativity. The intuitive feeling is that the effect is not large and disappears at QFT limit of TGD.

In the case of algebras one has bilinear map $V \otimes V \to V$. Now this map is from $V \otimes V \to V \otimes V$ so that the two situations need not have much common. Despite this one can look the situation in the case of algebras.

Lie-algebras and Jordan algebras represent key examples about non-associative algebras. Associative algebras, Lie-algebras, and Jordan algebras can be unified by weakning the associativity condition $A(BC) = (AB)C$ to a condition obtained by cyclically symmetrizing this condition to get the condition

$$A(BC) + B(CA) + C(AB) = (AB)C + (BC)A + (CA)B$$

plus the condition

$$(A^2B)A = A^2(BA)$$

defining together with commutativity condition $AB = BA$ Jordan algebra (`http://tinyurl.com/y8n9ol9p`). Note that Jordan algebra with multiplication $A \cdot B$ is realized in terms of associative algebra product as $A \cdot B = (AB + BA)/2$. A good guess is that the non-associative Malcev algebra formed by imaginary octonions with product $xy - yx$ satisfies these conditions.

Could the analog of the condition $A(BC) + B(CA) + C(AB) = (AB)C + (BC)A + (CA)B$ make sense also for the braiding group algebra assignable to quantum states of braids? The condition would say that cyclic symmetrization by superposing different braiding topologies gives a quantum state, which is in well-defined sense associative. Cyclic symmetry looks attractive because it plays also a key role in twistor Grassmannian approach.

Bi-algebras and Hopf algebras

One must start from bi-algebra $(B, \nabla, \eta, \Delta, \epsilon)$. One has product ∇ and co-product Δ analogous to replication of algebra element: particle physicists has tendency to see it as "time reversal" of product analogous to particle decay as reversal of particle fusion. The key idea is that co-multiplication

is algebra homomorphism for multiplication and multiplication algebra homomorphism for co-multiplication. This leads to four commutative diagrams essentially expressing this property (see `http://tinyurl.com/y897z3es`).

Instead of giving the general definitions it is easier to consider concrete example of bi-algebra defined by group algebra. Bi-algebra has product $\nabla : H \otimes H \to H$ and co-product $\Delta : H \to H \otimes H$, which intuitively corresponds to inverse or time reversal of product. In the case of group algebra this holds true in very precise sense since one has $\Delta(g) = g \otimes g$: Δ is clearly analogous to replication. Besides this one has map $\epsilon : H \to K$ assigning to the algebra element a scalar and inverse map taking the unit 1 of the field to unit element of H, called also 1 in the following. For group algebra one has $\epsilon(g) = 1$. Bi-algebras are associative and co-associative. Commutativity is however only braided commutativity.

Hopf algebra $(H, \nabla, \eta, \Delta, \epsilon, S)$ is special case of bi-algebra and often loosely called quantum group. The additional building brick is algebra anti-homomorphism $S : H \to H$ known as antipode. S is analogous to mapping element of h to its inverse (it need not exist always). For group algebra one indeed has $S(g) = g^{-1}$. Besides the four commuting diagrams for bi-algebra one has commutative diagrams $\nabla(S, 1)\Delta = \eta\epsilon$ and $\nabla(1, S)\Delta = \eta\epsilon$, where ϵ is co-unit. The right hand side gives a scalar depending on h multiplied by unit element of H. For group algebra this gives unit at both sides. In the general case the situation $\Delta(h) = h \otimes h$ is true for group like element only and one has more complex formula $\Delta(h) = \sum_i a_i \otimes b_i$. One also defines primitive elements as elements satisfying $\Delta(h) = h \otimes 1 + 1 \otimes h$. Also Hopf algebras are associative and co-associative.

Quasi-bialgebras and quasi-Hopf algebras

Quasi-bi-algebras giving as special case quasi-Hopf algebras were discovered by Russian mathematician Drinfeld (for technical definition, which does not say much to non-specialist see `http://tinyurl.com/y7b6lpop` and `http://tinyurl.com/y89cs5oy`). They are non-associative or associative modulo isomoprhism.

Consider first quasi-bi-algebra $(B, \Delta, \epsilon, \Phi, l, r)$. Δ and ϵ are as for bi-algebra. Besides this one has invertible elements Φ (Drinfeld associator) and r, l called right and lef unit constraints. The conditions satisfied are following

- $$(1 \otimes \Delta) \circ \Delta(a) = \Phi[((\Delta \otimes 1) \circ \Delta(a)]\Phi^{-1} \ .$$

  For $\Phi = 1 \otimes 1 \otimes 1$ one obtains associativity.

- $$[(1 \otimes 1 \times \Delta)(\Phi)][(\Delta \otimes 1 \otimes 1)(\Phi)] = (1 \otimes \Phi)[1 \otimes \Delta \otimes 1)(\Phi)(\Phi \otimes 1) \ .$$

- $$(\epsilon \otimes 1)(\Delta(a)) = l^{-1}al \ , \ (1 \otimes \epsilon)(\Delta(a)) = r^{-1}ar \ .$$

- $$1 \otimes \epsilon \otimes 1)(\Phi) = 1 \otimes 1 \ .$$

These mysterious looking conditions express the fact that Drinfeld associator is a bialgebra co-cycle.

Quasi-bialgebra is braided if it has universal R-matrix which is invertible element in $B \otimes B$ such that the following conditions hold true.

$$(\Delta^{op})(a) = R\Delta(a)R^{-1} \ . \tag{5.4.1}$$

Note that for group algebra with $\Delta g = g \otimes g$ one has $\Delta^{op} = \Delta$ so that R must commute with Δ. Whether this forces R to be trivial is unclear to me. Certainly there are also other homomorphisms. A good candidate for a non-symmetric co-product is $\Delta g = g \times h(g)$ where h is a homomorpism of the braid group. This requires the replacement $S(g) \to S(h^{-1}g)$ in order to obtain unitarity for $\nabla(1, S)\Delta$ loop removing the braiding.

$$(1 \otimes \Delta)(R) = \Phi_{231}^{-1} R_{13} \Phi_{213} R_{12} \Phi_{213}^{-1} \ . \tag{5.4.2}$$

$$(\Delta \otimes 1)(R) = \Phi_{321}^{-1} R_{13} \Phi_{213}^{-1} R_{23} \Phi_{123} \ . \tag{5.4.3}$$

This and second condition imply for trivial R that also Φ is trivial.
For $\Phi = 1 \otimes 1 \otimes 1$ the conditions reduces to those for ordinary braiding. The universal R-matrix satisfies the non-associative version of Yang-Baxter equation

$$R_{12}\Phi_{321}R_{13}(\Phi_{132})^{-1}R_{23}\Phi_{123} = \Phi_{321}R_{23}(\Phi_{231})^{-1}R_{13}\Phi_{213}R_{12} \ . \tag{5.4.4}$$

Quasi-Hopf algebra is a special case of quasi-bialgebra. Also now one has product ∇, co-product Δ, antipode S not present in bialgebra, and maps ϵ and η. Besides this one has two special elements α and β of H such that the conditions $\nabla(S,\alpha)\cdot\Delta = \alpha$ and $\nabla(1,\beta S)\cdot\Delta = \alpha$. To my understanding these conditions generalize the conditions $\nabla(S,1)\Delta = \eta\epsilon$ and $\nabla(1,S)\Delta = \eta\epsilon$.

Associativity holds but only modulo a morphism in the same way as commutativity becomes braided commutativity in the case of quantum groups. The braided commutativity is characterized by R-matrix. The morphism defining "braided associativity" is characterized by the product $\Phi = \sum_i X_i \otimes Y_i \otimes Z_i$ acting on triple tensor product $V \otimes V \otimes V$ and satisfying certain algebraic conditions. Φ has "inverse" $\Phi^{-1} = \sum_i P_i \otimes Q_i \otimes R_i$ The conditions $(1,\beta S,\alpha)\Phi = 1$ and $(S,\alpha,\beta S)\Phi = 1$. Here the action of S is that of algebra anti-homomorphism rather than algebra multiplication.

Drinfeld associator, which is a non-abelian bi-algebra 3-cocycle satisfying conditions analogous to the condition for weakened associativity holding true for Lie and Jordan algebras. These quasi-Hopf algebras are known in conformal field theory context and appear in Knizhnik-Zamolodchikov equations so that a lot of mathematical knowhow exists. According to Wikipedia, quasi-Hopf algebras are associated with finite-D irreps of quantum affine algebras in terms of F-matrices used to factorize R-matrix. The representations give rise to solutions of Quantum Yang-Baxter equation. The generalization of conformal invariance in TGD framework strongly suggests the relevance of Quasi-Hopf algebras in the realization of non-associativity in TGD framework.

Drinfeld double

Drinfeld double provides a concrete example about breaking of associativity. It can be formulated for finite groups as well as discrete groups. Drinfeld's approach is essentially algebraic: one works at the level of group algebra. In TGD framework the approach is geometric: algebraic constructs should emerge naturally from geometry. Braiding operations should induce algebras.

The basic notions involved are following.

1. One begins from a trivial tensor product of Hopf algebras and modified. In trivial case algebra product is tensor product of products, co-product is tensor product of co-products, antipode is tensor product of antipodes, map ϵ is product of the maps from the factors of the tensor product and delta maps unit element of field K to a product of unit elements. Drinfeld double represents a non-trivial tensor product of Hopf algebras.

2. One application of Drinfeld double construction is tensor product of group algebra and its dual. One can also interpret it as tensor product of braids as non-closed paths and closed braids (knots) as closed paths: in TGD framework this interpretation is suggestive and will be discussed later.

3. Drinfeld double allows breaking of associativity. It can be broken by introducing 3-cocycle (see `http://tinyurl.com/y9vcsmyg`) of group cohomology (see `http://tinyurl.com/y755gd36`). In the recent case group cohomology relies on homomorphism of group braid G to abelian group $U(1)$. n-cocycle is a map $G^n \to U(1)$ satisfying the condition that its derivation vanishes $d_n f = 0$. $d_n \circ d_{n-1} = 0$ holds true identically.

   The explicit definition of n-cocycle is in additive notion for U(1) product (usually multiplicative notation is used is) given by to illustrate that d_n acts like exterior derivative.

$$(d_n f)(g_1, g_2, g_n, g_{n+1}) = g_1 f(g_1, ...g_n) - f(g_1 g_2, g_2, ..., g_{n+1}) + f(g_1, g_2 g_3, ..., g_{n+1}) \\ -... + (-1)^n f(g_1, g_2 ... g_n g_{n+1}) + (-1)^{n+1} f(g_1, g_2 ... g_n) \ . \tag{5.4.5}$$

This formula is easy to translate to multiplicative notion. The fact that group cohomology is universal concept strongly suggests that 3 co-cycle can be introduced quite generally to break associativity in the sense that different associations differ only by isomorphism.

The construction of quantum double of Hopf algebras is discussed in detail at `http://tinyurl.com/ybbvjaw5`. Here however non-associative option is not discussed. In `http://tinyurl.com/ya8n98o5` one finds explicit formula for Drinfeld double for the Drinfeld double formed by group algebra and its dual. Just to give some idea what is involved the following gives the formula for the product:

$$(h, y) \circ (g, x) = \frac{\omega(h, g, x)\omega(hgx((hg)^{-1}, h, g)}{\omega(h, gx(g)^{-1}, h, g)}(hg, x) \ . \tag{5.4.6}$$

Without background it does not tell much. What is essential however that the starting point is algebraic. The product is non-vanishing only between (g, x) and (h, gxg^{-1}). For gauge group like structure one would have x instead of $g^{-1}xg^{-1}$. ω is 3-cocycle: it it is non-trivial one as associativity modulo isomorphism.

I do not have any detailed understanding of quasi-Hopf algebras but to me they seem to provide a very promising approach in attempts to understand the character of non-associativity associated with the braiding hierarchy. The algebraic construction of Drinfeld double does not seem interesting from TGD point of view but the idea that group cocycle is behind the breaking of associativity is attractive. Also the generalization of construction of Drinfeld double to code what happens in braiding geometrically is attractive. One of the many difficult challenges is to understand the role of the varying parameters p, h_{eff}, q at the level of braid group algebras and their projective representations characterized by quantum phase q.

5.4.2 Construction Of Quantum Braid Algebra In TGD Framework

It seems that there is no hope that naïve application of existing formulas makes sense. The variety of different variants of quantum algebras is huge and one should have huge mathematical knowledge and understanding in order to find the correct option if it exists at all. Therefore I bravely take the approach of physicists. I try to identify the physical picture and then look whether I can identify the algebraic structure satisfying the axioms of Hopf algebra. In the following I first list various inputs which help to identify constraints on the algebraic structure, which should be simple if it is to be fundamental.

Trying to map out the situation

Usually physicists have enough trouble when dealing with single algebraic structure: say group and its representations. Unfortunately, this does not seem to be possible now. It seems that one must deal with entire collection of algebraic structures defined by braid groups B_n with varying value of n forming a hierarchy in which braid groups act on lower level braid groups.

1. What is clear that the algebraic operation $(A \otimes B) \to AB$ is somehow related to the braiding of flux tubes or fermionic strings connecting partonic 2-surfaces. One can also consider strings connecting the ends of light-like 3-surfaces so that one has both space-like and time-like braiding. One has flux tubes inside flux tubes.

   The challenge is to identify the natural algebra. It seems best to work with the braiding operations themselves - analogs of linguistic expressions - than the states to which they act. Braiding operations form discrete group, braid group. One must deal with the quantum

superpositions of braidings so that one has wave functions in braid group identifiable as elements of discrete group algebra of braid group B_n. One can multiply group algebra elements and include the group algebra of B_m to that of B_n m a factor of n so that the desired product structure is obtained. The group algebras associated with various braid numbers can be organized to operad.

The operad formed by the braid group algebras has the desired hierarchical structure, and braid group algebra is one of the basic structures and quantum groups can be assigned with its projective representations.

2. For a given flux tube (and perhaps also for the fermionic string(s) assigned with it) one has degrees of freedom due different values of the quantum deformation parameter q for which roots of unity define preferred values in TGD framework. In TGD framework also hierarchy $h_{eff}/h = n$ of Planck constants brings in additional complexity. Also the p-adic prime p is expected to characterize the situation: preferred p-adic primes can be interpreted as so called ramified primes in the adelic vision about quantum TGD [K82] unifying real and various p-adic physics to a coherent whole. This brings in new elements. It is still unclear how closely n and $q = exp(i2\pi/m)$ are related and whether one might have $m = n$. Also the relationship of p to n is not well-understood. For instance, could p divide n.

3. Geometrically the association of braid strands means that they belong to the same flux tube. Moving the brackets in expression to transform say $(A(BC))$ to $((AB)C)$ means that strands are transferred from flux tube another one. Hence the breaking of associativity should take place at all hierarchy levels except the lowest one for which flux tube contains single irreducible braid strand - fermion line.

   The general mechanism for a weak breaking of associativity is describable in terms of Drinfeld's associator for quasi-bialgebras and known in some cases explicitly - in particular, shown by Drinfeld to exists when the number field used is rational numbers - is the first guess for the mechanism of the breaking of associativity. Drinfeld's associator is determined completely by group cohomology, which encourages to think that it can be used as such as as a multipler in the definition of product in suitable tensor product algebra. How the Drinfeld's associator depends on the p,n, and q is the basic question.

4. Besides the geometric action of braidings it is important to understand how the braidings act on the fundamental fermions. An attractive idea is that the representation is as holonomies defined by the induced weak gauge potentials as non-integrable phase factors at the boundaries of string world sheets defining fermion lines. The vanishing of electroweak gauge fields at them implies that the non-Abelian part of holonomy is pure gauge as in topological gauge field theories for which the classical solutions have vanishing gauge field. The em part of the induce spinor curvature is however non-vanishing unless one poses the vanishing of electromagnetic field at the boundaries of string world sheets as boundary condition. This seems un-necessary. The outcome would be non-trivial holonomy and restriction to a particular representation of quantum group with quantum phase q coming as root of unity means conditions on the boundaries of string world sheets. Quantum phase would make itself visible also classically as properties of string world sheets which together with partonic 2-surfaces determined space-time surface by strong form of holography. An interesting question relates to the possibility of non-commutative statistics: it should come from the weak part of induced connection which is pure gauge and seems possible as it is possible also in topological QFTs based on Chern-Simons action.

Hints about the details of the braid structure

Concerning the details of the braid structure one has also strong hints.

1. There two are two basic types of braids: I have called them time-like and space-like braids. Time-like (or rather light-like) braids are associated with the 3-D light-like orbits of partonic 2-surfaces at which the signature of the induced metric changes signature from Minkowskian to Euclidian. Braid strands correspond to fermionic lines identifiable as parts of boundaries of string world sheets. Space-like braids are associated with the space-like 3-surfaces at the

ends of causal diamond (CD). Also they consist of fermionic lines. These braids could be called fundamental.

If these braids are associated with magnetic flux tubes carrying monopole flux, the flux tubes are closed. Typically they connect wormhole throats at first space-time sheet, go to the second space-time sheet and return. Hence two-sheeted objects are in question. The braids in question can closed to knots and could correspond to closed loops assigned with the Drinfeld quantum double. The tensor product of the groupoid algebra associated with time-like braids and group algebra associated with space-like braids is highly suggestive as the analog of Drinfeld double.

Also magnetic flux tubes and light-like orbits of partonic 2-surfaces can become braided and one obtains the hierarchies of braids.

2. Since strong world sheets and partonic 2-surfaces have co-dimension 2 as sub-manifolds of space-time surface they can also get braided and knotted and give rise to 2-braids and 2-knots. This is something totally new. The unknotting of ordinary knots would take place via reconnections and the reconnections could correspond to the basic vertices for 2-knots analogous to the crossing of the plane projections of ordinary knot. Reconnections actually correspond to string vertices. A fascinating mathematical challenge is to generalize existing theories so that they apply to 2-braids and 2-knots.

3. Dance metaphor emerged in the model for DNA-lipid membrane system as topological quantum computer [K3, K79]. Dancers whose feet are connected to wall by threads define time-like braiding and also space-like braiding through the resulting entanglement of threads. The assumption was that DNA codons or nucleotides are connected by space-like flux tubes to the lipids of lipid layer of cell membrane or nuclear membrane.

   If they carry monopolo flux they make closed loops at the structure formed by two space-time sheets. The lipid layer of cell membrane is 2-dimensional and can be in liquid crystal state. The 2-D liquid flow of lipids induces braiding of both space-like braids if the DNA end is fixed and of time-like braids. This leads to the dance metaphor: the liquid flow is stored at space-time level to the topology of space-time as a space-like braiding of flux tubes induced by it. Space-like braiding would be like written text. Time-like braiding would be like spoken language.

4. If the space-like braids are closed, they form knots and the flow caused at the second end of braid by liquid flow must be compensated at the parallel flux tube by its reversal since braid strands cannot be cut. The isotopy equivalence class of knot remains unchanged since knots get gg^{-1} piece which can be deformed away. Second interpretation is that the braid X transforms to gXg^{-1}. This kind of transformation appears also in Drinfeld construction. This suggests that the purely algebraic tensor product of braid algebra and its dual corresponds in TGD framework semi-direct tensor product of the groupoid of time-like braids and space-like braids associated with closed knots. The semi-direct tensor product would define the fundamental topological interaction between braids.

5. One can also consider sequence of n tensor factors each consisting of time-like and space-like braids. This require a generalization of the product of two tensor factors to $2n$ tensor factors. Dance metaphor suggests that a kind of chain reaction occurs.

What the structure of the algebra could be?

With this background one can try to guess what the structure of the algebra in question is. Certainly the algebra is semi-direct product of above defined braid group algebras. The multiplication rule would have purely geometric interpretation.

1. The multiplication rule inspired by dance metaphor for 2 tensor factors would be

$$(a_1, a_2) \circ (b_1, b_2) = (a_1 a_2 b_1 a_2^{-1}, a_2 b_2) \ . \tag{5.4.7}$$

Here a_1, b_1 correspond label elements of time-like braid groupoid and a_2, b_2 the elements of braid group associated with the space-like braid. This would replace the trivial product rule $(a_1, a_2)(b_1 g_) = (a_1 b_1, a_2 b_2)$ for the trivial tensor product. The structure is same as for Poincare group as semi-direct product of Lorentz group and translation group: $(\Lambda_1, T_1)(\Lambda_2, T_2) = (\Lambda_1\Lambda_2, T_1 + \Lambda_1(T_2))$.

It is easy to check that this product is associative. One can however add exactly the same 3-cocycle factor

$$(h, y) \circ (g, x) = \frac{\omega(h, g, x)\omega(hgx((hg)^{-1}, h, g)}{\omega(h, gx(g)^{-1}, h, g)}(hg, x) \quad . \tag{5.4.8}$$

Here (h, y) corresponds to (a_1, a_2) and (g, x) to (b_1, b_2). This should give breaking of non-associativity and third group cohomology of braid group B_n would characterize the non-equivalent associators.

2. The product rule generalizes to n factors. This generalization could be relevant for the understanding of braid hierarchy.

$$(a_1, a_2, ...a_n) \circ (b_1, b_2, ...b_n) \equiv (c_1, ..., c_n) \quad , \tag{5.4.9}$$

where one has

$$\begin{array}{lll} c_n = a_n b_n \quad , & c_{n-1} = a_{n-1} Ad_{a_n}(b_{n-1}) \quad , & c_{n-2} = a_{n-2} Ad_{a_{n-1}a_n}(b_{n-2}) \quad , \\ c_{n-3} = a_{n-3} Ad_{a_{n-2}a_{n-1}a_n}(b_{n-3}) & , ... & c_1 = a_1 Ad_{a_2.....a_n}(b_1) \quad . \\ Ad_x(y) = xyx^{-1} \quad . & & \end{array} \tag{5.4.10}$$

In this case a good guess for the breaking of associativity is that the associator is defined in terms of n-cocyle in group cohomology.

What is remarkable that this formula guarantees without any further assumptions the condition

$$\begin{aligned} \nabla_{1\otimes 2}(\Delta_1(a), \Delta_2(b)) = \nabla_1(\Delta_1(a))\nabla_2(\Delta_2(b)) = \sum_{(a)} a_1 a_2 \sum_{(b)} b_1 b_2 \quad , \\ \Delta_1(a) = \sum_{(a)} a_1 \otimes a_2 \quad , \quad \Delta_2(b) = \sum_{(b)} b_1 \otimes b_2 \end{aligned} \tag{5.4.11}$$

as a little calculation shows. For group algebra one has $\Delta(a) = g \otimes g$. $\nabla_{1\otimes 2}$ refers to the product defined above.

3. The formula for $\Delta_{1\otimes 2}$ is also needed. The simplest guess is that it corresponds to replication for both factors. This would mean $\Delta^{op} = \Delta$: non-symmetric form guaranteeing non-trivial braiding is however desirable. A candidate satisfying this condition in $n = 2$ case is asymmetric replication:

$$\begin{array}{r} \Delta_{1\otimes 2}(bab^{-1}, b) \otimes (a, b) \\ \Delta^{op}_{1\otimes 2}(a, b) \otimes (bab^{-1}, b) \quad . \end{array} \tag{5.4.12}$$

4. In $n = 2$ case the formula for antipode would read as

$$S(a_1, a_2) = (a_2^{-1} a_1^{-1} a_2, a_2^{-1}) \tag{5.4.13}$$

instead of $S(a_1, a_2) = (a_1^{-1}, a_2^{-1})$. Again the semi-direct structure would be involved. One can check that the formula

$$\nabla_{1\otimes 2}(1, S)\Delta_{1\otimes 2} = 1 \otimes 1 \tag{5.4.14}$$

holds true.

5.4.3 Should One Quantize Complex Numbers?

The TGD inspired proposal for the concrete realization of quantum groups might help in attempts to understand the situation. The approach relies on what might be regarded as quantization of complex numbers appearing as matrix elements of ordinary matrices.

1. Quantum matrices are obtained by replacing complex number valued of matrix elements of ordinary matrices with operators. They are are products of hermitian non-negative matrix P analogous to modulus of complex number and unitary matrix S analogous to its phase. One can also consider the condition $[P, S] = iS$ inspired by the idea that radial momentum and phase angle define analog of phase space.

2. The notions of eigenvalue and eigenstate are generalized. Hermitian operator or equivalently the spectrum of its eigenvalues replaces real number. The condition that eigenvalue problem generalizes, demands that the symmetric functions formed from the elements of quantum matrix commute and can be diagonalized simultaneously. The commutativity of symmetric functions holds also for unitary matrices. These conditions is highly non-trivial, and consistent with quantum group conditions if quantum phases are roots of unity. In this framework also Planck constant is replaced by a hermitian operator having $h_{eff} = n \times h$ as its spectrum. Also $q = exp(in2\pi/m)$ generalizes to a unitary operator with these eigenvalues.

3. This leads to a possible concrete representation of quantum group in TGD framework allowing to realize the hierarchy of inclusions of hyperfinite factors obtained by repeatedly replacing the operators appearing as matrix elements with quantum matrices.

4. This procedure can be repeated. One might speak of a fractal quantization. At the first step one obtains what might be called 1-hermitian operators with eigenvalues replaced with hermitian operators. For 1-unitary matrices eigenvalues, which are phases are replaced with unitary operators. At the next step one considers what might be called 2-hermitian and 2-unitary operators. An abstraction hierarchy in which instance (localization to a point as member of class) is replaced with wave function in the class. This hierarchy is analogous to that formed by infinite primes and by the sheets of the many-sheeted space-time. Also braids of braids of ... form this kind of abstraction hierarchy as also the parsing hierarchy for linguistic expressions.

I have proposed that generalized Feynman diagrams or rather - TGD analogs of twistor diagrams - should have interpretation as sequences of arithmetic operators with each vertex representing product or co-product and having interpretation as time reversal of the product operation.

1. The arithmetic operations could be induced by the algebraic operations for Yangian algebra [A5] [B6, B4, B5] assignable to the super-symplectic algebra. I have also proposed that there TGD allows a very powerful symmetry generalizing the duality symmetry of old-fashioned string models relating s- and t-channel exchanges. This symmetry would state that one can

freely move the ends of the propagator lines around the diagrams and that one can remove loops by transforming the loop to tadpole and snipping it away. This symmetry would allow to consider only tree diagrams as shortest representations for computations: this would reduce enormously the calculational complexity. The TGD view about coupling constant evolution allows still to have discrete coupling constant evolution induced by the spectrum of critical values of Kähler coupling strength: an attractive conjecture is that the critical values can be expressed in terms of zeros of Riemann zeta [L19].

2. One can represent the tree representing a sequence of computations in algebra as an analog of twistor diagram and the proposed symmetry implies associativity since moving the line ends induces motion of brackets. If co-algebra operations are allowed also loops become possible and can be eliminated by this symmetry provided the loop acts as identity transformation. This would suggest strong form of associativity at the level of single sheet and weaker form at the level of many-sheeted space-time. One could however still hope that loops can be cancelled so that one would still have only tree diagrams in the simplest description. One would have however sum over amplitudes with different association structures.

3. Co-product could be associated with the basic vertices of TGD, which correspond to a fusion of light-like parton orbits along their ends having no counterpart in super-string models (tensor product vertex) or the decay of light-like parton orbit analogous to a splitting of closed string (direct sum vertex). For the direct sum vertex one has direct sum (unlike string models): one can say that the particle propagates along two path in the sense of superposition as photons in double slit experiment. For the tensor product vertex $D(g) = \Delta(g) = g \times g$ is the first guess. $D(g) = (1, S)\Delta(g) = g \otimes Sg$ or $D(g) = Sg \otimes g$ or their sum suitably normalized is natural second guess. Unitarity allows only the latter option since $\nabla\Delta$ does not conserve probability for probability amplitudes unlike $\nabla(1, S)\Delta$ although it does so for probability distributions. For the direct sum vertex $\Delta(g) = 1 \otimes g \oplus g \otimes 1$ suitably normalized is the natural first guess.

4. Co-product Δ might allow interpretation as annihilation vertex in particle physics context. Co-product might also allow interpretation in terms of replication - at least at the level of topological dynamics of braiding. The possible application of co-product to the replication occurring biology assumed to be induce by replication of magnetic flux tubes in TGD based vision is highly suggestive idea. Is the identification of co-product as replication consistent with its identification as particle annihilation?

   Second question relates to the antipode S, which is anti-homomorphism and brings in mind time reversal. Could one interpret also S as an operation, which should be included to the braid group algebra in the same way as the inclusion of complex conjugation to the algebra of complex numbers produces quaternions? Could one interpret the identity $\nabla(1 \otimes S)\Delta(g) = \eta\epsilon(g) = 1$ by saying that the annihilation to $g \otimes S(g)$ followed by fusion produces braid wave function concentrated on trivial braiding and destroying the information associated with braiding completely. The fusion would produce non-braided particle rather than destroying particles altogether.

5. The condition that loop involving product and annihilation does not affect braid group wave function would require that it takes g to g. For the standard realization of co-product Δ of group algebra $g \to g \otimes g \to g^2$ so that this is not the case. The condition defining Δ is not easy to modify since one loses homomorphism property of Δ. The repetitions of loops would give sequence of powers g^{2n}. For wave function $\sum D(g)g$ this would give the sequence $\sum D(g)g \to \sum D(g)g^2 \to .... \to \sum D(g)g^{2n}$: since given group element has typically several roots one expects that eventually the wave function becomes concentrated to unity with coefficient $\sum D(g)$! For wave functions one has $\sum D(g) = 0$ if they are orthogonal to $D(g) = constant$ as is natural to require. Almost all wave functions would approach to zero so that unitary would be lost. For probability distributions the evolution would make sense since the normalization condition would be respected.

   Also the irreversible behaviour looks strange from particle physics perspective unless $D(g)$ is concentrated on identity so that braiding is trivial. Topological dissipation might take care that this is the case. For elementary particles partonic 2-surfaces carry in the first

approximation only single fermion so that braid group would be trivial. Braiding effects become interesting only for strand number larger than 2. The situations in which partonic surface carries large number of fermion lines would be more interesting. Anyonic systems to which TGD based model assigns large h_{eff} and parton surfaces of nanoscopic size could represent a condensed matter example of this situation.

6. Does the behavior of Δ force to regard generalized Feynman diagrams representing computations with different numbers of self-energy loops non-equivalent and to sum over self-energy loops in the construction of scattering amplitudes? The time evolution implied by topological self energy loops is not unitary which suggest that one must perform the sum. There are hopes that the sum converges since the contributions approaches to $\sum D(g) = 0$. This does not however look elegant and is in conflict with the general vision.

   Particle physics intuition tells that in pair annihilation second line has opposite time direction. Should one therefore identify annihilation $g \to g \otimes S(g)$. Antiparticles would differ from particles by conjugation in braid group. The self energy loop would give trivial braiding with coefficient $\sum D(g)D(g^{-1}) = \sum D(g)D(g)^* = 1$ so that unitarity would be respected and higher self energy loops would be trivial. The conservation of fermion number at fundamental level could also prevent the decays $g \to g \otimes g$.

One could also take biological replication as a guide line.

1. In biological scales replication by $g \to g \otimes g$ vertex might not be prevented by fermion number conservation but probability conservation favors $g \to g \otimes Sg$. Braid replication might be perhaps said to provide replicas of information: whether this conforms with no-cloning theorem remains to be seen. Braid replication followed by fusion means topological dissipation by a loss of braiding and loss of information. Could the fusion of reproduction cells corresponds to product and that replication to co-product possibly involving the action of S one the second line. Fusion followed by replication would lead to a loss of braiding: for $g \to g \otimes g$ perhaps making sense in probabilistic description gradually and for $g \to g \otimes Sg$ instantaneously: a reset for memory? Could these mechanisms serve as basic mechanisms of evolution?

2. There might be also a connection with the p-adic length scale hypothesis. The naïve expectation is that $g \to g^2$ in fusion followed by Δ means the increase of the length of braid by factor 2 - kind of ageing? Could the appearance of powers of two for the length of braid relate to the p-adic length scale hypothesis stating that primes p near powers of 2 are of special importance?

To summarize, the proposed framework gives hopes about description of braids of braids of .... Abstraction would mean transition from classical to quantum: from localized state to a de-localized one: from configuration space to the space of complex valued wave functions in configuration space. Now the configuration space would involve different braidings and corresponding evolutions, and various values of p, h_{eff} and q. If this general framework is to be useful it should be able to tell how the braiding matrices depend on p and h_{eff}: note that p and h_{eff} would be fixed only at the highest abstraction level - the largest flux tubes. This indeterminacy could be interpreted in terms of finite measurement resolution and inclusions of HFFs should help to describe the situation. Indeterminacy could also be interpreted in terms of abstraction in a way similar to the interpretation of negentropically entangled state as a rule for which the state pairs in the superposition represent instances of the rule.

Part II

ARROW OF TIME AND NEUROSCIENCE

Chapter 6

Arrow of time and neuroscience: TGD based view

6.1 Introduction

This chapter has been written together with Reza Rastmanesh. The question that inspired this article is whether memories about the future are possible. This requires retrocausality. The criticism of retrocausality relies on the assumption that time, in particular the thermo-dynamical time, has always the same arrow.

If one gives up this assumption, there is no reason forbidding retro-causality and phenomena like sensory perception of signals arriving from future giving rise to precognition. In fact, our ability to predict a lot about our future might be due to this kind of sensory perception rather than only due to computation using a neuronal model.

There is empirical evidence for non-standard arrow of time. Phase conjugate light rays [D5] (`https://cutt.ly/ys4x4dX`) obeying second law in wrong time direction, Fantappie's work [**?**, **?**] self-organization in biology - the self-assembly of the tobacco mosaic virus is a classical example [I25]. The latest finding that I learned of is that an isolated system can extract organized energy from its thermal energy [D6] (`https://tinyurl.com/y9ycj3nt`).

In the framework of Topological Geometrodynamics (TGD) zero energy ontology (ZEO) [L96] leads to a quantum measurement theory solving the basic problem of standard quantum measurement theory due to the conflict between determinism of Schrödinger equation and non-determinism of quantum jump. Key prediction is that the arrow of time changes in ordinary "big" state function reduction (BSFR) whereas in "small" state function reductions (SSFR) analogous to "weak" measurements the arrow of time is not changed.

This forces a generalization of thermodynamics and dissipation with opposite arrow of time allows to understand self-organization and also energy feed necessary for it in terms of generalized second law. A system dissipating in non-standard time direction seems from the point of view of the outsider to develop structures and extract energy from the environment. The non-standard arrow of time would be associated with the magnetic body (MB) carrying $h_{eff} = nh_0$ phases of ordinary matter identifiable as dark matter and making it a macroscopic quantum system for sufficiently large values of n. MB would act as master of the ordinary matter and induce effective time reversal at the level of ordinary matter in long time scales.

The TGD view about the neural system differs from the standard picture.

1. The first new element is the different role of nerve pulses: they create communication pathways along which dark photons can propagate.

2. Second new element is the presence of linear flux tube structures assignable to neural pathways assignable to linguistic cognition unstable against effective axonal splitting occurring in Alzheimer disease (AD) [J26], and the presence of 2- and even 3-D flux tube structures assignable to geometric and holistic cognition: this would survive in AD [L57] and in states involving cognitive defects (idiot savants). Meridian system and glial cells could relate to this aspect.

Communications in this system would be based on dark photons transforming to bio-photons and travelling along flux tubes with light velocity. This system would be the precedessor of the neural system and could be realized even in the case of plants. In the neural system the real communications would rely on dark photons - ordinary photons with effective Planck constant $h_{eff} = nh_0 > h$.

The communication lines would be dynamical consisting of axonal flux tubes connected by nerve pulse transmission to longer structures serving as wave guides along with dark photons signals would propagate. Metabolic economy could motivate this kind of realization as for electronic communications in modern society. Nerve pulses would only build the connection lines for communications inside the brain. They would however modulate the frequency of Josephson radiation from neuronal membrane to the MB of the brain and in this way communicate sensory data from cell membrane to MB.

3. According to ZEO based theory of consciousness causal diamond (CD) identified as CD $= cd \times CP_2 \subset H = M^4 \times CP_2$, where H denotes 8-D embedding space containing space-time as 4-surface, and cd is the intersection of future and past directed light-cones in 4-D Minkowski space M^4 and CP_2 is 4-D complex projective space. The passive boundary would correspond to holistic, spatial, and the "timeless" component of conscious experience dominating in meditative states and active boundary to reductionistic, temporal part of conscious experience such as sensory perception and cognition. These components correspond to opposite arrows of time at certain layers of MB.

4. I have considered the realization of the holistic emotional intelligence in terms of the notion of bio-harmony [L15, L16, L77]. Here one must however remember that emotions could be sensory percepts at the level of MB so that they should correspond to the dynamical aspects of consciousness rather than the permanent part. Music expresses and induces emotions and harmony codes for the emotional state. A model involving icosahedral and tetrahedral symmetries leads to a model that Pitkänen calls bio-harmony: the model predicts correctly the basic aspects of the vertebrate genetic code. The codons would correspond to 3-chords of bio-harmony. The realization of bio-harmony is assigned with magnetic bodies of the basic biomolecules including RNA and DNA.

5. EEG frequencies $f > 10$ Hz assigned to wake-up consciousness could correspond to the effectively 1-D and "linguistic" neural system and frequencies $f < 10$ Hz to the system responsible for holistic aspects. During sleep $f < 10$ Hz dominates so that the consciousness should be holistic. Since we do not remember anything about this period, it could correspond to time reversed mode making possible precognition as sensory perception of signals from geometric future.

6. The effective change of the arrow of time in the neural system induced by its real change at the level of MB could mean the change of the direction of nerve pulse conduction. This reversal could explain phenomena like reverse writing and reverse speech discussed in [K47]. There is evidence that AD patients have precognitive and prophetic dreams [J30, J31]. Ordinary nerve pulse conduction is prevented in AD by axonal plaque and exponentially attenuated. In the reverse time direction there would be an exponential amplification with respect to standard direction of time. This suggests that AD neurons are dead in standard time direction but re-incarnated in the opposite time direction. Death would be a gradual process.

This proposed hypothesis is testable. To hold true, manipulation of the level of acetylcholinesterase inhibitors (AChEIs) should reduce the formation of past event memory and increase the formation of future oriented precognitive memory traces. Indeed, there is evidence that Rivastigmine, a reversible ACEI used in the treatment of AD, increases memory and rapid eye movement sleep, and has been suggested that aside form those normal properties it could be implicated in retrograde dream formation, i.e., precognitive dreaming [J35]. Similar pilot study has yielded same results before [J30].

Further support comes from the bidirectional relationship between AD and sleep disorders through a model of brain rhythm attractor breakdown [J66]. In fact, individual differences were found in prophetic dream belief and experience, with a high frequency of prophetic dream experiences associated with disordered sleep patterns and sleep medication use [J95].

In the sequel this picture is discussed in more detail. In particular, the question how the possibility of non-standard arrow of time could make possible precognition as sensory perception of signals from geometric future, is considered. Our ability to predict our future is usually regarded as trivial. Computationalists explain it by assuming that the brain is a computer predicting the future. This ability could involve this sensory perception in an essential way.

Note: This chapter was prepared in collaboration with Dr Reza Rastmanesh who provided a lot of biological and neuroscientific knowhow and made stimulating critical questions.

6.2 Some aspects of TGD inspired quantum biology and theory of consciousness

6.2.1 TGD based quantum biology very briefly

One can approach TGD inspired quantum biology by making questions.

How to understand coherence of living systems?

If only bio-chemistry is involved, we would be sacks of water and sacks of water do not climb in trees or write poems. Could quantum coherence induce the coherence? What entity serve as intentional agent and how it could realize its intentions?

1. Topological field quantization applies to electric and magnetic fields [L3, L2]. For instance, magnetic field decomposes to flux tubes having finite thickness. Radiation fields are topologically quantized to topological light rays. Each system has its fields at separate space-time sheets touching each other only via wormhole contacts: system has field body, in particular magnetic body (MB) having hierarchical onion-like structure corresponding to the hierarchy of space-time sheets. Magnetic flux tubes would take a role analogous to wormholes in the ER-EPR correspondence proposed by Maldacena and Susskind [B9] in GRT context serving as topological correlates and prerequisites for entanglement.

2. MB serves as the intentional agent using biological body (BB) as motor instrument and sensory receptor. MB controls BB via dark photon dark photon beams with large h_{eff}. The double BB + environment is replaced with the triple MB + BB+ environment. The vision about life as nothing but biochemistry is given up.

3. Experiments of Blackman [J24] and others demonstrated the quantal effects of extremely low frequency (ELF) radiation - say in EEG range - on vertebrate brain. For the ordinary value of Planck constant these effects are however impossible since the energy $E = hf$ of EEG photons is extremely small. This motivated what eventually became $h_{eff}/h_0 = n$ hypothesis derivable now from adelic physics [L39].

4. Dark matter at the flux tubes of MB corresponds to $h_{eff}/h_0 = n$ phases and induces coherence of visible living matter. The generalization and re-interpretation [K67] [L24] of Nottale's hypothesis [E1], which reads as $h_{eff} = h_{gr} = GMm/v_0$, where $v_0 < c$ has dimensions of velocity and M and m are masses at the ends of the magnetic flux tube along which gravitons travel is essential element. The hypothesis implies that the cyclotron energy scale for charged particle is independent on m. The spectrum of Josephson frequencies for cell membrane is universal but now the energies are inversely proportional to h_{eff}. The flux tubes containing dark matter would make possible essentially dissipation-free communications based on supra currents and on dark photons.

How MB uses BB as sensory receptor and motor instrument?

How does MB use BB as sensory receptor and motor instrument?

1. Dark photons with large h_{eff} serve as as communication and control tools. Josephson frequencies would be involved with the communication of sensory data to MB and cyclotron frequencies with control by MB. Dark photons are assumed to transform to bio-photons [I20]

with energies covering visible and UV associated with the transitions of bio-molecules [L7, L6]. The control by MB which layers having size even larger than that of Earth means that remote mental interactions are routine in living matter.

2. In ZEO field body and MB correspond to 4-D rather than 3-D field patterns. Quantum states are replaced by quantum counterparts of behaviors and biological functions. The basic mechanism used by MB would be generation of conscious holograms by using dark photon reference beams from MB and their reading. In ZEO also the time reversals of these processes are possible and make possible to understand memory as communications with geometric past. Sensory perception and memory recall would be time reversals of each other and correspond to sequences of SSFRs. Motor action would correspond to BSFRs.

Why metabolism?

Particles with nonstandard h_{eff}/h_0 have higher energy as a rule. For instance, atomic binding energies are proportional to $1/h_{eff}^2$ and thus smaller. Cyclotron energies are proportional to h_{eff}. Metabolic energy is needed to excite particles to dark states and thus to increase their "IQ" .

This picture suggests a generalization of the view about self-organization based on non-equilibrium thermodynamics with a quantum view based on number theory, in particular the hierarchy of Planck constants [L78]. In non-equilibrium thermodynamics energy feed is a prerequisite of self-organization leading to a generation of coherent structures in long length scales and master-slave hierarchy is central. TGD can be at least formally seen as complex square root of thermodynamics, which leads to the question whether also ordinary self-organization could reduce to the hierarchy of Planck constants so that quite generally the coherent structures in long length scales could be seen as analogs of life forms with coherence induced by quantum coherence at the level of MBs. Hierarchy of MBs defining master slave hierarchy with ordinary matter at the bottom of the hierarchy would replace ordinary master slave hierarchy and quantum theory would make itself visible in all scales.

6.2.2 Some aspects of ZEO based theory of consciousness

Active and passive aspects of conscious experience in TGD vision

In the TGD framework one can understand the presence of the temporal, active and passive aspects of consciousness at the fundamental level.

1. In ZEO conscious entities have as geometric correlates causal diamonds (CDs) having two light-like boundaries. The quantum states are products of analogs of ordinary quantum states assignable to these boundaries and the state is in the general case superposition of these state pairs meaning time-like entanglement.

2. During the life cycle of self the active boundary of CD drifts farther away from static passive boundary in statistical sense and the members of state pairs at it change during the sequence of SSFRs. The contribution of the active boundary to conscious experience corresponds to a sensory input and cognition and changes with time:this gives rise to the experience of time flow.

3. The 3-D states at the passive boundary are identified as superpositions of 3-surfaces remaining unaffected in SSFRs. The 4-D tangent planes of 4-surface at them however change and contribute to conscious experience. This contribution would be almost constant, holistic, spatial, and "timeless" and dominate in meditative states where sensory and cognitive input assignable to the SSFRs is minimal. This contribution would correspond to "soul".

In the popular literature about brain science these two contributions are often assigned with the left and right hemisphere. This assignment is certainly over-exaggeration but might have some seed of truth if considered at the level of many-layered MB and taking into account the hierarchy of CDs.

1. Could evolution favor formation of systems for which MBs tend to appear in pairs with the first member in active state and second member in passive state.

   The members of the pair need not have an opposite arrow of time. One can however imagine two parallel sub-CDs of CD with opposite arrows of time and shifting towards geometric future with the active boundary of CD - this shifting is necessary since mental images of CD shift to future. The active contribution from sub-CD_1 and passive contribution from sub-CD_2 would correspond to the same value of experience time inside CD.

   CD_1 would certainly give sensory input. Could CD_2 give a meditative contribution masked by CD_1 except in meditative states?

2. Pairings of nearly identical systems are very general in living matter [K49]. Basic examples are brain hemispheres and also pairs of identical sub-systems inside left and right hemispheres. The strands of DNA provide the second example: given strand has both active and passive portions and there is active-passive pairing. Lipid layers of the cell membrane and epithelial sheets associated with skin have two cell layers giving rise to a binary structure. Whether the active-passive dichotomy applies also now - perhaps at the level of their MBs - is an interesting question.

   Having both arrows of time would make possible sensory input from both past and future and make possible to both remember and predict. This would certainly increase the changes of survival.

3. Could the members of these pairs change their roles by changing their arrows of time? Kind of division of labour would be in question. Some birds (swift for instance) fly always and the explanation is that the second hemisphere sleeps when another one is in wake-up state [J52, J48]. Could this happen during sleep for some neuronal functions also in humans? Or do both hemispheres remain neurally passive during sleep?

Redefining the basic concepts related to time in ZEO framework

TGD based quantum measurement theory extending to a theory of consciousness relies on what Pitkänen calls zero energy ontology (ZEO) [L96]. In this framework experienced time and geometric time are not anymore identified. This has strong motivation, since although these times are strongly correlated, they differ dramatically in many respects. This compels to study every standard concept separately and see how it changes. The new ontology forces to reconsider various basic definitions.

The notion of event

The notion of event has many meanings.

1. Einstein regarded event as a space-time point. Event refers to subjective experience and in the geometric framework it is more natural to talk about space-time point.

2. Events can be identified a classical states assignable to time= constant snapshots of space-time in standard ontology: basically initial values for the time evolution dictated by field equations.

3. In ZEO event in classical sense can be regarded as a classical time evolution - preferred extremal connecting 3-surfaces at the opposite boundaries of CD and analogous to Bohr orbit dictated by the boundary values at either boundary of CD - 3-surface. The analogies with behavior, biological function, and computer program are suggestive.

   Strong form of holography (SH) allows to fix this surface by using 2-D data associated with partonic 2-surfaces and string world sheets. A weaker condition is that the 2-dimensionality for partonic 2-surfaces corresponds to the metric 2-dimensionality for their topologically 3-D light-like orbits. The quantum counterpart of event would be zero energy state identified as a superposition of these space-time surfaces - quantum behavior.

4. Conscious event could be also seen as a state function reduction: moment of re-creation identifiable as an act of free will. There are "small" and "big" state function reductions: SSFRs and BSFRs. SSFR is the analog of weak measurement and BSFR corresponds to

the ordinary state function reduction identifiable in ZEO as "death" of the conscious entity defined by the sequence of SFRSs and "reincarnation" with opposite arrow of time. These notions would be universal, not only biological.

The notions time and causality

For the notions of time and causality doubling takes place. There are

1. Two times - subjective and geometric.
2. Two causalities - that of free will/BSFRs for sub-CDs and that of classical field equations.
3. Two arrows of time. Also the thermo-dynamical arrow of time can be non-standard. This leads to a totally new view about self-organization. Retrocausation (subjective and geometric) becomes possible.
4. Two kinds of memories - subjective memories possible only about subjective past (one cannot remember what one has not experienced yet). and geometric memories about external world, which can also be about geometric future. In the latter case one can speak about precognition or sensory perceptions of geometric future.

The geometric counterpart of subjective "Now"

What geometrical correlate does the subjective "Now" have?

1. The first proposal was that it corresponds to the active boundary of CD. It however turned out that the subjective "Now" could more naturally correspond to the $t = T$ slice of CD with maximal size located in the middle of CD. Here t corresponds to linear Minkowski time axis connecting the tips of CD.

   If one accepts $M^8 - H$ duality, this picture can be made precise. The moments "Now" would correspond to "special moments in the life of self" [L79, L95] identifiable as intersections of 6-spheres, which are brane-like entities (branes are encountered in M-theory) appearing as universal special solutions of algebraic equations determining the space-time surfaces in M^8_c. The values of T correspond to he roots of the real polynomial defining the space-time surface so that the values of "Now" are quantized.

2. During the sequence of state function reductions the active boundary of CD would shift towards geometric future and the size of CD would increase (in statistical sense). The sub-CDs accompanying sensory and other mental images would shift to the direction of geometric future as CD increases and become potential memory mental images suffering BSFRs in a shorter time scale.

   The self would experience memory mental image as a sub-self in memory recall to be discussed below. The time=constant snap-shots at the upper half of CD assignable to the memory mental images are ordered with respect to the Minkowski time t but the order is opposite to that for the subjective experiences. This was a great surprise to me. They would correspond to subselves to which memory recall builds a connection by entanglement quantally or by sending a signal, which is reflected back in BSFR for the memory mental images.

The recall of the episodic memories

What about recall of episodic memories in ZEO?

1. Spontaneous memory recall could correspond to a death of a memory mental image with opposite arrow of time and re-incarnation with the same arrow of time as self. This could be accompanied by emission of past directed "negative energy" signal received by self associated with moment "Now". The interpretation would be in terms of extraction of metabolic energy: memory recall indeed requires metabolic energy.

   Active memory recall could correspond to a receive of future directed "positive energy" signal coming from "Now" having interpretation as metabolic energy feed. Energy conservation would force the memory mental image to change the arrow of time.

2. The prediction would be that in active memory recall by a "positive energy" signal received by the memory sub-CDs, the order of recalled memories is opposite to that for the real experiences. There is evidence for this kind of change [J71] (see also the popular article "The human brain works backwards to retrieve memories" at `http://tinyurl.com/y7hbqmug`).

3. One also consider a mechanism based on time-like quantum entanglement between the memory sub-self and sub-self associated with "Now".

Two variants for geometric memories

Geometric memories - non-personal "memories" - about the external world seem to be possible. The information would arrive as signals from the external world (exterior of CD) and would be "objective". Signals can arrive also from the interior of CD. For instance, as light-signals affecting the state at the active boundary of the CD at which also personal memories are stored. The states are not changed at the passive boundary of the CD during the life cycle of self.

Geometric memories come in two variants corresponding to the two arrows of time.

1. The sensory input from the external world of the geometric past could generate geometric memories, most naturally memories in the behavioristic sense meaning changes of the behavior induced by the changes of synaptic strengths. Sub-selves with an opposite arrow of time could have geometric memories also from the geometric future and give rise to geometric precognition. During sleep this could occur.

2. The geometric memories about future - geometric precognitions or sensory perceptions of signals from future - would be what we regard as an ability to predict what happens tomorrow or after one year. They would not be absolute since quantum jumps affect also the future in scales longer than that for my personal MB. Usually these memories would be identified in terms of a model for the behavior of the external world. Physics itself would realize this model.

6.3 Holistic and reductionistic aspects of cognition at the level of brain

6.3.1 New view about the role of nerve pulse transmission in brain communications

Usually nerve pulses are regarded as signalling in brain. In TGD framework the situations changes [L59].

1. Axons would be accompanied by flux tubes - actually closed flux tubes with a shape of very narrow and long parallelogram. Nerve pulse transmission connects the flux tubes associated with pre- and postsynaptic neurons to longer flux tubes. Nerve pulses make possible real communications by dark photons by creating connected signal pathways from pieces. Dark photon communications are much faster than neuronal ones. There is an analogy with modern electric communications. Communications lines are dynamic and created before communications using relays to save energy.

2. There is dark photon feedback from the brain or even "large" layers of MB to sensory organs giving rise to virtual sensory input. This feedback leading to a stationary situation would make possible pattern recognition producing standardized sensory mental images as kind of artworks by feedback leading to a stationary situation. Light velocity allows very large number of feedback loops in neuronal time scales.

3. In REM dream virtual sensory input dominates. Interpretation for imagination as virtual sensory input stopping at some higher level than sensory organs.

4. Nerve pulse patterns affect dramatically membrane potential and make possible communications from the brain to the "large" layers of MB and fractal hierarchy of analogs of EEG can

be considered. Axons act as generalized Josephson junctions generating dark Josephson radiation travelling to the "large" layers of MB. Frequency modulation of Josephson frequencies codes for sensory input represented by nerve pulses.

6.3.2 Two aspects of cognition

Linear, reductionistic, and time-local aspects of cognition

The neural transmitters promote in the healthy brain the formation of memories understood as neural level behaviors basically by allowing to connect axons temporarily to longer linear neuronal structures: Hebb's rules (`https://cutt.ly/os4ckD9`) characterize this dynamics. This would be the role of the information molecules quite generally.

The key topological observation is that only a single axon emanates from a given neuron. It can however branch so that several neurons can receive the nerve pulse signal from a given neuron so that the network is not tree-like - neither fully linear nor fully non-linear. Also loops are possible.

Tree-likeness means that if an axon becomes dysfunctional, neural signals do not propagate further. This could happen in AD. Nerve pulse conduction fails also if Ach or other needed neural transmitters are not available so that nerve pulses are not mediated over synaptic clefts. The failure of linguistic consciousness in AD [J27] motivates the hypothesis that neuronal level is responsible for this mode of consciousness.

Spatial and holistic aspects of cognition

Cognition has besides the linear and temporal linguistic aspects assignable to neural activity - also spatial and holistic aspect.

1. The TGD based vision about MB is as a fractal structure having besides the "large" part also "small" parts in the scale of body and brain. This vision predicts that neurons appear as nodes of magnetic flux tube networks, which can be 2- or even 3-D. Part of these flux tubes can be parallel to axons. These magnetic flux tube networks could relate to the holistic, geometric aspects of cognition. If these flux tubes carry monopole flux, they are stable against splitting. Therefore episodic memories assignable to these networks would be stable.

   More probably, the flux tubes are closed looking like very long and narrow parallelograms connecting two systems. These flux tubes could split by reconnection to two pieces forming smaller long parallelograms. These networks could be rather permanent at the scale of the body, and also these networks could have nodes where reconnections can occur. Psychoactive drugs could induce this kind of reconnections over very long distances [L23]. In particular, to the large part of personal MB.

2. In music experience these two aspects combine: rhythm corresponds to the time-local, linear aspect and harmony to the holistic aspect [J79]. It is quite possible that the neural system alone cannot represent the latter aspect. This suggests that neurons - or perhaps glial cells - form 2- or 3-D networks connected by the analogs of axons identifiable as flux tubes in TGD framework [K2, K5] [L39]. Also the meridian system postulated by eastern medicine could relate to this. This system would precede the nervous system and even plants could have it.

   These 2- or 3-D structures are stable against the splitting of axon-like units so that the holistic aspects of cognition would be preserved in AD. The AD patient can indeed understand the words of songs. The signaling in this system would take place by dark photons with non-standard value $h_{eff} = nh_0$ of effective Planck constant, which are photon-like particles transforming to biophotons [L7].

3. The vision about the brain based on the theory of consciousness and living systems [K2] [L96] inspired by Topological Geometrodynamics [K5] [L39, L40] leads to the view that also neural system uses dark photons to the communications in brain. The function of nerve pulse activity would be to build communication lines by combining the magnetic flux tubes accompanying axons to longer structures serving as analogs of wave guides along which dark photons can

propagate [L59, L60]. The information molecule would play the role of a relay element. The analogy with modern electronic communications is obvious.

The evolutionary reasons could be the reduction of metabolic costs and the advantages due to the ability to rapidly modify the topology of the flux tube network. For instance, flux tube structure would make possible topological quantum computation based on the braiding of the flux tubes [K3, K79].

4. TGD leads to a model of genetic code based on the notion of bio-harmony inspired by the attempt to understand the notion of musical harmony. The model relies on the realization of harmony as collection of allowed 3-chords realized in terms of frequency triplets. It turns out that the representation in terms of icosahedral and tetrahedral geometries leads to a large number of harmonies allowing representation of vertebrate genetic code [L15, L16, L77]. Since music creates and expresses emotions, the interpretation is that these bio-harmonies represent emotional states, moods [L60, L64]. Bio-harmony would represent collective aspects of cognition, emotional intelligence whereas neural activity would represent its time-local and linear aspects.

5. Idiot savants are capable of amazing memory feats [J29]. For instance, they can play an entire music piece having heard it just once or draw an entire landscape from memory. This strongly suggests that holistic memories are indeed subjective- re-experiences rather than learned behaviors. Idiot savant would see the landscape that he is drawing. These memories are also holistic, which suggests that subjective memories are assignable to the 2-/3-D magnetic flux tube networks rather than basically linear neural networks.

   Could brain chemistry provide tools - say various psychoactive drugs - promoting holistic cognition [L23]. N,N-dimethyltryptamine (DMT) - a psychoactive compound produced by the brain itself - is what comes first in mind [L59]. Idiot savants have severe cognitive defects but are able to perform miraculous feats related to memory, mathematics, and arts. Could holistic cognition replace neural linear cognition in these situations?

Are holistic and geometric aspect of cognition associated with meridian system or glial system?

MB would give rise to a flux tube network with flux tubes connecting basic units which could be neurons but possibly (also) glial cells. This network would be also fractal appearing in various scales. Axonal network would be only part of this network with axons accompanying flux tubes forming a sub-network with the property that from a given node only a single axonal flux tube emerges which possibly branches later. There is however no reason to assume that the number of flux tubes emerging from a given node is only one. Also flux tubes without accompanying axons are possible.

Therefore non-dynamical 2- or even 3-D magnetic flux tube networks are also possible but not as neural systems. The attractive identification is as correlates of 2- or even 3-D holistic consciousness. Dark photon signals can propagate also along these networks. Key feature is the stability against splitting of a single flux tube distinguishing these systems from 1-D linear systems. If neural transmitters serve as relays connecting flux tubes to longer units for axonal pathways, a subset of information molecules such as DMT could also act in the similar manner in the entire flux tube network.

1. Could holistic aspects correspond to the meridian system with meridians associated with flux tubes and acu points acting as nodes? This kind of networks could be possessed also by invertebrates such as plants. Could glial cells form nodes of this kind of network? Could glial *resp.* neuronal systems forming a coupled pair be responsible for holistic and spatial *resp.* reductionistic, time-local, and linear aspects of consciousness.

2. Is there a connection with AD? Linear language based consciousness associated with nerve pulse activity would degenerate in AD since the axons with plaque would not conduct nerve pulses and the formation of temporary signal networks would fail. The 2- or 3 D holistic consciousness stable under this kind of splitting would however remain [L57].

3. What is the relationship to the right-left dichotomy often assigned with the holistic-reductionistic dichotomy? It is said that the left brain talks and he right brain sings. AD patients understand words, which are sung. How strictly this is true? Should R-L dichotomy be replaced with neural-meridian or neural-glial dichotomy as a realization of holistic-reductionistic dichotomy.

Sleep *resp.* **awake as holistic consciousness** *resp.* **linguistic consciousness?**

How the two kinds of consciousness relate to time reversal and left-right division of the brain?

1. Neuronal consciousness dominates during wake-up but during sleep neural activity is suppressed by hyperpolarization. Sleep could therefore correspond to the dominance holistic, spatial consciousness assignable to the meridian system or glial system.

2. What about the arrow of time for the consciousness during sleep (about which we - at least apparently - would not remember anything). Could the MB for the meridian-/glial system have reversed arrow of time during sleep and have sensory input from the geometric future? This could explain precognitions and prophecies.

3. One can also ask whether right- and left hemispheres have opposite arrows of time in time scales longer than nerve pulse duration T. This is not possible in the axonal length scale since axonal potential would change its sign in times scales longer than T.

How these two modes of consciousness relate to EEG and electric fields of brain and body.

1. Cyclotron frequencies characterizes the flux tubes. Time reversed part of MB in scales corresponding to "us" does not contribute to "our" consciousness during wake up. We do not remember anything about the sleep period without dreams: could it be that "we" are in time reversed mode so that there are no memories about this time.

   During sleep $f < 10$ Hz dominates in EEG: it does not correlate with "wake-up" consciousness. Could sleep correspond to holistic time reversed consciousness with reduced neural activity (by hyper-polarization) perhaps assignable to meridian or glial network. During wake-up $f \geq 10$ Hz dominates and correlates with the contents of consciousness. Linear neural consciousness would dominate.

2. How the time reversal reflects itself in EEG? There are indications that EEG consists of slices of duration about 300 ms decomposing to order and chaotic pieces [J41]. Could these pieces correspond to dissipation in standard arrow of time and with opposite arrow meaning effective generation of order [L5]?

3. What about longer spatial and time scales? Could the change of the arrow of time show itself somehow. The direction of velocity and electric field changes opposite in time reversal. Could the propagation direction of say thalamo-cortical EEG waves with 40 Hz resonance frequency in the cortex change. 40 Hz resonance occurs also in the transition to meditative state. What could this mean?

   It is known [J89, J19] that the change of the direction of the electric field along the body axis leads to a loss of consciousness (for TGD based model for the direct currents of Becker see [L4]): could this mean actually the change of the arrow of time at the layer of MB controlling the dynamics in this length scale. Same is true concerning the reversal of electric field from frontal lobes to hindbrain. Longitudinal electric fields are also associated with microtubuli and DNA.

Also oscillating electric fields are important in living matter.

1. By Faraday's law oscillating electric fields also accompany oscillating magnetic fields and could generate bio-rhythms as repeating cycles living-alive-living-alive or ..-wake-up-asleep–wake-asleep.. . Cyclotron frequencies, generalized Josephson frequencies, and Schumann resonance frequencies would define various bio-rhythms forcing biochemical rhythms. Rhythm of breathing and of heartbeat would be examples of such bio-rhythms. Also EEG rhythms

would define life-death cycles. For instance, EEG decomposes to pieces with duration of 300 ms having this kind of structure [J41] [L5].

Both quasi-static and oscillating longitudinal electric fields accompany microtubules [I26]. Ghosh *et al* [J60] have found that oscillating electric fields along microtubuli can generate longitudinal ballistic currents (perhaps supra currents) along them at certain critical frequencies: the results are discussed from the TGD perspective in [L14].

2. There is evidence for the healing of cancer by using an extremely weak oscillating magnetic (and thus also electric) field in nanotesla range with frequency of 60 Hz, which is a Schumann resonance frequency [I34]. The TGD inspired model for the finding [L132] missed the interpretation as a re-establishment of a lost life cycle.

6.4 Brain science and recalling memories of future

The notion of memory must be defined more precisely first.

1. In neuroscience memory is defined essentially as a learned behavior and reduces to the change of synaptic connections. The episodic and sensory memories are not like this: they are genuine re-experiences. Idiot savants would have this kind of sensory memories. For instance, they can play an entire music piece or draw an entire landscape from memory such that all details come out correctly. Idiot savant sees again the landscape that he is drawing. Neuroscience cannot provide a convincing explanation for these memories, which suggests that something very important is missing from the picture.

2. Subjective memories predicted by the TGD framework are different from learned behaviors. They are indeed genuine re-experiences - direct sensory experiences or symbolic representations of sensory mental images involved. They do not involve the emergence of new behavior or new associations by strengthening of synapses. They would be essentially at the level of the MB and perhaps precedessors of the memories as identified by neuro-scientists.

6.4.1 What memories of the future could mean?

What the memories of the future could mean?

1. In TGD framework subjective precognition is not possible since the subjective future does not yet exist: moment of consciousness corresponds to a re-creation of the quantum sub-Universe as zero energy state.

2. In TGD Universe geometric precognition is in principle possible and corresponds to a receival of objective information - physical signals - from the geometric future and might occur routinely. My subselves (mental images) with an opposite arrow of time can represent geometric memories from my geometric past. Precognition as a recall of future geometric memories would rely on sensory perception with an opposite arrow of time by some subselves assignable to the structures of the brain. The arrow of time would be reversed at some layer of MB and induce effective change of arrow at the level of ordinary biomatter in longer time scales than usual.

   Remark: At molecular level BSFRs occur very frequently so that the period with fixed arrow of time is very short.

3. Neuroscientists usually interpret memories as learned associations assignable basically to the strengthening of synaptic contacts (Hebb's rules, `https://cutt.ly/os4ckD9`). These memories are like a text carved to stone and should be distinguished from genuine subjective memories. The sensory inputs from the geometric past and perhaps even from geometric future could induce memories in this sense.

   The interesting question is what the change of the arrow of time could mean at the level of nerve pulse conduction. Axons realize the arrow of time as a fixed direction of neural conduction. MB in time reversed mode changes effectively the arrow of time as the level of

ordinary matter in long length scales. Does this mean that nerve pulses travel in an opposite direction than usual?

This has also interesting connection with AD [J26] discussed from the TGD point of view in [L57]: the approximately exponential attenuation of signals along axon with plaque would look like exponential amplification in the standard time direction, and the neural signalling with reverse arrow time might be possible! In the TGD framework death would be a universal phenomenon and mean re-incarnation with a reversed arrow of time. In AD death would have already started at the neural level. What would be conforting that death would be accompanied by a re-incarnation.

4. There is an objection against the change of the arrow of time at the level of axons. The behavior of electric field in time reversal suggests that the sign of membrane polarization should change in the time reversal. Time reversal occurs during nerve pulses if they involve BSFR. For the time reversed states the periods of pulse-on and pulse-off would be permuted so that the effect might not be very dramatic during firing. In the absence of firing the sign of membrane potential would be opposite and this cannot occur in long time scales.

   The duration of the nerve pulse varies from $T_1 = 1$ ms (sodium based action potential) to about $T_2 = 100$ ms (time scale for sensory mental images!) for Calcium based action potentials and can be understood as being due to BSFRs. One could argue that T_2 corresponds to the maximal duration of the time reversal in the axonal length scale. In longer length scales the time reversal periods could be longer and manifest themselves in different manner such as a change of the direction of conduction velocity.

   Since the time scale T and size scale L for any CD are related by $L = cT$, the change of the arrow of time at brain level during sleep should occur in a considerably longer time scale. The ratio of the time scale of sleep period taken for definiteness to be $T = 6$ hours to $T_1 = 1$ milliseconds is $r = T/T_1 \simeq 2 \times 10^7$. What is the length scale L assignable to T. If the length scales assignable to axonal conduction is cell membrane thickness $L_1 = 10^{-8}$ m, ab one has $L/L_1 = T/T_1 = r$, one has $L \sim .2$ m not far from the size scale of the brain.

   A good guess is that the spatial scale associated with $T_2 = 100T_1 = 100$ ms (no sensory mental images during sleep) is given by $(T_2/T_1)L_1 = 100L_1 \sim 1\mu$m and is thus the length assignable to cell nucleus. For the same value of the scaling factor r, this would give $L \sim 20$ m, longer than the length scale of the human body but roughly consistent with the size scale of largest animals.

6.4.2 Are memories of the future possible in some sense?

Dr. Reza Rastmanesh asked in personal communications whether the Acetylsalicylic esterase (AChE) inhibitors could promote the formation of memories in the reverse time direction - to precognize in some sense. The mainstream view of neuroscience does not distinguish between future and past memories at fundamental level and the asymmetry can be understood only in terms of thermodynamics postulating a fixed arrow of time.

In TGD framework one can speak about precognition of geometric future - sensory experiences about geometric future possible for time reversed conscious entities with time reversal taking place at the level of MB. Conscious entities cannot have direct subjective memories of the future since subjective future does not exist. If the MB of the sleeping brain has a non-standard arrow of time, its partial wake-up could give rise to a dream, which can but need not be precognitive.

Two proposals for understanding memories of future

The level of the transcription factor cAMP/Ca(2^+)-response element binding protein (CREB) is a key factor governing which neurons are recruited for a given memory trace [J36]. Recently a similar role has been proposed for cGMP response element binding (GREB) protein. Inhibition of phosphodiesterase 5 restored cognitive function in scopolamine-induced amnesia mice by activating the cGMP/CREB signaling pathway and attenuating oxidative stress [J46], with promising implications for treatment of AD. Collectively, in addition to cAMP, cGMP and Amyloid β has been proposed as critically important for memory formation [J88].

CREB is a ubiquitously expressed transcription factor expressed in the brain. It regulates neuroplasticity by modulating gene expression [J44], and so loss or dysfunction in CREB is lethal (at least in mice, and presumably embryonically lethal also in humans), and it may not be feasible to modulate CREB in interventional clinical trials. Down-regulation of AChE in the brain [J21] has been considered as the most important pathway by which CREB modulates memory allocation.

It has been argued that we do have memories of the future; we just cannot make sense of them [J22]. In the framework of behavioristic neuroscience, one can ask whether the factors such as CREB, GREB and Amyloid βthat enable to memorize the past, meanwhile prevent disable from remembering the future. They would select the arrow of time. Note however that these factors relate to memories interpreted as learned behaviors and it is far from clear that episodic memories are such. In any case, the sensory input from the geometric future can also modify synaptic strengths.

There are two options to consider.

Option I: Suppose that also episodic memories reduce to the synaptic strengths as in behavioral approach. Since Ach plays a major role in the formation of memories in this sense [J63], further information about the relationship between AD with memory and precognition would be essential to design a novel and innovative technology to remember the future using specific agents selectively targeting the neural transcription factors or neurotransmitters involved in memory formation. There are numerous factors involved in the memory formation, consolidation and transformation [J69], however, because of its central role, the focus will be on Ach and AChE in this paper, for convenience.

Option II: In the picture based on ZEO the MB carrying dark matter bio-chemistry are in a master-slave relationship. The arrow of time is changed in BSFR at the level of MB and induces its effective change at the level of ordinary matter. The most natural reason for BSFR would be however the depletion of metabolic energy sources: during time reversed phase the subself would be able to extract energy from the environment. For this option the technology to remember the future could be rather brutal: a down-regulation of metabolic energy feed! One can however ask whether MB as the wise boss reacts to the pressures from the lower level and for critical concentrations of neural transmitters makes a BSFR changing the arrow of time.

6.4.3 Future perspective assuming Option I

It remains to be determined whether our inability to remember the future is a biologic limitation or a physics limitation, but it is scientifically testable. In other words, the ability or disability to re-member the future with this perspective is mostly a matter of information sufficiency or deficiency, respectively, or biologic limitation rather than a limitation imposed by physics. The hypothesis will find enormous technological applications if proves to be true. If there are no means for humans to predict the detailed future of the world, it is not because of physics per se; rather it might be because of information deficiency. Below, we propose two thought experiments to investigate a priori hypothesis

Increased precognitive dreaming following administration of AChE inhibitor (Rivastigmine) in AD patients has been reported before by de Pablos [J30, J31]; however this has not been replicated by other researchers. To investigate the correlation between AChEIs and precognitive dreaming entails meta-analyzing results on experimental dream-ESP studies carried out before.

Retrospective design

Independent Data sets about dream-ESP (if there are any) from previous trials that have administered AChEIs to AD patients be re-analyzed retrospectively to attempt to find out any effect from AChEIs on precognitive dreaming. Dream-ESP is defined as a form of extra-sensory perception (ESP) in which a dreaming perceiver seemingly gains information about a randomly selected target without using the logical inference or normal sensory modalities, as described before [J45].

According to the procedure described by Strom *et al* [J45], studies can be categorized into two categories: the Maimonides Dream Lab (MDL) studies, and independent (non-MDL) studies. Mean ES for both MDL dataset and the non-MDL studies should be calculated in order to find a significant or meaningful difference between the two mean values. Using a homogeneous dataset with a sufficient sample size, it is possible to yield a mean z, with corresponding Stouffer Z, to

elucidate whether dream content can be used to identify target materials correctly and more often than would be expected by chance. Also, any significant differences between: (i) three modes of ESP (telepathy, clairvoyance, precognition), (ii) senders, (iii) perceivers, or (iv) REM/non-REM monitoring can be measured. For details of the protocol see [J45].

We suggest that trials investigating AChEIs in AD patients, measure appropriate variables such as alterations in sleep architecture, EEG power spectral analysis, and quantitative EEG of rapid-eye-movement sleep to yield preliminary data for future double blinded clinical trials. Retrospective design cannot be used for investigation of causality.

Controlled design

In a double-blind, placebo-controlled, randomized, study, sufficient sample sizes of patients with mild to moderate AD who are taking stable doses of AChEIs will be enrolled. Within 28 days prior to study drug administration, patients will be screened based on National Institute of Neurological and Communicative Disorders and Stroke/Alzheimer's Disease and Related Disorders Association (NINCDS/ADRDA) criteria with attention to revisits [J36] for probable AD, Mini-Mental State Examination (MMSE) and Modified Hachinski Ischemic Scale (MHIS) scores, medical history, physical examination, neurological examination, vital signs, ECG, laboratory tests and response to Columbia-Suicide Severity Rating Scale (C-SSRS).

Participants will be administered standard precognitive dreaming questionnaires and will be invited to a sleep laboratory. Patients will be asked to dream about a target video they would later view. A blinded judge would rate patients' dreams against the target and decoys. Evidence for dream precognition will be recorded. The study can be accomplished with testing the hypothesis that precognitive dream experiences may occur when an AD patient subconsciously incorporates sensory information into their dream. A sound clip would be played to sleeping patients and a blinded judge would rate the target and decoy clips against the patients' dream transcripts. The correlation between degree of sensory incorporation and prior precognitive dream experience will be measured, as described before [J22].

We suggest that a combined controlled sleep laboratory study and EEG or event-related potential (ERP) indices would be instrumental in AD patients who are taking AChEIs compared with that of AD patients who are taking placebo to find out any effect of AChEIs on EEG and ERP and precognitive dreaming and a possible causal correlation between EEGs and precognitive dreaming and dream content. Cortical AChE activity will be measured in both groups and spearman correlation coefficient will be calculated between the cortical AChE, AChEI and Ach concentrations with dream content/precognitive dreaming.

Also, to test the hypothesis, it would be also useful to investigate whether AD patients who score lower on a Wechsler Memory Scale–III [J35], are more likely to have a higher report of precognitive dreaming. This is especially important in the case that AD patients *premember* an event, but cannot *remember* to report that event.

6.4.4 An attempt to relate Option II to biochemistry

The following arguments suggest that the findings about AD patients are consistent with Option II based on ZEO.

Consistency with the findings about AD patients

The following represents an attempt to understand these effects assuming **Option II** that is ZEO.

1. Acetylcholine (ACh) is a neutral transmitter involved with synaptic transitions and important for the formation of memories understood as learned associations and behaviors to be distinguished from genuine subjective memories. In TGD framework ACh promotes in a healthy brain the formation of memories basically by allowing connect axonal flux tubes temporarily to longer linear structures so that associations can form.

   If the postsynaptic axon becomes dysfunctional neural processing partially fails: this is like cutting a linear chain. This could happen in AD [J26] [L57]. Nerve pulse conduction fails also if Ach is not available so that nerve pulses are not mediated over the synaptic clefts and formation of signal pathways for dark photons signals is prevented.

2. AChE promotes the decay of ACh so that it stays for a shorter time period in the synaptic contact. AChE inhibitor (AChEI) causes an opposite effect. The longer ACh lifetime is in turn expected to promote the formation of short term memories in the behavioristic sense via stronger synaptic strengths and would thus help in AD. This is true if the postsynaptic axon conducts nerve pulses. But doesn't plaque formation effectively cut the axon so that the strengthening of the synaptic connection is useless in AD?

3. If linear memories do not survive in AD due to the failure of nerve pulse conduction along the postsynaptic axons, their formation is a waste of the metabolic energy. If this is prevented, the metabolic energy could be used to form non-linear and holistic right-brain memories as 2- or 3-D structures. These memories would be subjective mental images rather than behaviors. The system behind holistic cognition might come in rescue.

4. Consider now the question of Dr. Reza Rastmanesh. It would seem that AChE could promote the transition to the mode in which holistic subjective memories dominate by shortening the life-times of ACh molecules. Even the reduction of ACh level could favor holistic cognition since ACh is useless if the postsynaptic axons are dysfunctional. AChE inhibitors would favor synaptic transmission but in AD this would not help if axon is not able to conduct. Is the transition to a holistic mood the optimal response?

   But if the memories are subjective in this case, it would seem that precognition is not possible - contrary to the reported evidence including prophetic dreams!

5. This paradox disappears if the change of the arrow of time means change of the direction of nerve pulse conduction. The approximately exponential attenuation of signals along an axon with plaques would look like exponential amplification in the standard time direction, and the nerve pulse conduction could be possible! Also now neural transmitters would be needed in the synaptic transmission to connect the flux tubes to longer units.

Precognitive dreams as communications of episodic memories between conscious entities having different arrows of time?

The precognitive dreams suggest also the subjective memories of future or their analogs are possible. Self as a conscious entity can have only memories of previous experiences of subjective past and direct episodic memories of future are not possible since it does not yet exist for self.

One could perhaps overcome this restriction. Suppose that the MB of the sleeping brain has a non-standard arrow of time. Dreams could correspond to the wake-up of some part of the MB of the sleeping brain by BSFR. It would have the standard arrow of time and would contain information about the sensory mental images of the sleeping brain. Could this information be experienced as a dream? Not all dreams need be precognitive since the sensory input from geometric could come only from the interior of the CD of the sleeping brain.

6.5 Appendix: FQA related to the possibility of the memories of future

In the following we will propose possible answers to some questions posed during the collaboration by Dr. Reza Rastmanesh related to the proposal that memories of the future might be possible as memories in the behavioristic sense and being induced by the non-standard arrow of time at the MB of the system.

6.5.1 General questions

Q1: Can we have a thought experiment, by which one can prove the occurrence of time reversal in the human brain?

A1: ZEO implying both arrows of time can be justified by a simple thought experiment. Ordinary thermodynamics with a single arrow of time predicts heat death of the Universe since the energy flows between systems making self-organization possible die away by the second law of

thermodynamics. Life must be regarded as a thermo-dynamical fluctuation - and as it seems in cosmological scales and even characterized by evolution. This is nonsensical.

Q2: Most skeptics urge that precognition is not possible, could one propose some techniques by which other researchers amend or correct their methodology.

A2: I do not believe that proving is possible since all depends on fundamental assumptions. Experimental testing is however possible.

1. The direction for the nerve pulse conduction would change *if the arrow of time is effectively reversed for axons that in length scales about the length of or thickness of the axon.* This is a rather dramatic prediction and could explain the claimed phenomena like reverse writing [J70] and reverse speech (`http://www.reversespeech.com/words.shtml`) discussed from the TGD point of view in [K47].

   I remember an article that I read a couple years ago telling that recalled episodic memories have order opposite to that for the actual events. This supports the TGD view about active memory recall.

   Remark: Real time reversal would occur only at some layer of MB and induce an effective time reversal in shorter time scales.

2. Second prediction is that axonal potential could change sign in the effective time reversal *if it occurs in the length scale defined by the thickness of axonal membrane different from axonal length.* This kind of change of arrow of time would place also for ordinary nerve pulses so that the roles of no-pulse and pulse periods would change. This would occur for ordinary nerve pulse transition in the time scale of nerve pulse varying from ms to 100 ms but not longer scales.

Q3: What is the most pronounced weakness of current methodologies which fail to detect or recognize the phenomenon of bilateral time arrow in the human brain? Is it just our ontology and epistemology which is uni-biased over time and history? Is it because of our language which prohibits a bilateral arrow of time?

A3: The fundamental weaknesses are in the basic ontology, which postulates a fixed arrow of time already at the level of physics. Science relies on language and this might partially explain even this postulate although there is experimental evidence supporting the possibility of a non-constant arrow of time.

The basic problems of also modern physics are due to the obviously wrong (to my view) philosophical dogmas. For instance, memories are defined as changes of behavior and reduced to changes of synaptic contacts. This has nothing to do with episodic memories, memories as re-experiences about which idiot savants are an excellent example.

Q4: Why don't we realize that we have precognition?

A4: One can imagine several reasons.

1. Precognition is quite too familiar. We can predict quite well what we will do tomorrow and what the world will look like tomorrow. This is regarded as totally trivial or as an outcome of computations in the brain. It would be interesting to look whether AI can do this precognition easily.

2. Second reason is that we do not remember anything about periods with a reversed arrow of time. Sleep could be such a period and the only memories are from the state in which some brain regions have standard arrow and remaining still the reversed arrow.

3. The time reversed sensory perception would in the TGD picture give rise to memory in behaviouristic sense - not episodic memories. This would mean that synaptic strengths would change and change our behaviour. This change is not manifest to us!

Q5: Isn't that partially because our evolutionary biology dictated such a unilateral time arrow?

A5: Here I disagree. I understand with "unilateral" that the arrow of time is fixed and always same for both hemispheres always.

1. In TGD framework The period for a fixed arrow of time in atomic scales changes is very short: the average time duration between two ordinary state function reductions, lifetime of self in the atomic scale. This continual living and dying actually gives rise to thermalization.

2. Dark matter as $h_{eff} = nh_0 > h$ phases at MB makes possible much longer time scales with fixed arrow of time and conscious entities can have long lifetimes. The lifetime depends on the level of the self hierarchy. At brain level it could be perhaps 6 hours - of the order of wake-up - or sleep period. At he higher levels of the self hierarchy it could be longer, say human life-time. At axonal level it corresponds to the duration of the nerve pulse between 1 ms and 100 ms etc.. ZEO - that is geometry of CD- allows to expect that the length scale L and time scale T of self are related by $L = cT$.

Q6: What are the possible benefits of an unilateral time arrow? Is there any way for acquisition of such experiences?

A6: I can answer to a question with "unilateral" replaced with "bilateral" meaning that brain hemispheres can have different arrows of time. Even more generally, subsystems of brain can have varying arrow of time. Suppose the system consists of a pair for which magnetic bodies live in opposite arrows of time at some level of self hierarchy - say brain hemispheres. This would make the system able to have geometric memories (sensory perceptions) of both past and future. Anticipation of the future would become possible besides memory and this would certainly be an evolutionary advantage. This prediction does not look so dramatic, when one realizes these memories would be memories in behavioristic sense: changes in the synaptic strengths.

Q7: For example, using EEG we can record the frequencies of the brain, is there any technological possibility by which in future humans can differentiate between forward arrow of time and backward arrow of time?

A7: Long time ago, I [Pitkänen] had long discussions with two neuroscientists - brothers Fingelkurts - living in Finland. They had observed that the EEG decomposes to segments of about 300 ms [J41] [L5]. The segments seem to have division to order and chaotic pieces. A possible interpretation would be that chaotic piece corresponds to ordinary arrow of time with dissipation causing the chaos and the order piece to opposite arrow of time in which dissipation looks like generation of coherence and order for a human observer.

Q8: Option II states that in the wake-up state with standard arrow of time we don't remember the future in the sense of having sensory input from it, but what about our working memory capacity and confabulation? One may argue that we may not remember the future in detail; another person may argue that this is partly because of amnesia. For example, we cannot remember the past as well, even though we have physically experienced it. We forget some true memories and experiences related to the past, we add some fake memories or experiences which never happened, we confabulate some memories that never happened, etc. The fact that we cannot remember the future, in addition to any biological advantage, maybe is partly because of limitation in our working memory capacity. In fact, there is evidence that during sleeping state, working memory is lower compared to that of wake up state [J54], and working memory span is restricted during sleep state compared to that of wakefulness [J1]. There are also inter-individual differences for example, in terms of genetic polymorphisms [J53], age [J76] or time of day [J56] from the stand point of working memory. These seemingly minor variables may partially explain why some studies of testing the implicit processing hypothesis of precognitive dream experiments have failed before [J49]. Therefore, close attention to hidden variables is necessary when designing clinical trials to test precognitive effect of any potential specific agents selectively targeting neurotransmitters involved in memory formation during sleep state.

A8: In the TGD framework there are two fundamental reasons for not seeing the future in detail.

1. Zero energy state as a superposition of space-time evolutions changes all the time, in each quantum jump. There is no unique objective reality nor future in classical sense. Only the changing superposition. The prediction of future given by sensory perception with a reversed arrow of time is only a prediction: it holds true only if now further acts of free will re-creating the world or part of it in 4-D sense do not occur.

2. Finite measurement resolution is the key element of adelic approach. The positive aspect of finite cognitive resolution is that it prevents us from drowning to information and selects the

most important digits. This notion has been accepted in theoretical physics but its mathematical description is primitive. In TGD adelic physics leads to a unique discretisation of space-time surface for the given evolutionary level characterised by an extension of rationals. The higher the level, the better the resolution of cognition and sensory perception.

Concerning the amnesia hypothesis.

1. We would not have episodic memories - re-experiences - at all in reverse time direction. Subjective future does not yet exist.

2. We can have sensory percents of geometric future. They are not episodic memories.These would affect the synaptic contacts and change our behaviours: it is not easy to see changes in one's behavior and even more difficult to assign them to time reversed sensory perception! But of course, our future expectations - precognition - can dramatically affect our behavior!

About confabulation I can only propose what it correponds in the TGD framework.

1. Confabulation is an interesting phenomenon closely related to imagination. Adelic and p-adic physics can be seen as an attempt to identify physical correlates of imagination, which is indeed confabulation in some sense . p-Adic variants of space-time surfaces are not completely deterministic and could be seen as correlates of imagination of confabulation.

   In general the -adic space-time surfaces can only partially correspond to real space-time surfaces since for the latter the determinism is complete. Imaginations could correspond to p-adic space-time surfaces having only partially real counterparts. Say those representing dark photon signals from he brain or even from the MB to the sensory organ and generating virtual sensory input during REM, hallucinations, or psychedelic experiences.

2. In the case of imagination they would never reach the sensory organs and would not give sensory input. Same is true for motor actions: motor commands do not reach muscles during dreams. Imaginations are almost sensory experiences and motor actions. Sensory input strongly bounds imagination and confabulation: in think tanks the constraints are absent and the person starts to hallucinate.

Q9: Can you add some applications?

A9: Electric fields populate living systems. Both static and oscillating electric and magnetic fields are abundant in living matter. Becker [J89, J19] was one of the first researchers to realize their role for life. If the sign of an endogenous electric field assignable to organelle changes as the arrow of time changes for the corresponding layer of MB, its change might force time reversal. Oscillating electric fields would estabish bio-rhythms as life-death cycles. This suggests quite science-fictive sounding applications.

1. Healing by rejuvenation could be one application. Becker *et al* found that in the cleft between wound tissue and CNS and electric potential having a sign opposite to that in the normal situation develops, and after the healing has occurred, the normal voltage is re-established [J89, J19]. Note that nerve pulse is in certain sense a wound but in a shorter scale.

   Could this mean that the layer of MB associated with the wound region makes a BSFR - dies and reincarnates with an opposite arrow of time - and eventually returns to the healthy state by a BSFR? If so, external electric fields changing the sign of the appropriate voltage might be used for healing purposes [L4].

2. Healing by re-establishment of lost bio-rhythms could be a second application using oscillating external electric field or magnetic field accompanied automatically by electric field. Year ago we wrote with Dana Flavin an article [L132] about the evidence for a healing of cancer by using an extremely weak oscillating magnetic (and thus also electric) field in nanotesla range with frequency of 60 Hz, a Schumann resonance frequency but did not realize this interpretation [I34]. The interpretation could be as a re-establishment of a lost life cycle.

3. Also the production of germ cells from highly differentiated cells could be based on the time reversal and electric fields might be used to return the diseased cell population to its earlier state: somewhat like returning the computer to its earlier stage when some problem occurs.

4. Chemists Guido Ebner and Heinz Schuerch [J17] have studied the growth and morphogenesis of various organisms in presence of electric fields. Germ, seeds, or eggs were placed between conducting plates creating an electric field in the range .5-2 kV/m: note that the Earth's electric field is in the range $.1 - 4$ kV/m and of the same order of magnitude. The outcome was rather surprising and in the year 1989 their employer Ciba Geigy applied for a patent "Method of enhanced fish breeding" for what is called Ciba Geigy effect. The researchers describe how fishes (trouts) develop and grow much better, if their eggs have been conditioned in an electrostatic field. The researchers also reported that the morphology of the fishes was altered to what seems to represent an ancient evolutionary form: this was not mentioned in the patent.

   The explanation discussed in [L4] would be that the DNA serves as a kind of evolutionary archive realizing "ontogeny recapitulates phylogeny" very concretely. The presence of the electric field would stop the phylogeny by allowing the expression of an older variant of the genome. A more abstract realization would be that the genome experiences phylogeny during ontogeny. The application of an electric field with a proper sign and magnitude could stop the ontogeny to an earlier stage.

   One could even imagine changing the arrow of geometric time and producing earlier evolutionary variants of a simple organism or organelle by using electric field: the strength of the electric field needed might relate to that prevailed during the earlier evolutionary stage.

Second application could be a creation of artificial life. Also the relationship to AI is highly interesting. Electronic circuits involve both energy feed as a counterpart of metabolic energy feed, they involve electric and magnetic fields, and also resonance frequencies. This makes self-organization possible and even a self-sustaining situation in which the system experiences a sequence of life-death cycles can be considered.

1. The findings about simple systems having life-like properties involve typically an oscillating electric or magnetic field. One such system consists of plastic balls [I16]: the TGD inspired model for the system is discussed in [L38].

2. It would be interesting to arrange a coupling to the MB of Earth by using Schumann resonance frequencies and by the cyclotron frequencies in endogenous magnetic field $B_{end} = 2/5B_E$ explaining the findings of Blackman and others [J24] (B_E denotes Earth's magnetic field) so that the MB of Earth could become the boss. Plasma structures would be also ideal candidates for living systems and bio-matter is indeed a cold plasma. Ball lightning would be one example about a plasmoid as a primitive life-form.

3. The manipulation of bits induces changes of the electric and magnetic fields and there are oscillating electric fields present such as the computer clock. If MB is involved actively, this could give rise to a living system having even its own intentions and free will. Note however that the MB in questions would be most naturally that of the user! Can one build a computer whose personal MB takes the lead? It might be that the computer is living in some sense which is even related to the program running in it.

6.5.2 More questions about the arrow of time

Q1: We have to mention energy cost of memory, in its broad meaning (either one considers memory from the standpoint of reductionism and molecular or episodic memory. Also, the issue of memory erasure should be at least briefly discussed or at least mentioned).

A1: Creating memories requires an increase of h_{eff} and keeping it - h_{eff} tends to decrease by emission of energy. This is why all life requires metabolic energy. Also memory mental images require metabolic energy to survive. They can get it from environment as usual or if not, they acan die and reincarnate with opposite arrow of time and later do this again in the original time direction. Very elegant!

Memory erasure tends to take place spontaneously in ZEO. Mental images die if they do not get metabolic energy feed. In BSFR a large fraction of mental images sub-CD associated with active half of CD disappear since the size of CD decreases in BSFR: this means that new self has

childhood and gets rid of the often negative Karma carried by mental images of the later life which is often painful and filled with unpleasant memories. This also means erasure of unpleasant mental images and liberating also metabolic energy usable by the re-incarnate.

Q2: So, I understand that you are not happy with the behavioristic point of view in this regard. It is OK, however, you have to justify and explain this with an alternative approach. One can represent this as a question. What is the relationship between the behavioristic and TGD views about memories?

A2: Behavioristic picture describes behaviors and learning of them, not episodic memories.

In TGD alll memories as re-experiences (also in symbolicform) correspond to earlier mental images created by say sensory input and continuing to shift towarsgeometric future inside increasing CD and experiencing re-incarnations. If the memory mental images has the same arrow of timeas self, self experiences it as memory mental image.

In TGD the generation of *symbolic* memories as modulations of Josephson radiation frequencies by nerve pulses would correspond to their generation at MB by EEG and its possibly existing fractally scaled up variants as mental images consisting of resonance peaks when the modulated frequency equals to cyclotron frequency of flux tube for some charged particle.

The time scale of the memory is proportional to h_{eff}. Long term memories correspond to rather large values of h_{eff} and to very large layers of MB. The time span of long term memories directly measures the universal IQ as h_{eff} and time and spatial scales of quantum coherence. No memories without dark matter.

In ZEO episodic memory recall would naturally correspond to dark photon signals propagating along closed flux loops back to the brain waking up memory sensory metal images - I almost said "in the brain of the geometric past" but actually it is the brain of geometric future ,where the sensory mental images shift during sequences of SSFRs as CD increases and its upper part shift to the direction of future. When one sends a signal waking up the memory mental images, the latest memory mental images wake up first as the mentione article claims.

Q3: LTP or long-term potentiation means that if an action and or event etc. is repeated, systemic brain and/or neural network and/or a single neuron learn it, and afterwards, cost lesser energy and consume less time to be remembered and/or summoned or practiced. How can one undertand LTP?

A3: Nerve pulse patterns create temporary flux tube networks with flux tubes assignable to axons. Dark photons as carriers of the signals propagate along these. Nerve pulse generation costs metabolic energy. LPT means that the more often the network is created, the easier it is to create it again. This is learning of a habit, not episodic memory.

How to understand LPT in ZEO? Does this living network learn to get the energy needed by nerve pulse patterns by making partial transitions to opposite arrow of time - also nerve pulse is such - making possible extracting it from the environment rather than passively waiting to get it. ZEO would allow the network to become self-sustaining. A habit would develop.

Q4: What about the durations of wake and sleep (ordinary arrow of time and reverse arrow of time): are they equal or not?

A4: The durations of wake and sleep depend on "individual" and depend on the metabolic use: if I use a lot of metabolic energy, I get tired in shorter time and must sleep.

Time reflection is an approximate geometric symmetry of TGD and slightly violated. If the thermo-dynamical reversal of the arrow of time, call it T_{th}, corresponds to T, one can guess that the periods of wake-up and sleep are approximately equal as it seems to be the case in our case. One must be however careful here. There is a rather dramatic violation of CP and therefore T since matter dominates over antimatter in the Universe.

Does one really have $T_{th} = T$? The dark variant of genetic code [L58] is represented by dark proton sequences with 3-protons defining a codon. $T_{th} = T$ would replace protons with antiprotons. This cannot be the case. The assumption is indeed that the change of arrow of time changes roles of the boundaries of CD and those of fermionic creation and annihilation operators and $T_{th} = T$ is not true.

Q5: What the addition of MB means from the point of view of metabolism? What about the metabolism during sleep and wake-up?

A5: The presence of MB means additional sink of metabolic energy. "Getting tired" means that metabolic energy resources deplete. Whose? BB or MB or both?

1. TGD predicts that generalized Josephson radiation from neuronal membranes in EEG range communicates sensory input to the MB [L1, L2]. This happens during wake-up state but not during sleep.

   The flux tubes associated with the Josephson junctions accompanying the lipid membrane-membrane proteins, ion channels and pumps act as sending antennas for dark photons during daytime: what is sent is both sensory information and energy to appropriate parts of MB. The frequency of the generalized Josephson radiation would sum formed from the difference of cyclotron frequencies and ordinary Josephson frequency $f = ZeV/h_{eff}$, where V is membrane potential and giving rise to frequency modulation coding nerve pulse activity representing sensory input. The dark photons at MB would resonantly excite the cyclotron states at flux tubes of the large layers of MB, which would eventually decay and emit dark photon radiation.

   Control actions of MB could occur via the dark variant [L58] of genome realized as sequences of dark proton triplets representing codons and activating the gene expression. Motor actions are assumed to correspond to BSFRs changing the arrow of time for the flux tubes involved. This means that the control signals could actually extract energy from BB. No energy storage at MB would be needed.

   For the simplest option the only new energy storages would be in the length scales of BB and assignable to the cell membrane and genome and identifiable as cyclotron Bose-Einstein condensates analogous to a population inverted laser. For the cell membrane energy storages would be associated with the flux tube portions at the two sides of the cell membrane. For the genome they could be magnetic flux tubes of the dark genome with codons realized as dark proton triplets and accompanying DNA.

   During the wake-up both these energy storages would be depleted by sensory activities and during sleep they would be recharged.

2. The EEG bands above 10 Hz assigned with wake-up state are absent during sleep so that in these bands the energy transfer to MB would occur only during wake-up. The EEG frequencies present during sleep state would correspond to some kind of sensory input to some parts of MB and corresponding motor response. During sleep MB would be awake in longer scales than during wake-up periods.

The challenge of BB is to build these population inverted lasers during sleep - magnetic flux tubes containing charged particles in excited cyclotron states. Dark photon radiation must do this. Where could it come from? Certainly from the molecules responsible for metabolic energy storage but how?

1. Dark photons transform to bio-photons and induce molecular transitions: this makes possible for MB to control the biochemistry.

2. The chemically stored metabolic energy should be transformed to the energy of Bose-Einstein condensates: the energy of these molecules stored to their bonds would be liberated as they return to less energetic states as photons transformed to dark photos.

3. How could this happen? Here ordinary metabolic mechanism would be at work with produced photons transforming to dark photons unless they are dark enough already (increase of h_{eff} might be required). I have proposed that one has $h_{eff} = nh_0 > h$ for the valence bonds and h_{eff} increases towards the right end of the rows of the Periodic Table containing atoms appearing in metabolite molecules [L37]. Molecular transitions during molecular catabolism liberating energy would generate photons and they could be transformed to dark photons with some rate and excite B-E condensates accompanying the Josephson junctions.

   By the fractality of the TGD Universe, a similar mechanism is expected to be a work for ordinary cells but in a scaled wavelength range since the value of h_{eff} is expected to be smaller by the lower evolutionary level: the analog of EEG would be at scaled-up frequency range.

The experimental situation is not yet settled.

1. The mainstream opinion seems to be that the metabolism during sleep is considerably lower than during wake-up. On the other hand, the reduction of energy metabolism during sleep is reported to be surprisingly small [J32]. This would conform with the proposed view about the population inverted cyclotron B-E condensates as an additional energy storage needed by MB.

2. The summary of the introduction [J32] suggests that during NREM sleep the oxidation of glucose is to a some extent replaced by the oxidation of fatty acids and ketone bodies. This would allow roughly similar metabolic rates during sleep and wake-up. The natural guess is that the metabolic energy from these processes is used to excite cyclotron B-E condensates.

   According to [J32] the catabolism of glucose and glycogen via aerobic pathway is a hallmark of wakefulness, whereas the transition to sleep is marked by decreased brain lactate levels due to decreased production as well as increased glymphatic clearance. The rise in the oxygen-glucose index during sleep would not be due to a reduced aerobic glycolysis, i.e. more lactate oxidation, but rather to a shift towards utilization of fatty acids and ketone bodies as metabolites.

   According to the same reference, the FFA passing from circulation to the brain supports ATP production via mitochondrial β-oxidation (~ 60 per cent). Astrocytes are the primary cell type carrying out fatty acid oxidation and ketogenesis in the brain, whereas the concurrent ketosis probably occurs in neurons. The increased plasma levels of FFAs during sleep probably support the metabolic shift to lipid metabolism compared with normal wake-up state.

   Why this shift? The oxidation of glucose and glycogen are fast processes needed by neural activities occurring in a millisecond time scale and would be naturally used during wake-up periods. Oxidation of fatty acids and ketone bodies are slower processes and could be used to replenish the metabolic energy reservoirs utilized during wake-up to the communications of the sensory data to and control responses by MB. During sleep the time scale for the sensory communications to and control responses by MB at slow EEG waves is a considerable fraction of second and the same energy source could be used.

3. In [J32] glucose and lactate levels are reported to be somewhat similar during REM sleep and waking. The levels are the same for some regions of the brain. The partial wake-up of the MB force wakeup of the brain inducing ordinary metabolism in these regions.

   Note that there is empirical evidence that the brain effectively obeys hyperbolic geometry [J38]. The functionally similar neurons in the brain are close to each other in a statistically determined hyperbolic geometry. In the TGD framework the effective hyperbolic geometry could be naturally assigned as a real geometry to the MB of the brain [L89]. The neurons which are functionally similar but possibly far away from each other would send their information along flux tubes to the same part of MB and be near to each other in the hyperbolic geometry. The synchronously firing neurons scattered around the brain and using glucose oxidation could correspond to a region assignable to a mental image corresponding to a connected region of MB.

Q6: Can one formulate these questions within the frame of brain waves (EEG) during wake and sleep? I mean to mention REM and propose some explanations or some answers or some hypotheses do we expect that precognition entails energy cost? Or not?

A6: Ordinary memory recalls require metabolic energy to wake-up memory mental images. Metabolic energy for memory recall by time reversed self looks like a liberation of energy in the standard time direction.

But these memories should be communicated to the self with opposite arrow of time! How? The memory mental images of self with opposite of arrow time can also die and re-incarnate with our arrow of time giving rise to dreams: this would require metabolic energy from our view point. When self forgets, the self with the opposite arrow of time remembers! Dreams and precognition would thus require metabolic energy.

The electromagnetic signals generated by the earthquakes could explain the ability of the native people to predict them several hours before their occurrence. There are also indications

that the perception of different electromagnetic signals impending to an earthquake do not cost any ATP in animals: rather there is possibility that extremely low frequency oscillations (10–70 Hz) may even enhance ATP synthesis during the earthquake in mammals [J59].

The time reversed signal from the geometric future would generate a sensory mental image - sub-self - of the time reversed self. With respect to the arrow of time of the observer this process would liberate energy as the observations indicate. To become an observer's mental image, this sub-self must experience a BSFR. From the observer's point of view this requires metabolic energy. These two contributions to the energy costs are of opposite sign and could also sum up to negative.

Q7: If not, can we consider that the reverse arrow of time is accompanied with negentropy or negative entropy? Why? i.e. if all reverse arrow of time memories or precognitions of the future should correspond with negentropy?

A7: Generalized form of the second law applies to subjective time and states that the entropy increases with respect to the subjective time always. It increases also in the reverse arrow of time but to us in wake-up state it looks like decrease: as if negentropy were generated. For us the system indeed seems to develop ordered structures, to self-organize - rather than losing them as ordinary second law would dictate. Self-organization can be forced by feeding energy to the system or system can have subsystems with non-standard arrow of time extracting energy from the external world by dissipating. This could be a self-sustaining order. It might relate to self-organized criticality which is a concept not well-understood. Systems are able to stay around critical state, which conflicts intuitive picture. TGD Universe is actually quantum critical.

Q8: What about dreams that already happened in our life and we already have experienced them? For example, consider that Person A has divorced his life two years ago at 2018. On 2020, He may have dreamt that he has divorced his wife. Does such a situation entail an energy cost? The energy is not important per se here, but the physical meaning of such a question is of worth for future implications.

A8: If dreams are wake-up of some regions of the sleeping brain creating mental images then they require metabolic energy.

Chapter 7

Sensory Perception and Motor Action as Time Reversals of Each Other: a Royal Road to the Understanding of Other Minds?

7.1 Introduction

This article was motivated by article in Quanta Magazine (see `http://tinyurl.com/y8a4puca`) telling about the work of David Poeppel and his student Florencia Assaneo.

7.1.1 Poeppel's criticism of neuro-computationalism

The article inspired the reading of the article "*Neuroscience Needs Behavior: Correcting a Reductionist Bias*" of Poeppel *et al* [J51] (see `http://tinyurl.com/ybeeetr6`) criticizing the computational theory of behavior assuming that behavior reduces to an algorithm analogous to computer program, the software, implemented by neural circuit serving as a hardware.

Poeppel mentions as an example of Caenorhabditis elegans, the roundworm that is one of the most studied lab animals. This animal has only 302 neurons and its neural circuitry is known very precisely as also its full genome. Despite this there is no understanding about what the algorithm encoding the behavior is and how the neural circuitry implements it. Something is missing.

More generally,o ne cannot deduce the behavior of even simple animals from the neural circuitry regarded as computer. Several programs can give rise to the same behavior or same circuitry to several behaviors. The deduction of hypothetical algorithm from behavior is impossible. Poeppel mentions also an experiment in which one tried to deduce from the behavior of the computer game characters the algorithm behind the game for three games. The attempt failed. This finding can be also seen as a failure of behaviorism not anymore a leading dogma in neuroscience anymore since even simple creatures like Caenorhabditis elegans refuse to believe like doorbells.

From the philosophical point of view the failure of reducing behavior to a deterministic algorithm is obvious to me. There is a thing called free will and round worm is not a deterministic computer. One could model its basic behavioral patters using computer programs as analogs but the choice, which program is run involves free will, and one must construct theory of consciousness allowing free will as something consistent with physics. This requires going beyond the recent view about physics.

Poeppel mentions as an example the determination of the direction of a sound source. Depending on the direction sound signal arrived to ears at different times. This can be used as data allowing to deduce the direction of the sound source. There are however several other algorithms for deducing the direction of the sound source.

There is also philosophical criticism. One assumes that there is a small homunculus inside brain able to write computer programs and implement them. This bit virtuoso has found from

some text book of physics a formula allowing to determine the direction of the sound source from the time lag between ears and then has written a computer code and implemented it. But how this tiny computer programmer can achieve this?: obviously it must have a tiny computer programmer inside. One ends on with infinite hierarchy of computer programmers inside computer programmers - infinite regress.

How to get rid of this hierarchy of homunculi? Could quantum physics alone with measurement theory extended to a theory of consciousness by making observer a part of physical system be enough to define and understand behaviors. No model for the physical world but just the physical world itself. This requires however new physics in which notions like behavior, intentionality, goal directedness, and memory have a well-defined meaning. All this notions refer to time or time evolution somehow. In standard physics quantum states are however time=constant snapshots so that going beyond standard quantum physics seems to be unavoidable.

Poeppel also talks about a hegemony of methods reducing neuroscience to the study of neurons and forgetting behavior and studying only neural circuits. Poeppel argues that one should start from behaviors, study them in detail and only after that start to study algorithms and neural circuits as possible way - not necessary correct way - to realize behaviors. One should also consider neuron groups besides neurons. The recent trend is however just the opposite: there is even an attempt to reduce behavior to the molecular biology in accordance with nothing-but-chemistry paradigm.

The coherent behavior of neuron groups manifesting itself as synchronous firing of neurons would be the natural starting point. Here one encounters EEG. EEG correlates both with the state of brain and contents of consciousness. Why brain should use large amounts of metabolic energy to communicate information to outer space? Just for fun? Biology does not waste metabolic energy. What is the purpose of this action bringing in mind communication? Who is the receiver? This question has led to a considerable progress in TGD framework [K24, K59] by applying the new physics predicted by TGD [L52].

A further important inspiration for this article came from learning of the basic facts about the notion of mirror neuron (see `http://tinyurl.com/d6svmf7`) briefly discussed in the first article of Poeppel *et al* [J51]. The notion of mirror neuron is extremely attractive because it could allow automatic understanding of the observed goal directed behaviors of living systems. Sensory input about behavior would generate automatically the imagined or even real motor action in some cases and there would be no need for the attempt to understand why sensory input about behavior can be associated to a neural activity representing intention about behavior or imagined behavior.

Mirror neuron hypothesis was deduced by studying macaque monkeys and generalized to higher behaviors of humans without testing it at neuron level since this was not possible ethically. The essential assumption is that understanding reduces to single neuron responses. Synchoronous neural firing is involved and therefore also EEG waves, whose real function is not known, are involved so that this kind of reductionism need not be realistic. One can also ask how neurons learn to be mirror neurons: could mirror neuron activity be understood in terms of sensory-motor associations.

The list of the proposed applications to humans is impressive: understanding intentions, imagination, learning facilitation, learning by imitation, automatic imitation and intentional motor mimicry, understanding and learning of language, empathy, autism, theory of mind, human self awareness. Also not so obvious applications such as understanding of gender difference, sleep paralysis - disinhibition of mirror neuron system, hallucinations, and empathy characterizing schizophrenia. One can however argue that mirror neuron hypothesis is not realistic in its strong form stating that observed behavior (bodily motor action) active mirror neurons, which induce the motor action.

The proposed applications of mirror neuron hypothesis in its strong form lead to many inconsistencies. Poeppel mentions [J51] what he calls merological fallacy: psychological properties assignable to entire organism are assigned to single neuron. Behavior is used to deduce hypothesis that mirror neurons understand - a more realistic approach would rely in neuron groups and this again brings in EEG and the questions raised by its unknown function. There are critical articles about mirror neurons describing in detail various failures [J72, J84, J64] (see `http://tinyurl.com/y7jqljwv`, `http://tinyurl.com/y8pelhhl`, and `http://tinyurl.com/y7vhyfe6`). The most intriguing anomalies from TGD point of views relate to time anomalies: mirror neurons would act too fast, considerably faster than simple estimates based on the rate of nerve pulse conductions and neural information processing allow.

7.1.2 Brain wave synchrony between brain regions related to speech understanding and speech production

The popular article (see `http://tinyurl.com/y8a4puca`) that inspired this article mentioned also an article [J57] (see `http://tinyurl.com/y79r62v9`) by David Poeppel and his student Florencia Assaneo. The frequency f for syllables of understandable speech varies between 2 and 7 Hz and the average frequency of the syllables in various languages is about 4.5 Hz. Auditory region related to the understanding of speech - Wernicke's area - entrains with the frequency for the rate for syllables in the range 2-7 Hz.

The discovery was that speech motor region - Broca's area- at opposite brain hemisphere - entrains with the auditory region in the range 4-5 Hz and resonance occurs around 4.5 Hz. Therefore the synchronous firing and associated brain waves could play an essential role in the understanding of speech. The interpretation could be that the speech input at these frequencies generates internal speech as imagined motor action not propagating to the level of speech organs (usually).

7.1.3 Time mirror relation and mirror neuron hypothesis

TGD based model for behavior and also mirror neurons relies on TGD inspired theory of consciousness [L42] in which zero energy ontology (ZEO) plays a crucial role. ZEO predicts that the arrow of time can vary and indeed does so in living matter. A natural conjecture is that sensory perception and motor action are time reversals of each other so that motor action would be sensory perception in reverse time direction. Sub-selves of self - mental images - would form an analog of monad network introduced by Leibniz long time ago. They would however reflect each other time direction rather than spatial directions: ...-sensory-motor-sensory...

Time mirror hypothesis explains surprisingly many time-related anomalies in living matter and neuroscience such as the classical discovery of Libet [J18] that neural activity precedes conscious decision by a fraction of second: physicalistic explanation would be forced to give up free will. The study of mirror neurons has revealed further anomalies of this kind: in particular, mirror neurons react much faster than the estimates based on the conduction velocities of nerve pulses and the rates of information processing in brain would suggest. If motor action is sensory perception in reversed time direction, one could get rid of these anomalies. Quite generally, sensory perception of B by A and its time reversal as motor action would be fundamental building brick in conscious information processing and would allow to use memory storages in geometric past to generate planned responses in much shorter time than velocities of nerve pulse conduction would suggest.

Besides the sensory-motor duality as time reversal, the TGD based view about space-time and classical fields predicts that any system has field identity - field body or magnetic body (MB) and that MB can be seen as an intentional agent using biological body as a sensory receptor and motor instrument. A further piece in TGD story is the identification of dark matter as a hierarchy of phases of ordinary matter labelled by the value of $h_{eff} = n \times h_0$ of effective Planck constant and residing at MB. In this framework the observed entrainment of left and right language regions around 4.5 Hz can be seen as additional support for the idea that EEG is involved with communication from brain to MB possessing a hierarchical onion-like structure corresponding to analogs of EEG at in various frequency ranges.

This vision allows to build a model of sensory memories with motivation coming from the findings [J37] challenging the standard view about them. This model in turn inspires a very general model of motor action applying also to basic biochemical processes such as transcription, replication, and translation as being induced by topological quantum computer programs running in non-standard time direction.

7.2 TGD based model for sensory-motor consciousness

TGD based model for sensory-motor consciousness relies on the hypothesis that sensory perception and motor action are time reversals of each other. Second assumption is that sensory percept and therefore also motor action is constructed by an iterative process involving forth-and-back

communications by dark photons between sensory areas and sensory organs at which sensory qualia are assigned in TGD framework (this is possible assuming ZEO based view about time). The outcome of this iteration is standardized mental image as near as possible to the sensory input picking up only the features relevant for survival.

This process could correspond to single sub-self representing mental image and communications in single direction of geometric time. A more general view is that this process corresponds to a sequence of this kind of iterations as sequence of re-incarnations of mental images so that communications in both directions of time would be involved. The prediction is that sensory consciousness is not a continuous stream but contains black spots.

7.2.1 Basic ideas of TGD related to consciousness and biology

It is good to start by listing the basic assumptions of TGD inspired quantum theory of consciousness and of biology.

MB is central for TGD inspired biology.

1. A first key notion appearing at the level of TGD inspired quantum biology is due to the differences between Maxwellian and TGD based view about classical em fields. In Maxwellian world the em fields of separate systems superpose and the information is lost much like in the formation of sum 7= 3+4: one does not know whether '7' is the outcome of 7+0, 6+1,5+2, or 4+3. Now one does not know what the fields in the superposition are. In TGD framework many-sheeted spacetime stores the information since the fields of given system are at their own space-time sheets defining field identity, field body or MB.

   MB has hierarchical onion-like structure corresponding to different lengths scales. The communications from biological body to EEG and vice versa are possible by the generalization of EEG. Josephson radiation assignable to cell membrane mediates information about sensory input and MB controls BB by using cyclotron radiation as a tool.

   One can say that MB serves as an intentional agent using biological body as a sensory receptor and motor instrument. Biochemistry would be controlled by MB and represent a kind of shadow dynamics. The MB of DNA is conjectured to realize genetic code in terms of dark proton sequences with entangled state of 3 protons defining genetic codon. Similar picture applies also to other basic biomolecules. This encourages the hypothesis that inheritance is basically realized at the level of MB and genes code for 4-D dynamical patterns - biological functions - rather than only for 3-D structures.

2. MB can be seen as 4-D entity rather than 3-D object. The biological interpretation of 4-D MB would be as the classical correlate for behavior. In WCW picture the second end of MB at the active boundary of CD cannot be fixed like the end at the passive boundary to single state. For the cognitive representations with finite measurement resolution to be discussed below this could be the case so that one could speak of unique classical space-time in fixed measurement resolution in accordance with everyday thinking. In fermionic degrees of freedom one cannot fix the state at active boundary.

   MB is preferred extremal of the action and satisfies extremely powerful additional conditions so that it represents kind of archetypal field pattern. 4-D MB is also analogous to a computer program and the superposition of time evolutions of MB could be regarded as quantal computer program running. State function reductions as acts of free will put a new program running.

Adelic physics is second central part of TGD.

1. Number theoretic vision about physics - adelic physics [L39, L40] leads to the hypothesis about hierarchy of effective Planck constants $h_{eff} = n \times h_0$ defining a hierarchy of phases of ordinary matter identified as dark matter. n corresponds to the dimension of extension of rationals and for Galois extensions to that of Galois group. The larger the value of n, the larger the maximal value of p-adic entanglement negentropy so that n serves as a kind of IQ. The energies of quantum states as function of n increase and the increase of n requires a feed of metabolic energy.

2. The preferred p-adic primes p are tentatively identified as ramified primes for which the ordinary primes do not decompose to a maximal number of primes of extension but there are less than the maximum number of them and some primes occur several times. There is a direct analogy with the decomposition of polynomials to a product of monomials. At criticality some roots co-incide and power of monomial appears. The natural interpretation would be in terms of quantum criticality.

3. p-Adic length scale hypothesis [K46] emerged via p-adic mass calculations already before I had not realized that p-adic physics is an excellent candidate for the physics of imagination, intention, and cognition and is in central role in concrete applications. For instance, the length scale range between 10 nm and 2.5 μm especially relevant for biology contains four Gaussian Mersenne primes - this is a number theoretical miracle [K37].

4. In adelic physics imagination would correspond to the failure of strict determinism of p-adic differential equations due to the existence of p-adic pseudo constants - functions depending on finite number of pinary digits but having vanishing derivative. The challenge is to find concrete examples in which this p-adic vision about cognition, imagination, and intention is be realized. The challenge is not easy since p-adic number fields represent mathematics completely new for even physicists.

TGD inspired theory of consciousness [L42] relies on zero energy ontology (ZEO).

1. ZEO based theory of quantum measurement allowing to solve the basic paradox of the standard quantum measurement theory make observer part of the physical. The nondeterministic causality of free will and deterministic causality of unitary time evolution and of classical field equations are not in conflict anymore. The basic outcome is the notion of self as a conscious entity.

   Causal diamond (CD) and zero energy state are the key notions of ZEO. Zero energy state is a superposition of pairs of ordinary quantum states at opposite boundaries of CD with members having opposite total quantum numbers to guarantee classical conservation laws for the time evolutions connecting the members also classically. These pairs are analogous to events with members of zero energy state defining analogs of initial and final state of both classical and quantal time evolution.

2. Evolution of self can be seen as a sequence of unitary evolutions leaving the passive boundary of CD and members of states at it unaffected but inducing dispersion of the active boundary in the moduli space of CDs. This is followed by "small" state function reduction defining an analog of weak measurement (see `http://tinyurl.com/zt36hpb`) inducing localization of the active boundary of CD in the moduli space, in particular meaning measurement of clock time identified as temporal distance between the tips of CD. As a consequence, the size of CD increases at least in statistical sense and this is experienced as flow of time.

   The process eventually stops since one expects that all observables are eventually measured and further time evolution would require extension of rationals involved if one wants that the eigenstates of density matrix are still in the extension. The proposal is that the extension cannot increase in "small" state function reduction. Next step is "big" state function reduction as analog of ordinary state function reduction in which the roles of boundaries of CD are changed. Self dies and reincarnates in opposite time direction and CD starts to increase in opposite time direction.

3. Since deterministic time evolution of state replaces time= constant snapshot as a basic notion, this leads to a new view about geometric time and its relation to experienced time: one can speak about 4-D brain, about signalling in both time directions, a new view about memory emerges, and various time anomalies such as that found by Libet [J18] find an explanation.

4. Motor action as time reversal sensory perception is a conjecture made for years ago. The challenge is to find support for the hypothesis. In this article this hypothesis is studied in more detail and the generalization of mirror neuron hypothesis to time mirror hypothesis is proposed. This generalization would apply to any conscious entity and one could see all conscious entities perceiving each other and interacting as kind of Leibniz monads time mirroring each other.

7.2.2 Challenging ZEO and CDs

In order to proceed it is best to not forget to invent objections against the the new assumptions. The notion of ZEO and CD are the certainly such notions.

There are critical questions related to the definition of the hierarchy of CDs.

1. What determines CD? Somehow the space-time dynamics should do it without any ad hoc assumptions. There are indeed strong indications from $M^8 - H$ correspondence, that CDs emerge naturally from the properties of octonionic polynomials [L33].

   For instance, 8-D Poincare transformation generate different octonion structures and time axis as real axis for octonions must contain the tips of CD. The preferred octonionic coordinates are highly unique and allow only the rotations leaving time axis defining the rest system invariant. Poincare symmetries are real symmetries but change the octonion structure. If the definition of octonion structure involves also the preferred associative subspace as $M^4 \subset M^8$ and the choice $M^2 \subset M^4$ as preferred commutative sub-space, the coordinates are highly unique as required by the number theoretic vision. This uniques corresponds to uniqueness at the level of H.

2. Do space-time surfaces continue beyond CD or do they have naturally ends at boundaries of CD? For instance, could it happen that all the roots for the octonionic polynomials become complex outside CD so that one cannot have real roots. If one requires that space-time surface corresponds to real root rather than projection to a real sub-space of M^8 this cold force CDs. Why the ends would be M^4 light-cones (with points replaced with CP_2? Twistor Grassmann approach [K26, L41] suggests that CDs can contain sub-CDs connected by the analogs of lines of twistor diagrams and represented as 4-surfaces representing mass shall particles in complex sense and having minimal surfaces as space-time correlates.

3. Can CDs intersect and overlap and how to describe this mathematically at space-time level? What would be the physical interpretation for the overlap?

One can also invent criticism related to conscious experience.

1. CDs would represent kind of spot-light of consciousness defining 4-D perceptive field of sub-self. The size of CD increases reduction by reduction at least in statistical sense. Sub-selves of self would correspond to mental images and have sub-CDs as embedding space correlates.

   The intuitive idea is that mental images can appear and disappear. Does this mean that sub-CDs can also appear and disappear in some sense? Is this natural mathematically?

   Conservation laws force the total quantum numbers at its opposite boundaries to be opposite. The analogy of zero energy state in QFT would be vacuum fluctuations. The CD and corresponding zero energy state would obey the usual evolution giving rise to self. If CD of finite size has vacuum quantum numbers at its both boundaries, its creation from vacuum is allowed by conservation laws. Is this kind of zero energy state for any CD equivalent with having no CD at all? If so then the disappearance of mental images is possible if the mental image contains in its wave function also vacuum-vacuum part carrying no information.

2. It has been assumed that CDs increase monotonously in size during the sequence of "small" state function reductions giving rise to self as a generalized Zeno effect. The assumption about monotonic increase of size is however un-necessarily strong. The reason is that in the moduli space of CDs (determined by the action of Poincare group and size scale of CD) the number of CDs larger than given CD is infinitely larger than those with smaller size so that in statistical sense CD is bound to increase.

3. What about sub-selves of given self? Is self conscious also about its sub-selves with an opposite arrow of time? If one looks at lamp and closes eyes, one finds that the after image appears and disappears periodically. If this corresponds to a periodic re-incarnation of sub-self, the sub-selves with opposite time orientation would not be experienced as mental images by self. The interpretation of sensory percept in opposite time direction as a motor action would make the absence of after image natural.

4. The idea that big state function reductions take place when the density matrix has eigenvalues not belonging to the extension of rationals defining the entanglement coefficients is very attractive number theoretically but can be claimed to be somewhat ad hoc.

7.2.3 ZEO based model for sensory-motor consciousness

Let us summarize the ZEO based view about sensory-motor consciousness.

1. Quantum jumps between superpositions of temporal patterns define selves and therefore also mental images in ZEO. Consciousness is in the quantum jumps - between initial and final worlds - rather than in the world itself so that consciousness is not a property and one should not use "-ness" of physicalist.

   That visual consciousness fades if the pupil is not in saccadic motion relative to the visual field conforms with the prediction that consciousness in the quantum jump replacing the quantum world with a new one.

2. Motor action is identified as time reversal of sensory perception. The interpretation in standard direction of time is as a motor response. During this period there would be not sensory consciousness. The phenomenon of after images supports the vision about sequence of re-incarnations of mental images as sub-selves. Even the prediction of re-incarnation, which certainly tests the patience of physicalist, finds direct support. The temporary absence of after image correspond to an after image living in opposite direction of time and having interpretation as motor action. The mental images with time direction opposite to that of self would not be consciously experienced.

3. In the model proposed earlier [L32] sensory mental images are produced by iteration in which signals travel forth and back between sensory organ and brain (and even MB and sensory organ) and the virtual sensory input adds to the real one to generate standardized mental images containing only the features relevant for survival. This would be essentially pattern recognition, finding the standard mental images nearest to the sensory input by using virtual sensory input.

   The signalling is by dark photons - nerve pulses would be quite too slow for this purpose and they would only generating communication pathways - kind of wave guides - by building transmitter bridges connecting pre- and post-synaptic neurons. The flux tubes of MB would accompany axons and dark photons would propagate along them.

4. One can ask whether the forth-and-back communication is in a fixed direction of time or whether the time direction varies so that one would have a sequence of re-incarnations for mental images: ...-sensory-motor-sensory-...

   It must be emphasized that each step between two time reflections involves a sequence of unitary evolutions followed by weak measurements, and that this period could involve forth and back communications between sensory organ and say brain with single direction of time. Therefore both mechanisms could be involved. One can also argue that the virtual sensory input should contain the component in the standard time direction. If it were in the opposite direction of time only, it is not clear whether it could superpose with the ordinary sensory input.

   The sensory input in opposite time direction is free from the limitations posed by the finite conduction velocity of nerve pulses and light-velocity. In principle, time travel to the layers of MB in distant past providing information about memories could contribute to the eventual motor response. Also now time would grow in the sense that the size of CD grows in statistical sense at least.

   One could also speak of pattern recognition in 4-D sense at classical level. For cognitive representations in terms of common points of real and p-adic space-time surfaces (belonging to an extension of rationals) there could be a complete localization in the "world of classical worlds" (WCW) to a discretized space-time surface. Actually this would be only localization modulo finite measurement resolution.

5. This picture would apply as such to motor action. Also motor action would be generated by a similar sequence using virtual sensory input in opposite time direction to reach standard motor output. Also sensory and motor imagination can be understood in this framework as also hallucinations and psychedelic experiences [L11].

6. The basic prediction is gaps in sensory (say visual) consciousness due to the motor actions inducing a motion of sensory organ or part of it, say pupil. By looking at mirror anyone can indeed verify that eye cannot see the motion of pupil. A general qualitative implication would be that the performance on motor action is optimal when sensory input is minimal and vice versa. It is known that sensory consciousness is not continuous but contains black spots.

   It is known that during attention shift visual consciousness is lost (see `http://tinyurl.com/ych6atb6`), and since saccadic motion means shifting of attention, one can argue that visual awareness is lost during the motion of pupil.

   Saccadic motions (see `https://en.wikipedia.org/wiki/Saccade`) induced by an unexpected stimulus normally take about .2 seconds to initiate, and then last from about 20–200 ms (20–30 ms is typical in language reading). The estimate for the duration of the sensory mental image is about .1 seconds as cronon of sensory subjective time. If the unexpected stimulus emerges during visual mental image it does not affect it since attention is not directed towards it yet. Mental image must die and re-incarnate in reversed time direction as motor action inducing saccadic motion. After that reincarnation in the original time direction as visual mental image would occur. This would take about .2 s at least.

   Attention blinking (see `https://www.verywellmind.com/what-is-attentional-blink-2795017` is an analogous phenomenon. The subject person perceives a rapid series of numbers in monitor and is asked to report when she sees numbers 2 and 7 in successions. It turns out that if the numbers follow each other within time interval about .5 seconds, the subject does not notice their appearance. This suggests that the duration of sensory percept is about .5 seconds and longer than the time scale about .1 seconds providing estimate for the lifetime of visual mental image. A hierarchy of time scales is predicted and attention blinking would correspond to a considerably longer time scale in the hierarchy.

Pieces of evidence for this vision emerge from various time anomalies of consciousness.

1. Libet's findings [J18] about neural activity preceding conscious decision are so familiar that there is no need to repeat them. The reaction times of boxers are of order 60 ms and are too fast to be understood in terms of neuroscience. Penrose has also described similar strange findings in the case of tennis players. There are also strange findings in the case of mirror neurons. All these findings can be understood if motor action is sensory perception in reversed time direction.

2. The observed de-synchrony of motor neurons after motor action came as a news to me. Synchrony is identifiable as a correlate of quantum coherence at the level of MB controlling the neurons. It has TGD based interpretation in terms of "big" state function reduction changing the roles of motor neurons and of motor organs. Motor organs become quantum coherent passive boundary of CD and neuronal end of CD becomes active boundary and ceases to be in synchrony.

Motor action as a time reversal of sensory percept inspires fascinating ideas [L11] [**?**, K80, K61, K35] about communications with geometric past since light-velocity ceases to be a limiting factor and one can visit in distant past. TGD based vision about memories indeed is that the geometric memories are in geometric past, in principle where the events first happened. It is of course possible possible and useful to construct copies of the memories and active memorizing by repeated memory recalls would be one form of learning.

In this picture sensory percept would be followed by a visit to geometric past or even sequences of visits forth and back to rummage memories. Only the time lapse assignable to the increase of the size of CD would pose limits on the time used. This might revolutionize the picture about sensory and motor consciousness.

7.2.4 p-Adic physics as correlates of imagination, cognition, and intention

The idea that p-adic physics could provide physical correlates of imagination, cognition, and intentionality is very attractive. The challenge is to formulate in more concretely and perhaps even find direct applications in neuroscience.

Imagination, intention, cognitive representations and real world

p-Adic preferred extremals involve p-adic pseudo constants having vanishing derivative by definition and depending on finite number of pinary digits. For p-adic extremals having interpretation as real preferred extremals the pseudo constants become genuine. Imagination is realized when p-adic pseudo constants are possible.

1. This inspires the general idea is that motor action is generated by a repeated trial and error procedure in which p-adic variant of the preferred extremal is replaced by a more realistic one. The real counter part of p-adic preferred extremal would increase in size scale and eventually connect both boundaries of CD and define a realization of intention as action. I have compared this process to building a four-dimensional statue starting from a rough sketch.

2. One has two interpretations for what this could mean at the level of motor system. Motor action as time reversal of sensory action would suggest that the process begins from muscles as time reversed sensory signal providing a rough sketch of the motion and is reflected back if the completion to full real extremal fails and followed by a new trial. The process would be repeated until full realization would be achieved. In standard direction of time motor action would begin from brain as neuroscience pictures it or even MB. This would conform with the fact that we experience the motor action as starting from muscles rather than brain. The intuitive picture that MB controls brain rather than muscles conforms with the idea of motor action as time reversed sensory perception.

   A similar description would apply to sensory perception in standard time direction. The forth-and-back iteration as trial and error process would proceed gradually to higher and higher levels in the hierarchy starting from sensory organ and continuing via primary, secondary and tertiary sensory areas and eventually possibly reaching MB via EEG.

There are several descriptions for this completion process giving rise to a full perception or motor action via trial and error process.

1. Continuum picture is based real and p-adic space-time surfaces. Here the notion of "world of classical worlds" (WCW) is essential [K63]. At this level strong form of holography (SH) allows a formulation of the idea about completion of intention to action. One can assign data to 2-D surface and continue so that it gives 4-D space-time surface by strong form of holography.

   In p-adic case this is easy by the existence of p-adic pseudo constants. In the real case the continuation need not be possible. If p-adic pseudo constants can be chosen to be genuine constants then the realization of imagination and intention is realizable.

2. Second view is based on discrete cognitive representations as intersection of p-adicities and reality [L39, L40]. One assigns to real and p-adic preferred extremals common points having coordinates in the extension of rationals considered. The symmetries of the embedding space allow very restricted class of preferred coordinates so that problems with general coordinate invariance can be overcome. This set of points is discrete and perhaps even finite set.

3. $M^8 - H$ duality provides a third view. One must complexify M^8 so that one has complexified octonions M^8_c. This means the addition of imaginary unit i commuting with octonionic imaginary units. The vanishing of real or imaginary part of octonionic polynomial in quaternionic sense ($o = q_1 + Jq_2$) defines the space-time surface. Octonionic polynomial itself is obtained from a real polynomial by algebraic continuation so that in information theoretic

sense space-time is 1-D. The roots of this real polynomial fix the polynomial and therefore also space-time surface uniquely. 1-D line degenerates to a discrete set of points of an extension in information theoretic sense. In p-adic case one can allow p-adic pseudo constants and this gives a model for imagination.

The roots $x + iy$ of the real polynomial need not however be real. There are two options.

(a) I have proposed in [L33, L35] that the *projection* from M^8_c to real M^4 (for which M^1 coordinate is real and E^3 coordinates are imaginary with respect to i!) defines the real space-time surface mappable by $M^8 - H$ duality to CP_2.

(b) An alternative option, which I have not considered in the original versions of [L33, L35] is that only the roots of the 4 vanishing polynomials as coordinates of M^4_c belong to M^4 so that m^0 would be real root and m^k, $k = 1, ..., 3$ imaginary with respect to $i \to -i$. M^8_c coordinates would be invariant ("real") under combined conjugation $i \to -i, I_k \to -I_k$. In the following I will speak about this property as *Minkowskian reality*. This could make sense. Outside CD these conditions would not hold true. This option looks more attractive than the first one. Why these condition can be true just inside CD, should be understood.

4. The first two approaches would be equivalent if $M^8 - H$ duality defines the cognitive representations as roots of polynomials. The use of polynomials or rational functions could be also an approximation. Analytic functions of real variable extended to octonionic functions would define the most general space-time surfaces but the limitations of cognition would force to use polynomial approximation. The degree n of the polynomial determining also $h_{eff} = nh_0$ would determine the quality of the approximation and at the same time the "IQ" of the system.

Consider now the third approach in more detail.

1. One argument against number theoretic vision is that it breaks general coordinate invariance since the choice of cognitive representation depends on the choice of embedding space coordinates. At level of M^8 this objection can be circumvented since the choice is highly unique. 8-D Poincare transformations generate different octonion structures and time axis as real axis for octonions must contain the tips of CD. The preferred octonionic coordinates are highly unique and allow only the rotations leaving time axis defining the rest system invariant. Poincare symmetries are real symmetries but change the octonion structure. Since the definition of octonion structure involves also the preferred associative subspace as $M^4 \subset M^8$ and the choice $M^2 \subset M^4$ as preferred commutative sub-space, the coordinates are highly unique as required by the number theoretic vision. This uniqueness induces uniqueness at the level of H.

2. One can think of starting from one of the 4 vanishing conditions for the components of octonionic polynomial guaranteeing associativity. Assuming real roots and continuing one by one through all 4 conditions to obtain 4-D Minkowskian real regions. The time coordinate of M^4 coordinates is real and others purely imaginary with respect to $i \to -i$. If this region does not connect 3-D surface at the boundaries of real CD, one must make a new trial.

   Cusp catastrophe determined as the zero locus of third order polynomial provides an example. There are regions with single real root, regions with two real roots (complex roots become real and identical) defining V-shaped boundary of cusp and regions with 3 real roots (the interior of the cusp).

3. The restriction of the octonionic polynomial to time axis m^0 identifiable as octonionic real axes is a real polynomial with algebraic coefficients. In this case the root and its conjugate with respect to i would define the same surface. One could say that the Galois group of the real polynomial characterizes the space-time surface although at points other than those at real axis (time axis) the Galois group can be different.

   One could consider the local Galois group of the fourth quaternionic valued polynomial, say the part of quaternionic polynomial corresponding to real unit 1 when other components are

required to vanish and give rise to coordinates in $M^8 \subset M_c^8$ - Minkowskian reality. The extension and its Galois group would depend on the point of space-time surface.

An interesting question is how strong conditions Minkowskian reality poses on the extension. Minkowskian reality seems to imply that E^3 roots are purely real so that for an octonionic polynomial obtained as a continuation of a *real* polynomial one expects that both root and complex conjugate should be allow and that Galois group should contain Z_2 reflection $i \to -i$. Space-time surface would be at least 2-sheeted. Also the model for elementary particles forces this conclusion on physical grounds. Real as opposite to imagined would mean Minkowskian reality in mathematical sense. In the case of polynomials this description would make sense in p-adic case by allowing the coefficients of the polynomial be pseudo constants.

4. What data one could use to fix the space-time surface? Can one start directly from the real polynomial and regard its coefficients as WCW coordinates? This would be easy and elegant. Space-time surface could be determined as Minkowskian real roots of the octonionic polynomial. The condition that the space-time surface has ends at boundaries of given CD and the roots are not Minkowskian real outside it would pose conditions on the polynomial. If the coefficients of the polynomial are p-adic pseudo constants, this condition might be easy to satisfy.

The situation depends also on the coordinates used. For linear coordinates such as Minkowski coordinates Minkowskian reality looks natural. One can however consider also angle like coordinates representable only in terms of complex phases p-adically and coming as roots of unity and requiring complex extension: at H-side they are very natural. For instance, for CP_2 all coordinates would be naturally represented in this manner. For future light-cone one would have hyperbolic angle and 2 ordinary angles plus light-cone proper time which would be real and positive coordinate.

This picture conforms with the proposed picture. The point is that the time coordinate m^k can be real in the sense that they are linear combinations of complex roots, say powers for the roots of unity. $E_c^4 \subset M_c^8$ could be complex and contain also complex roots since $M^8 - H$ duality does not depend on whether tangent space is complex or not. Therefore would could have complex extensions.

7.3 TGD view about mirror neurons

Mirror neurons provide an application for the TGD view about sensory-motor activity replacing mirror neuron hypothesis with time mirror hypothesis.

7.3.1 Basic facts about mirror neurons

A mirror neuron (see `http://tinyurl.com/d6svmf7`) is a neuron that fires both when an animal acts and when the animal observes the same action performed by another. Mirror neurons were discovered by studying macaques: the inferior frontal gyrus (region F5) and the inferior parietal lobule were found to contain them. Mirror neurons are motor neurons firing when the animals perceives visually motor action and also when animal itself generates a goal directed motor action. 10 per cent of neurons in inferior frontal and inferior parietal cortex of macaques are mirror neurons. The mirrored motor actions could correspond to heritable genetic factors.

Such neurons have been directly observed in some primate species. Birds have been shown to have imitative resonance behaviors and neurological evidence suggests the presence of some form of mirroring system. For ethical reasons the testing of the hypothesis is not possible at neuronal level for humans and other methods such as fMRI must be used. Bain activity consistent with that of mirror neurons has been however found in inferior frontal cortex, premotor cortex, supplementary motor area, the primary somatosensory cortex and the superior parietal lobe.

The function of the mirror system in humans is a subject of much speculation. Some researchers in cognitive neuroscience and cognitive psychology consider that this system provides the physiological mechanism for the perception/action coupling (see the common coding theory). They argue that mirror neurons may be important for understanding the actions of other people, and for learning new skills by imitation. Some researchers speculate that mirror systems may simulate observed actions, and thus contribute to theory of mind skills, while others relate mirror

neurons to language abilities. Neuroscientists such as Marco Iacoboni (UCLA) argue that mirror neuron systems in the human brain help us understand the actions and intentions of other people. In a study published in March 2005 Iacoboni and his colleagues reported that mirror neurons could discern whether another person who was picking up a cup of tea planned to drink from it or clear it from the table. In addition, Iacoboni has argued that mirror neurons are the neural basis of the human capacity for emotions such as empathy.

In humans mirror neurons would be involved in action knowledge, imitation and pantomime interpretation (not possessed by adult monkeys), and biological motion perception. Supplementary motor area and medial temporal cortex would be also involved. In the case of language interpretation possibly as internal speech speech motor region - Broca's region proposed to be a homologue of monkeys ventral premotor cortex, and Wernicke's are in opposite brain hemisphere responsible for speech perception are especially interesting.

Many functions for mirror neurons have been suggested and some of the are not consistent with what has been found in monkeys or have not been found in monkeys. The list of the proposed applications to humans is impressive: understanding intentions, imagination, learning facilitation, learning by imitation, automatic imitation and motor mimicry, understanding and learning of language, empathy, autism, theory of mind, human self awareness. There are also not so obvious applications such as understanding of gender difference, sleep paralysis - disinhibition of mirror neuron system, hallucination, and empathy characterizing schizophrenia. Mirror neuron hypothesis is however criticized as being too limited in its basic form stating that the strong form stating that observed behavior (bodily motor action) activates mirror neurons, which induce the motor action.

7.3.2 Time mirror mechanism as TGD counterpart of mirror neuron hypothesis

Time mirror hypothesis is a natural generalization of mirror neuron hypothesis in TGD framework. The two systems would to correspond to opposite ends of CD and in big state function reduction their roles would change.

When two systems can be in time mirror relationship?

When two systems can be in time mirror relationship?

1. Speech and its understanding are in very special role as also the results of Poeppel and his student [J57] show. In TGD framework the time mirror relationship would be between the brain regions involved with the understanding of speech at and those involved with speech production at the opposite hemisphere.

2. The model for the generation of sensory percept as a forth-and-back communication between sensory organ and brain (or even MB) involving dark photon signals propagating with light velocity in same time direction. Time mirror hypothesis applied to sensory organs and brain suggests a generalization of this picture: sensory organ and the sensory cortex are in time mirror relationship making possible a sequence of reincarnations of the mental image so that signals can proceed in both directions of time. This would conform with the fact that the sensory consciousness has gaps.

3. Could any mutually communicating brain regions be in time mirror relationship? The presence of magnetic flux tubes along which dark photons can propagate is assumed to serve as a correlate for directed attention. Could their presence guarantee also the time mirror relationship. For instance, the neuron groups of primary, secondary and tertiary sensory and motor regions, and premotor regions and primary motor regions attend to each other and therefore be in time mirror relationship. This could be true also for the regions of brain and parts of MB. This would conform with the hypothesis that MB both perceives and controls biological body and is responsible for the third person aspect of consciousness [K70]. This would conform with Leibnizian monadology.

4. Could even sensory organs and target of attention be in time mirror relationship? The perceiver could to some degree control the target of her attention. It is known that authoritative

and charismatic persons such as performing artists can have very strong effect to persons that they attend and are attended by. Could also hypnosis be based on the same mechanism [K33]. The motor reaction of the attended target could come come "too fast", even before becoming becoming target of attention.

If directed attention induced by flux tube connections is enough for time mirror relationship then mirroring property is not static and depends on the relationship between two subsystems. Learning of mirror property would be generation of directed attention. This would make the model more flexible.

Time mirror hypothesis and the basic aspects of mirror neuron activity

Time mirror hypothesis allows to understand the basic aspects assigned with mirror neuron activity.

1. The percept of motor activity generates imagined or even real motor activity. Internal speech as almost speech is one example. Also real motor activity is generated by the same neuronal activity but for some reason the activity does not proceed to the muscles.

2. Mirror neuron activity is able to distinguish between biological motion and motion of inanimate matter. Time mirror hypothesis reduces the question to that about which systems can be in time mirror relationship. It is obvious that motor neuron activity cannot induce motion of in-animate matter since it is not under motor control so that the problem disappears.

   An interesting question relates to the possible distinction between actual motion and video about actual motion. If the attention involves formation of flux tubes between target and perceiver, there might be differences.

3. Mirror neuron activity seems to require goal directedness of the action meaning that the action is intentional. Time mirror hypothesis allows to understand also this.

Time mirror hypothesis and criticism of mirror neuron hypothesis

In the following I consider the criticism of mirror neuron hypothesis [J72, J84, J64] (see `http://tinyurl.com/y7jqljwv`, `http://tinyurl.com/y8pelhhl`, and `http://tinyurl.com/y7vhyfe6`) from the point of view of TGD.

There are several time anomalies involved.

1. Typically mirror neurons react "too fast" [J84, J64]. Sensory-motor associations are too slow to explain these time anomalies for the same reason so that the question is not about mechanism but about the view about time.

2. Measurements of neuron firing delay seem to be incompatible with standard reaction times [J84, J64]. The articles [J84, J64] mention boxers an an example. The estimate for the reaction time based on the knowledge of the conduction velocity of nerve pulses and neural processing would be about 200 ms. The actual reaction time is around 60 ms. The boxer cannot automatically perform the mirror the motion of the opponent but must be able to decide what to do on basis of the perceived motion. If mirror neurons are involved, there must be a step involving a reaction to the mirrored bodily movement with different movement.

   One could argue that anticipation based on facial expression realized in terms of mirror neurons is in question. But also now the mirror neuron response would be facial expression, real or imagined! Penrose mentions as similar example about tennis players in "Shadows of Mind" [J87]: in this case seeing of the facial expression is not possible.

3. Only the type of action, and not the kinematic force with which models manipulated objects, determines neuron activity. According to [J84, J64] it was also significant that neurons fired *before* the monkey observed the human model starting the second motor act (bringing the object to the mouth or placing it in a cup). Therefore, IPL neurons "*code the same act (grasping) in a different way according to the final goal of the action in which the act is embedded*". They may furnish a neural basis for predicting another individual's subsequent actions and inferring intention. How the mirror neurons knew that the action is goal directed

and intended to a particular goal although there was no information about it. Also in this case the same TGD based explanation applies: motor areas received actual information about the goal in by signals in non-standard time direction.

Time mirror hypothesis allows to understand these anomalies. The sensory percept corresponds to one end of CD and its second end corresponds to an action determining motor action as a reaction to the sensory percept. What is remarkable that a lot of processing could be done in geometric past since the signal could continue to the MB of geometric past.

One could also consider an alternative explanation. In TGD framework directed attention would correspond generation of magnetic flux tubes connecting boxers and making possible entanglement and sharing of mental images making possible telepathy. This could be tested: do mirror neurons react to actual motor actions (telepathy) and to a video about motor actions (no telepathy) in a similar manner.

There are also other objections against mirror neuron hypothesis.

1. One can argue that mirror neurons must learn to act as mirror neurons during the development of individual. There is however a problem: a new-born infants can mimic gestures although she has never seen them earlier. One explanation would be that these gestures correspond to fixed action patterns, innate and instinctive behaviors coded by genes.

   What about the situation in TGD framework. The first explanation would be that brain regions of infant direct their attention to the sensory areas considered. This is however more like learning.

   Second explanation would be genetic. One can say that genes code for the 4-D preferred extremals represent magnetic bodies and serve as templates for biochemistry. A basic hypothesis is that DNA and other basic biomolecules are accompanied by parallel flux tubes carrying sequences of dark protons - dark nuclei - realizing also genetic code and communicating between themselves using dark photon triplets - kind of 3-chords for music of light - realizing genetic code too [L9, L53].

   In this picture one could say that dark genes at the MB of DNA associate/code for ordinary genes in turn coding for the biolochemistry of the ordinary biomatter. This would be in accordance with the vision that bio-chemistry is controlled and induced by MB acting as boss and having larger value of h_{eff} and thus higher "IQ".

2. There are also problems with adaptation. Mirror neuron hypothesis in its original form predicts that there should be a complete symmetry between sensory and motor sides. Also adaptation should be completely symmetric. In the experiments [J72] (see `http://tinyurl.com/y7jqljwv`) adaptation to motor actions, which were performed and then observed or vice versa. Four cases were studied. Motor actions were repeated, motor actions were repeatedly perceived, motor action was first observed and then carried out, and motor action was first carried out and then observed.

   In the first two cases adaptation was observed. Also in the third case as one expects also in the case that association between sensory percept and motor action is in question. In the fourth case adaptation was not observed and this does not conform with mirror neuron hypothesis. It was however later found that the situation is symmetric in the case of goal directed action.

   In TGD framework the result can be understood if only goal directed actions involve the pairing between its sensory percept and realization and assignable at opposite boundary of CD. This of course is very natural definition of goal directed action.

3. At F_5 premotor regions of monkeys there many neurons, which do not act as mirror neurons in the sense that they would respond to a perception of goal directed motor actions. For instance, there are neurons firing for graspable objects alone. Could the mere sensory percept induce an imagined motor action - grasping the object. Is this sensory-motor association or analog of mirror neuron activity?

   What about the interpretation in TGD? Is sensory-motor association in question or do the boundaries of CD represent the percept of a graspable object and the act of grasping. If the

mirror neurons have learned to direct their attention to the sensory neurons active when the motor action induced by them is perceived, one could interpret the situation in terms of time mirror hypothesis. One might also argue that in the case of static perceptions there is no compelling reason for fast reactions so that sensory-motor association could be enough.

4. According to [J64], "*Despite its widespread acceptance, the proposal has never been adequately tested in monkeys, and in humans there is strong empirical evidence, in the form of physiological and neuropsychological (double-) dissociations, against the claim.*". These dissociations would mean that time mirror relationship is not present. As noticed, this relationship is in principle dynamical if generated by directed attention mediated by flux tube connections.

7.4 The findings about entrainment of the speech regions of right and left brain

The starting point was the popular article (see `http://tinyurl.com/y8a4puca`) telling about the findings of David Poeppel and his student Florencia Assaneo [J57] (see `http://tinyurl.com/y79r62v9`). The basic question inspiring their work was could be put as "*How sound waves put ideas into your head?*". The answer provided by their would can be phrased as "*Brain waves surf on the sound waves*". This work relates also to mirror neuron idea but mirror neurons are not mentioned in the article and Poeppel is critical about mirror neurons in his article [J51] discussed briefly in the introduction.

7.4.1 Findings

The basic characteristic of the speech is the frequency with which the loudness of speech changes. This frequency is determined as the average rate for syllables. This rate various in the range 2-7 Hz for comprehensible speech. Speech regions entrain to this frequency in the range 2-7 Hz The average frequency of entrained signals in auditory cortex is commonly about 4.5 Hz, which is also the men rate at which syllables are spoken in various languages.

In the experiments Assaneo studied people listening non-sense syllables (to avoid indirect effect on motor areas) with rate varying in the range 2-7 Hz. The idea is that if brain waves in auditory cortex are not independent on those in speech motor cortex they should entrain. This indeed occurred but only up to 5 Hz (theta waves are in the range 4-7 Hz and mu waves in the range 7-12 Hz) . At higher frequencies speech waves dropped out of synchrony. A computational model allowed to verify that this finding is consistent with the assumption that speech motor cortex has its own internal oscillator driven with a frequency in the interval 4-5 Hz. There was also a resonance around 4.5 Hz.

Neural model for the finding was based on a model known as Wilson-Cowan mean-field approximation treating excitatory and inhibitory neuron populations in speech motor region as competing synchronous units driven in non-linear manner by the oscillatory input from the auditory regions. Auditory region drive motor-cortex region with a periodic force. The time constant for the oscillations telling how fast they attenuate exponentially in absence of driving force was 60 ms, which happens to be also the reaction time of boxers mentioned earlier and could be assigned with mirror neurons.

The non-linear driving force was taken to be sigma function approaching value 1 for large positive values of the argument (saturation) and to zero for small values of the argument. The argument of sigma function was taken to be sum of various inputs excitatory and inhibitory inputs with opposite sign, background contribution, and the periodic driving force. For large enough amplitudes oscillatory input the positive part of the signal gives a considerable input whereas the negative part is cut away. Therefore the system responds essentially to the syllables but not to the silent periods between them.

7.4.2 TGD based model

Could the finding of Poeppel and Assaneo be understood in terms of the time mirror mechanism? If so, motor speech regions and auditory regions would be in time mirror relationship - motor

regions would attend the sensory regions and vice versa. The speech motor response - realized as imagined, inner speech - would in standard time direction appear before the sensory input and be due to the communication by negative energy signals. Maybe this could be tested by using sharp enough pulses as sensory input. The periodic appearance of the syllables is however expected to mask this effect unless one uses different syllables.

In TGD framework speech regions would communicate to a layer of MB with cyclotron frequency which $E_{g,J}$ and generate a resonant response in opposite time direction with this frequency in turn inducing resonant firing at the speech regions. Neuroscientist would assume resonant interaction of brain hemispheres using nerve pulses.

One can make this model more concrete if one accepts the vision about MB as receiver of sensory input from neuronal membranes as Josephson radiation with Josephson energy $E_J = ZeV$ and scaled down Josephson frequency $f_J = ZeV/h_{eff}$. A more general model [K37, K24, K59] assumes generalized Josephson energy supported by the basic facts about nerve pulse generation given by

$$\begin{array}{ll} E_{g,J} = \Delta E_c + E_J = h_{eff} f_{g,J} \ , & f_{g,J} = \Delta f_c + f_J \ , \\ f_c = \frac{ZeB_{end}}{2\pi m} \ , & f_J = \frac{ZeV}{h_{eff}} \ , \\ E_c = \hbar_{eff} \frac{ZeB_{end}}{m} \ , & E_J = ZeV \ . \end{array} \tag{7.4.1}$$

The generalized Josephson frequency is identified as a sum for the difference of cyclotron frequencies at two sides of the membrane and of the scaled down Josephson frequency. The assumption that scaled down Josephson frequency gives a small perturbation to the dominating difference of cyclotron frequencies and codes nerve pulse patterns as small modulations of $f_{g,J}$. One can however consider also a situation in which only f_J is present.

Here Z and m denote the mass and charge of the charged particle, say ion, or of corresponding Cooper pair, forming cyclotron Bose-Einstein condensate. One has $h_{eff} = n \times h_0$, where h_0 is the minimal value of h_eff and $h = 6 \times h_0$ is the most reasonable estimate for h found hitherto. There are two conditions on the model. The condition that $f_{g,J}$ is 4.5 Hz and the condition that $E_{g,J}$ is in visible and UV range.

The frequencies $f_{J,g}$ at cell membrane and f_c at MB should be roughly the same in resonance. In the applications the "endogenous" magnetic field B_{end} is assumed to have the minimal value $B_{end} = .2$ Gauss, 2/5 of the Earth's magnetic field. B_{end} is with inspiration coming from the p-adic lengths scale hypothesis [K46] assumed to have a spectrum spectrum consists of similar octaves with the frequencies in a given octave corresponding roughly to the spectrum of possible notes in music experience.

1. The expressions

$$E_{g,J} = \frac{n}{6} \frac{Ze\Delta B_{end}}{2\pi m} + ZeV \ , \quad f_{g,J} = \frac{Ze\Delta B_{end}}{2\pi m} + ZeV \ , \tag{7.4.2}$$

   allow to estimate the value of h_{eff} and ΔB_{end} for given Z and m. For the membrane voltage one can use the estimate $eV \simeq .06$ eV. $f_{g,J} = 4.5$ Hz gives one constraint. The condition that the dark photons involved transfrom to bio-photons with energies in visible and UV range gives second constraint. The condition that $E_{g,J}$ is at the lower limit of visible energies gives $E_{g,J} = 1.65$ eV.

   The cyclotron frequency for Ca^{2+} in $B_{end} = .2$ Gauss is 15 Hz and from Z/A scaling one can express the cyclotron energy for ion (A, Z) or Cooper pair with mass $(2A, 2Z)$ as $E_c(A, Z) = (20/A)E_c(A, Z) = (20Z/A) \times 15$ Hz. Signalling between hemispheres using radiation along short flux tubes connecting them is not of course excluded.

2. The hypothesis $\hbar_{eff} = nh_0 = \hbar_{gr} = GM_D m/\beta_0$ is central piece of TGD inspired quantum biology. $h = 6 \times h_0$ is the most plausible possibility. h_{gr} is the gravitational Planck constant introduced by Nottale [E1] and M_D corresponds to large dark mass and β_0 is a parameter with dimensions of velocity: for a detailed discussion see [L47]. The hypothesis implies that $h_{eff} \propto 1/A$ where A is mass number of ion so that cyclotron energies do not depend on mass

of the ion and are universal. Josephson frequencies would scale like $f_J \propto 1/A$ and cyclotron times as $\tau_J \propto A$. Different ions would be at flux tubes with different value of $h_{eff} \propto A$.

3. Comorosan effect corresponds to a universal biorhythm of 5 seconds [I30, I7] and recently it was found to relate to the clustering of RNA polymerase proteins in the transcription of RNA [I9] (see `http://tinyurl.com/y9wzt5yl`). The origin of Comorosan effect is not understood, and I have proposed [K86] that it relates to Josephson effect at the level of biomolecules in bio-catalysis. In [L48] I developed a model in which proton's Josephson time for proton in Josephson junctions involved with bio-catalysis equals to 5 s.

   If the cyclotron frequency $f_c = 300$ Hz of proton for $B_{end} = .2$ Gauss corresponds to bio-photon energy of x eV, one obtains in the case of proton the condition [L48]

   $$r = \frac{h_{eff}}{h} = \frac{\hbar_{gr}}{\hbar} \simeq .83 \times 10^{12} x \ .$$

   If cell membrane potentials are Josephson junction consistent with the model, the Josephson times for ions with mass number A would be $\tau_J = A \times 5$ seconds. These scales would obviously correspond to the scales of conscious experience. The cyclotron energies would not depend on the mass number at all. If the spectrum of bio-photon energies has lower bound at the end of visible spectrum at 1.65 eV one has $x = 1.65$ as a natural first guess.

4. One can look for cyclotron frequencies for ions for $B_{end} = .2$ Hz. The frequencies $f_c \in \{4.0, 4.5, 5.0\})$ Hz corresponds to atomic weights $A \in \{75, 67, 60)\}$. Josephson times would be for the above model of Comorosan effect given by $f_J(A) = A \times 5$ seconds. This gives the following table containing data also for iron for which cyclotron frequency is rather near to 10 Hz in alpha band.

ion	A	f_c/Hz	τ_J/s
Cu	63	4.8	315
Zn	68	4.4	340
Se	74	4.1	370
Fe	56	10.3	280

   (7.4.3)

   Josephson times are rouhgly between 5 and 6 minutes for Cu, Zn, and Se. The differences of cyclotron frequencies are expected to have same order of magnitude and therefore also corresponding energies for bio-photons.

   If one assumes that the energies are in IR but above thermal energy of photon at physiological temperatures the scales of cyclotron energies and Josephson times are reduced by a factor $\sim 1/50$: $x \to x/50$. For Fe one would obtain $\tau_J \sim 5$ seconds, which happens to be Comorosan time again.

5. The part of MB associated with motor regions controlling speech receives information at these EEG frequencies and sends control signal, which do not propagate down to speech muscles except in some special cases. Note that the size scale of this layer of MB is from the condition that cyclotron wavelength gives the size scale of MB roughly 1.7 times the circumference of Earth from Schumann frequency 7.8 Hz.

6. The prediction is that right and left speech regions are not conscious simultaneously. Auditory experience is not possible when one speaks or even when internal speech is present. This can however happen only in the time scale defined by the duration of syllable and would be of the order $1/2f \sim .11$ s defining the lifetime of sub-self and its time reversal as duration of syllable. This is roughly the estimated duration $\sim .1$ s of sensory mental image mentioned earlier. Syllable perception corresponds to quantum coherence and synchrony at auditory areas. The real motor action - rather than motor region at the moment of generation of motor action - corresponds to loss of quantum coherence and synchrony at speech motor regions.

7.5 TGD based model for sensory long term memories

There was a highly interesting popular article (see http://tinyurl.com/yaopecrh) inspired by the recent findings about long term memory [J37] in an experiment carried out by Timothy Brady, Talia Konkle, George Alvarez, and Aude Oliva (see http://tinyurl.com/y9yessmr). The findings are in conflict with the standard view about memories. Of course, also the memory feats of so called idiot savants known for decades are in sharp conflict with the standard view about memory.

The discussion of these findings in TGD framework led to a decisive improvement in the understanding of the proposed mechanism of sensory memory recall. Also a connection with the model of topological quantum computation [K3, K79] realized axon-microtubule level emerged. Sensory memory would be realized as a topological quantum computer program running in reversed time direction in memory recall and generating the virtual sensory input from brain to sensory organs creating the original sensory experience.

7.5.1 The findings

The following gives a brief summary of the results of the [J37] experiment discussed in the popular article.

1. A huge amount of storage capacity is required and it increases as more and more experiences are experienced. One can imagine an abstraction as a cure: store only essentials about the input. This is extremely powerful manner to store the relevant information. Picture about grandmother's house with all detail is replaced with world "grandmother's house". What is lost is detail. This storage mechanism is certainly used at higher levels of evolutionary hierarchy. Verbal memories are a good example.

   The experiment mentioned above however demonstrates that the memory storage is at least 1000 times more detailed than it could be, which suggest that a different very detailed storage mechanism usually unconscious to us is involved.

   Indeed, the memory feats of idiot savants show that sensory percepts can be stored in amazing detail. A possible TGD based explanation is that all of us have sensory memories - essentially re-experiences but at a lower level of personal self hierarchy, not as mental images represented as sub-selves but as sub-sub-..-selves not directly conscious to us. Temporal democracy would make it impossible to distinguish between recent and past and make it difficult to survive. Here would be the reason for why these persons are often called idiot savants.

   Sensory memories must be unconscious at our level of self hierarchy to allow the experience about living in definite moment of time and only cognitive (symbolic, verbal) memories involving a lot of abstraction satisfy this condition. If the percept is cognitive, it is about geometric past. If sensory, it is about "Now". Perceptive field effectively reduces from 4-D to 3-D (actually the duration of sensory chronon is about .1 seconds).

   Situation changes when temporal lobes are stimulated electrically as neuroscientists have known for decades but "forgotten". Perhaps animals do not conceptualize and have sensory memories.

2. Proteins used for the storage in terms of modified synaptic contacts is slow by a factor 1000 slower than required to understand the above experiment. Memorizing would require a repeated stimulation but now the pictures were seen only once or twice.

3. The lifetime of the proteins in synaptic contacts is only few weeks so that also long term memories would be unstable. Humans can remember for about 50 years, 1000 times longer than expected.

4. The technical realization of the 3-D storage is also a problem. One should remember also the place, where the memory is stored, not only the memory itself! Here the association mechanism seems the only possibility but would allow only conditionings. In computer language LISP this idea is very concretely realized. Conditionings are however only pseudo-memories.

7.5.2 Wrong views about time and the notion of memory as the basic problems

To sum up, the standard view about memories suffers from two fatal problems.

1. The first fatal problem of the standard model of memory is the wrong view about the relationship between experienced and geometric time. The identification of these times forces to the notion of memory storage analogous to that in computer. The information about what happened must be stored again and again. This view has many problems already discussed.

2. Second fatal problem is the conceptual flaw forced by behaviorism: memories are identified as conditiongs, habits, or behaviors - as you like. Genuine sensory memories are however re-experiences and would however correspond to re-experience to which is associated a synchronously firing neuron group: what neurons fire is not determined by synaptic contacts but by the sensory input mapped topographically to sensory area. This is very delicate and crucial difference.

7.5.3 TGD view about sensory memories

Could one realize memory as re-experience in TGD framework?

1. In zero energy ontology (ZEO) of TGD *no* 3-D memory storage to the "brain now" is required. Memories are ideally where (in 4-D sense) the event occurred but memory recall creates further - usually less detailed and more abstracted copies - of the memory [K61] [L54]. To remember (in the genuine sense of the word) is to re-experience. Memory in this sense would be in the geometric past. Memory recall would be seeing in time: sending a signal to geometric past, where it is time-reflected back. Each memory recall could generate at least a conceptual copy about the memory and in this manner the signal sent to the geometric past would have higher probability to generate the re-experience or at least secondary version of it. Learning, which is not mere conditioning, could rely on the generation of copies of the memory in 4-D perceptive field.

2. Memories as re-experiences would involve synchronously firing neuron groups associated with quantum coherent units defined by magnetic bodies (MBs) of neurons and representing mental images. To understand this concretely, one needs besides the notion of MB also the hierarchy $h_{eff} = n \times h_0$, $h = 6 \times h_0$ of Planck constants. The synchronously firing neuron group (involving quantum coherent part of MB) in the geometric past is woken up by the time reversed signal to the geometric past and reflecting from it by providing energy (now negative). ZEO makes this possible.

3. How the memory recall could realize this synchronous firing in the geometric past? This mechanism should be analogous to the reflection of negative energy signal in time direction from the brain of the geometric past. ZEO allows sending of a negative energy signal travelling to geometric past. It should somehow induce a transition generating the synchronous firing. The signal generating this transition should be very simple. It must induce the transition at correct location in the geometric past. Here the period of the carrier wave of the signal could be essential and large value of h_{eff} could make the signal energetic enough despite the period which could be measured in years so that energy for the ordinary value of Planck constant would be extremely small. Signal could also provide metabolic energy for the neurons, which should fire synchronously. Replicas of the memory help to achieve activation at the correct location.

4. There must be a coding of the sensory input to the physical state of neuronal pathways coded by nerve pulse patterns representing the original sensory input from the sensory organs. If genuine sensory re-experience is required a signal generating the original sensory experience and thus the nerve pulse pattern from sensory organs creating it should be re-generated.

   As if one had in the geometric past a magnetic tape representing somehow the original experience. When played it would generate a signal to the sensory organs in turn generating the signal to the brain (including nerve pulses) giving rise to the original sensory experience.

Note that ZEO indeed allows the sensory experience to be in geometric past. It is however communicate cognitive information about it to recent too.

TGD leads to a model for what could happen based on the idea that topological computation is realized in terms of the braiding of magnetic flux tubes connecting two subsystems [K3, K79](see `http://tinyurl.com/yawk2x4t` and `http://tinyurl.com/y9z499a6`). This model leads to a model of memory representations as a kind of topological quantum computer program giving the original experience as an output while running.

Let us assume that second system is axonal membrane along which the nerve pulse patterns (and whatever else is needed) representing the sensory input flow. Second system would be naturally microtubules inside it.

1. The flux tubes would connect the lipids of the axonal membrane to the tubulins (or units formed by them). Axonal membrane can be in liquid-crystal state meaning that the lipid are like liquid particles able to move. Nerve pulses would induce a 2-D liquid flow inducing the braiding of the flux tubes having second end fixed to (say) tubulin of the microtubule.

   There would be both time-like and space-like braiding. Dance metaphor is very helpful here. Consider dancers at the parquet with legs connected by threads (flux tubes) to a wall (microtubule). Time-like braiding would correspond to the dynamical dance pattern of lipids in time direction having a representation as a 2-D projection defined by the paths of dancers at the parquet. Time like braiding would be analogous to a running topological quantum computer program.

   Space-like braiding would be the outcome of the dance representing tangle of the flux tubes fixed to the wall and defining topological quantum computer program serving as a representation for the time like braiding and therefore also for the nerve pulse pattern (and whatever the signal involves) and the sensory input. Space-like braiding is analogous to the code representing the topological quantum computer program and should make possible to represent the program.

   If this space-like braiding can generate a signal serving as a virtual sensory input to the sensory organs, the sensory memory could be regenerated. The running of the topological quantum computer program would mean the opening/un-knotting of this braiding and would represent the time reversal of the sensory input, not yet sensory input, which could correspond to nerve pulse pattern from the sensory organs generating the sensory percept. It seems that the opening must generate a signal to sensory organs as virtual sensory input.

2. Virtual sensory input brain indeed is the basic element of TGD inspired model of sensory perception as construction of artwork [L32] (see `http://tinyurl.com/yczv2o5b`). The basic difference to the standard view is that the sensory qualia are at the level of sensory organs rather than in brain. Brain only gives names for the percepts and builds standard sensory mental images by using virtual sensory input from brain. The process is like pattern recognition by driving sensory input to a standard input near to the real input.

   In TGD framework however nerve pulse patterns would not carry the sensory information to the brain but would generate sensory input to MB as Josephson radiation from the cell membrane. The transmitters emitted at the synaptic contacts would generate bridges connecting axonal magnetic flux tubes to longer connected flux tubes and in this manner create the communication channels - kind of wave guides. Along thee dark photons (which can transform to bio-photons) could travel with light velocity.

   This communication mechanism is dramatically faster than the communication by nerve pulses and allows forth-and-back signalling involving virtual sensory input from brain to generate the standard percepts assignable to the synchronously firing neuron groups accompanied by magnetic bodies obtained by connecting neuronal magnetic bodies by flux tubes.

   The standard mental images would contain only the features relevant for survival or otherwise interesting. A still open question is whether the virtual sensory input corresponds to the time reversal of the ordinary sensory input [L54] (see `http://tinyurl.com/ybe4vf3j`). The following consideration suggests that time reversal is indeed in question.

3. If the virtual sensory input from brain to sensory organs is dark photon signal in time reversed time direction, one can think of very simple model for memory as re-experience. In ZEO based view about conscious entities "big" state function [L42] would occur meaning that the mental images associated with braiding generated by nerve pulse pattern and dark photon beam die and re-incarnate in opposite time direction. A time-reversed mental image would be generated. This mental images is not conscious at our level of hierarchy living in opposite time direction.

   This mental image is not quite exact time reversal of the original and there is non-determinism of state function reduction involved. One can have however statistical determinism possible if large enough number of neurons are involved. Therefore the differences need not be too big. Also standardization comes in rescue: it would take care that the sensory mental is very nearly the counterpart of the original.

   The time-reversed signal from brain to the sensory organ should generate a nerve pulse pattern just as in the case of ordinary perception and the dark photon signal generating the sensory mental image defining the original sensory memory in good approximation.

4. For the simplest alternative dark photons alone induce the flow of the lipids. Hitherto it has been assumed that the flow is induced by nerve pulse patterns. The most general option is that both are involved in the generation of the flow. One cannot exclude the possibility that the communication of data about nerve pulse pattern to MB generates a control signal which induces the liquid flow. There are many options to consider but the basic idea is clear and involves ZEO and MB in a crucial manner.

5. An important open question is whether the virtual sensory input using dark photons propagates

   (a) to the "sensory organs then" so that only cognitive memories would result as copies. In this case a person, who has lost eyesight during lifetime could have visual memories from time when she could see.

   (b) or via the MB to the "sensory organs now" and stimulates sensory experience in "brain now". Person lost eyes during lifetime could not have visual sensory memories in this case.

   For the latter option one can ask whether the sensory experience is

   (a) realized by the mere virtual sensory input to sensory organs. No copies of the sensory representation at the microtubule-axon level would be generated. If sensory organs are not intact, sensory memories would not be possible.

   (b) or whether also a signal from sensory organs to brain involving nerve pulse pattern is needed to generate the experience. Each memory recall would create an almost exact copy of topological computer program giving rise to a genuine sensory memory while running.

   Various options might be tested by electric stimulation of the temporal lobes known to generate sensory memories.

7.6 Are basic biochemical processes induced by topological quantum computer programs running in non-standard time direction?

The basic bio-chemical processes such as replication, transcription, translation have remained mysteries in standard biology. My conviction is that a lot of new physics is needed. Bio-chemistry is not enough, even QFT is not enough. Even standard views about space-time and classical fields, QM, and basic ontology are not enough.

TGD approach indeed brings in several new physics elements.

1. The notion of magnetic body (MB). MB carrying dark matter identified as dark variants of charged particles having non-standard value $h_{eff} = n \times h_0$ of Planck constant is central in TGD inspired quantum biology. MB is the intentional agent receiving sensory input from biological body and controlling it. The interactions at the level of ordinary bio-matter would be governed by the MBs of molecules, and bio-chemistry would be a shadow of this much simpler dynamics.

   MB of water entrains to the cyclotron frequencies of the MBs of the basic biomolecules by varying flux tube thickness. This makes possible water memory [L50] (see `http://tinyurl.com/y9mr9s2w`) and implies homeopathy like mechanisms serving as basic quantal building bricks in the functioning of the immune system. Dark variants of DNA, etc.. realized as dark proton sequences would be one aspect of this representation.

2. The braiding of the magnetic flux tubes makes possible realization of topological quantum computer (TQC) programs. Biological functions should correspond to TQC programs and the challenge is to understand how they emerge naturally. A possible answer to this question will be proposed in the sequel.

3. There are also other central notions such as zero energy ontology (ZEO) predicting that the arrow of time is not fixed. The following arguments suggests that ZEO is absolutely essential for the understanding of the miracles of bio-chemistry. TQC programs running *backwards in time* would generate as output various biological functions such as DNA transcription and other basic processes.

7.6.1 What are the big problems?

It is best to start from the problems that one should solve. At bio-molecular level the basic problem is to understand how complex temporal sequences of bio-chemical reactions involving bio-catalysts are possible as highly deterministic sequences.

1. How the reacting molecules - including catalysts - are able to find each other in the molecular soup?

   TGD answer: Contraction of flux tubes connecting molecules very selectively as h_{eff} is reduced brings molecules together. Connections between molecules are generated by re-connection of U-shaped flux tubes scanning enviroment and producing pair of flux tubes connecting the two systems provided they have the same cyclotron frequency. Resonant em coupling by dark photons is in question.

2. How the attached molecules are able to attach to just the correct spot and orient just in the correct manner?

   TGD answer: the contraction mechanism for flux tubes automatically guarantees also this.

3. How the rate of reaction can exceed the expected rate by so huge factor?

   TGD answer: Reactants are connected by flux tubes so that the probability that they find each other is much higher and depends on the occurrence of h_{eff} reducing transition which occurs spontaneously. The energy liberated in the contraction of flux tube allows to overcome potential wall in the reaction and exponential increase in the rate is achieve.

4. How bio-catalysis can proceed in time ordered manner like deterministic computer program so that very many initial states can lead to the same outcome?

   Here the initial states would correspond to positions orientations, etc of input molecules. Huge number of initial states lead to the same outcome.

   I think that this is the really difficult question. I am highly skeptic about the possibility to understand this in QFT framework. In the following I propose TGD inspired solution of this problem requiring ZEO, which means a revolutionary modification of basic ontology and of views about time.

7.6.2 Basic biological processes as TQC programs

Apparently a breaking of second law is involved. Very many initial states lead to the same outcome rather than vice versa. As if the process would be controlled by the time reversal of the original process and entropy would increase but in opposite time direction as usually but at the control level! The notion of syntropy introduced by Fantappie comes in mind!

TGD answer would involve at least the following pieces.

1. Dark DNA and dark variant associated with enzyme should be part of the story. Large h_{eff} brings in conscious information realized as algebraic complexity and large scale quantum coherence.

2. ZEO allowing time reversed processes should be essential. ZEO predicts both directions of time and motor actions are postulated to correspond to sensory perception in opposite arrow of time. What this precisely means is not however clear.

3. Magnetic body (MB) should be the boss controlling dynamics. This dynamics should be very simple. Biochemistry should be shadow dynamics and apparently extremely complex.

4. Topological quantum computational (TQC) [K3, K79] is also a central aspect but I have not been able to articulate what TQC programs are and how they would emerge: the following ZEO arguments suggests an astonishingly simple solution to both problems.

   The complex reaction sequences like transcription should correspond to a running of topological quantum computer (TQC) program coded by the braiding. The proposed realization of sensory memories serves as a guideline. Memory recall would be like a quantum computer program running backwards in time and producing sensory experience as output.

   There is a strong temptation to believe that this is completely general aspect of all also motor actions. By fractality also DNA transcription, translation, etc... are analogs of motor actions. Somehow they should be coded to TQC programs realized as braidings of flux tubes of MB.

   The output of the TQC program running *backwards* with respect to the standard direction of time would be motor action as we observe it. All basic bio-processes involving several steps be coded to braidings. One can imagine a hierarchical structure: programs, subprograms, etc... for the TQC programs. Braidings of braidings of.... This conforms with the hierarchical many-sheeted structure of space-time.

How to realize motor actions as outputs of TQC programs running in non-standard direction of time?

1. Assume that when some process - such as DNA transcription or its time reversal occurs - it induces braiding of flux tubes - topological quantum computer (TQC) program at the level of MB. The braiding flux tubes connecting systems of ordinary matter as they move would automatically generate the TQC program representing the motion as a motor action.

   As this TQC program runs backwards in time, the *time reversal* of the original process is generated as output at the level of ordinary bio-matter - inverse braiding in the previous example. The running in reverse time direction would follow a "big" state function reduction for the quantum system defined by the flux tubes inducing time reversed motion (meaning death of this sub-self and reincarnation in opposite time direction). The interaction with ordinary matter system living in ordinary time direction and corresponding to different values of h_{eff} would serve as a template for the dynamics of ordinary matter forcing it to obey time reversed dynamics.

2. For instance, in the case of transcription, one should assume that the time reversal of transcription meaning the decay of mRNA back to its building bricks generates the TQC program as braiding of flux tubs. Running of this TQC problem in the reverse time direction should generate transcription and bio-chemical level.

3. The sub-..-self corresponding to the TQC program is lost only temporarily in the process. A death and re-incarnation of time-reversed self creates the program in the original time direction but the corresponding CD has increased in size. Are all sub-CDs/TQC programs conserved or can they disappear? Also disappearance is in principle possible if zero energy state associated with CD is not orthogonal to a tensor product of vacuum states associated with its opposite boundaries.

4. What looks strange that the time reversal of the assembly process - essentially a decay process occurring in very ways - would code for the highly deterministic TQC program for the assembly process. But this is actually just what one wants!!

   The decay process is highly unpredictable but its time-reversal is highly predictable! There are very many TQC programs, which give rise to the desired output! The ways from Rome lead to all possible directions but all ways lead to Rome! In ZEO butterfly effect transforms to extreme predictivity in opposite time direction!

5. Also the standardized sensory percepts discussed in the model of sensory memory could be seen as TQC programs generating as an output standardized sensory mental image nearest to the actual sensory input. The propagation of bio-photons forth-and-back between sensory organ and brain would generate this standardized mental image. Is sensory memory just a motor action at the level of ordinary matter generated by the time-reversed signal to geometric past identifiable as TQC program running backwards in time? As a matter of fact, there should be no difference between sensory memory and sensory percept in 4-D sense.

6. How MB and space-time sheets assignable to ordinary matter and having opposite arrows of time - or more generally two levels of h_{eff} hierarchy with different values of h_{eff} and different arrow of time - could interact? If the arrows of time are opposite, the intersection of space-time sheets should have dimension smaller than $D = 4$. Since the classical dynamics determined by twistor lift breaks T symmetry (the analog of Kähler action in M^4 degrees of freedom is the reason), 3-D intersection does not imply that the surfaces co-incide for the space-time surface and its time reversal.

   The interaction should be via common boundary conditions: the space-time sheets with different arrow of time should intersect along 3-D or even lower-dimensional surfaces at the boundaries of CD and perhaps also at the 3-D light-like orbits of partonic 2-surfaces at which the signature of the induced metric changes. Magnetic flux tubes induce braiding, which suggests that magnetic flux tubes of MB as 4-D surfaces should have at most 3-D intersection with the space-time surfaces representing ordinary bio-matter and defining the nodes of tensor network [L28]. These 3-D - possibly light-like - intersections would mediate the interaction. For the usual arrow of time for MB the interaction would be sensory input to MB and induce braiding. For the opposite arrow of time for MB it would be motor action in which MB would be the controller forcing bio-matter to follow in the un-braiding process.

   In the generic case the intersection of two 4-surfaces in $M^4 \times CP_2$ is discrete. Could the intersection of space-time surfaces with different arrow of time consist of a discrete set of points? Could this be enough for MB to control bio-matter? Note that cognitive representations identified as intersections of real space-time surfaces and their p-adic variants consist of a discrete set of points [L33].

7. The connection with Sheldrake's vision about morphogenetic fields, in particular the generation of "habits" even at the level of so called dead matter [I28, I29] is rather obvious. TQC programs would indeed code for habits and would be generated by Nature without a need of a programmer writing the code. I have discussed Sheldrake's vision from a slightly different viewpoint in [L26].

There are interesting connections to ancient Indian philosophy and Christianity. ZEO has analog in ancient Indian philosophy as I learned from a discussion with Savyasanchi Ghose while writing this. As notions doer and un-doer are analogous to self and time reversed self. MB would be in the role of supreme observer although it would not be outsider to the Universe. The undoing

the time reversal of deed by MB would serve as a template for the dynamics of deed at the level of ordinary matter.

Building braids and opening them are indeed the basic operations in TQC according to ZEO. A visit to web using "undoer" reveals that it appears also in Christianity, Mary the undoer of knots! Knots are now a metaphor for sins and undoing them means mercy. In Christianity God would be the counterpart of MB and we would be 4-D dynamical images of God.

To sum up, this sounds like mystics and brings strongly in my mind a french movie about time that I saw decades ago. It was very poetic and somehow caught at the emotional level something very deep about the mysteries of time, life, and consciousness in a way not expressible using the vocabulary of scientist. It seems that TGD is providing the language that I did not have at that time and that ZEO is starting to demonstrate its magnificent explanatory power.

7.7 Three findings about memory recall and TGD based view about memory retrieval

I received within few weeks 3 highly interesting links telling about the work of neuro-scientists relating to memory recall. This inspired a construction of a detailed model for the memory recall which generalizes to a model of sensory perception and motor action based on the vision discussed in detail in [L54] (see `http://tinyurl.com/ybe4vf3j`). The original vision about motor action as time reversal of sensory percept is sharpened so that motor action corresponds to a "big" state function reduction (BSR) changing the arrow of time and sensory percept to "small" state function reduction (SRS) preserving it. What is also new, is the combination of this picture with the old TGD based vision [K11] about living system as a conscious hologram. The idea about brain as hologram is originally due to Karl Pribram [J67].

A short summary of TGD inspired theory of consciousness is in order to help the reader to follow the arguments.

1. Zero energy ontology (ZEO) predicts that quantum states are superpositions of deterministic time evolutions (preferred extremals representing space-time surfaces as minimal surfaces). These space-time surfaces connect 3-surfaces the opposite boundaries of causal diamond (CD) forming a scale hierarchy. There are two kinds of state function reductions.

   Zero energy states can be regarded as pairs of ordinary quantum states located at opposite boundaries of CD and having interpretation as wave function in the space of 3-surfaces at the boundary of CD. The 3-surfaces at opposite boundaries of CD are connected by space-time surface - preferred extremal - which is minimal surface apart from 2 dimensional string world sheets and their 1-D light-like boundaries at light-like 3-D orbits of partonic 2-surfaces at which the signature of the induced metric of space-time surface changes its signature from Minkowskian to Euclidian [L69, L56].

   "Small" state function reductions (SRSs analogous to weak measurements in standard quantum measurement theory) leave the passive boundary of CD unaffected as also states at it but affect the states are active boundary, and also shift the active boundary farther away from the passive one (in statistical sense at least). Each small state function reduction is preceded by a unitary evolution of state at the active boundary meaning shift of the active boundary: actually a time-delocalization of the active boundary takes place in the moduli space of CDs. SRS involves a localization with respect to time defined by the temporal distance between the tips of CD. The correlation between experienced time and geometric time identifiable as the distance between the tips of CD follows since state function reductions identifiable as basic building bricks of conscious experience increase this distance in a statistical sense.

   "Big" state function reduction (BSR) changes the roles of the boundaries of CD and corresponds to state function reduction as it appears standard quantum measurement theory. In particular, the arrow of time as a property of zero energy state changes. The change of arrow of time is in a fundamental role in TGD inspired quantum biology and corresponds to the death of self followed by a re-incarnation with reversed arrow of time.

4. Since the superposition of preferred extremals is only replaced with a new one in state function reductions, they are consistent with the determinism of classical physics, which is an exact part of quantum TGD - space-time surfaces can be regarded as analogs of Bohr orbits. One also avoids the basic paradox of standard quantum measurement theory and there is no need for "interpretations".

5. The original somewhat fuzzy vision about motor action and sensory perception was as time reversals of each other so that the difference between them would be only relative. The recent view is more precise and implies absolute difference: Motor actions correspond to BSRs and sensory percepts to SRSs. Also memory recall can be seen as time reversal of sensory perception in a well-defined sense [L54].

The model for various findings described below relies on this picture combined with the vision about living system as conscious hologram [K11]. The TGD inspired model for for the memory recall generalizes to a model of sensory perception and motor action. The common mechanism of sensory perception, motor action, and memory recall would be surprisingly simple.

Magnetic body (MB) would send reference beams R interfering with incoming beams O representing sensory input to build a sensory representation as a hologram H on living matter serving as a substrate. Conjugate hologram $\overline{H}$ would correspond to a time reversal of H constructed using conjugate beams $\overline{R}$ and $\overline{O}$. The reading of sensory percepts/memories would take place by illuminating $H/\overline{H}$ with $R/\overline{R}$ coming from MB.

An important challengeable assumption is that the time reversals of our mental images are not conscious-to-us. It implies that the reading of the memory by $\overline{R}$ does not yet produce mental image conscious-to-us: only the next BSR would generate memory representation readable by applying R. This picture is consistent with the empirical findings inspiring the detailed model.

7.7.1 The findings

In the following brief summary about findings is given.

Ripples race in the brain as memories are recalled

The first link was to a popular article in *Science News* with title "*Ripples race in the brain as memories are recalled*" (see `http://tinyurl.com/y5hohv2h`) telling about the findings of neuroscientists Vaz *et al* about memory recall published in Science as article with title "*Coupled ripple oscillations between the medial temporal lobe and neocortex retrieve human memory*" [J14] (see `http://tinyurl.com/y48kdkrl`).

1. Results

The results come from the study 14 patients suffering from epilepsy. They had electrodes placed on their brains as part of their treatment. The electrodes also allowed scientists to monitor neural activity while the people learned pairs of words.

One to three minutes after learning the pairs, people were given one word and asked to name its partner. As participants remembered the missing word, neuroscientist and neurosurgeon Kareem Zaghloul and his colleagues caught glimpses of fast brain waves rippling across parts of the brain at a rate of about 100 per second.

These ripples appeared nearly simultaneously in two brain regions — the medial temporal lobe known to be important for memory, and the temporal association cortex having a role in language. When a person got the answer wrong, or didn't answer at all, these coordinated ripples were less likely to be present, the researchers found.

The abstract of the article provides a more technical summary.

> *Episodic memory retrieval relies on the recovery of neural representations of waking experience. This process is thought to involve a communication dynamic between the medial temporal lobe memory system and the neocortex. How this occurs is largely unknown, however, especially as it pertains to awake human memory retrieval. Using intracranial electroencephalographic recordings, we found that ripple oscillations were*

dynamically coupled between the human medial temporal lobe (MTL) and temporal association cortex. Coupled ripples were more pronounced during successful verbal memory retrieval and recover the cortical neural representations of remembered items. Together, these data provide direct evidence that coupled ripples between the MTL and association cortex may underlie successful memory retrieval in the human brain.

2. Ripples as hologram

The basic question concerns the interpretation of the ripples appearing both during the formation and the retrieval of the memory. The TGD based vision about living system as a conscious hologram [K11] suggests an answer (for the notion of hologram see `http://tinyurl.com/qgjsdzz`).

1. During the sensory perception the ripples are created by the interference of the reference beam coming from magnetic body (MB) with dark photon beam representing sensory input transformed to dark photons at sensory organs as TGD inspired model for the generation of percept as forth-and-back communication between MB/brain and sensory organs assumes [L51].

2. During memory recall MB sends the phase conjugate of the reference beam scattering from the time reversed conscious hologram and generates phase conjugate beam representing the time reversal of the sensory input. At quantum level this involves BSR and the phase conjugate mental image resides at boundary of CD opposite to that carrying the ordinary mental images.

   This sensory mental image need not be conscious-to-us and this has been the assumption. The "death" of the phase conjugate mental image in a further BSR gives rise to a mental image at the "normal" boundary of CD. This mental image need not be sensory mental image (sensory/episodal memory) and could correspond to imagination or verbal memory.

There are several questions to be answered. Can one keep the earlier hypothesis that the phase conjugate sensory mental image is not conscious to us? Does the "normal" mental image correspond to sensory mental image (episodal/sensory memory) or almost sensory mental image (declarative or verbal memory)?

The human brain works backwards to retrieve memories

The second interesting link was to an popular article "*The human brain works backwards to retrieve memories*" (see `http://tinyurl.com/y7hbqmug`). The article tells about the work of Linde-Domingo & Wimber *et al* published in Nature Communications as article titled "*Evidence that neural information flow is reversed between object perception and object reconstruction from memory*" [J71] (see `http://tinyurl.com/y375ht5f`).

1. Results

During the study, participants saw images of specific objects, and then learned to associate each image with a unique reminder word, for example the word 'spin' or 'pull'. The participants were later presented with the reminder word and asked to reconstruct the associated image in as much detail as possible.

Brain activity was recorded throughout the task via 128 electrodes attached to the scalp, allowing the researchers to observe changes in brain patterns with millisecond precision. Finally the researchers trained a computer algorithm to decode what kind of image the participant was retrieving at different points in the task.

The abstract of the article summarizes the results.

Remembering is a reconstructive process, yet little is known about how the reconstruction of a memory unfolds in time in the human brain. Here, we used reaction times and EEG time-series decoding to test the hypothesis that the information flow is reversed when an event is reconstructed from memory, compared to when the same event is initially being perceived. Across three experiments, we found highly consistent evidence

supporting such a reversed stream. When seeing an object, low-level perceptual features were discriminated faster behaviourally, and could be decoded from brain activity earlier, than high-level conceptual features. This pattern reversed during associative memory recall, with reaction times and brain activity patterns now indicating that conceptual information was reconstructed more rapidly than perceptual details. Our findings support a neurobiologically plausible model of human memory, suggesting that memory retrieval is a hierarchical, multi-layered process that prioritises semantically meaningful information over perceptual details.

2. TGD vision

This picture is consistent with the general TGD vision predicting that memory recall and sensory perception differ by time reversal: it however turns that one must also assume that motor action corresponds to BRS and sensory perception to SRS. The picture is also consistent with an entire hierarchy of levels labelled by the values of effective Planck constant $h_{eff} = nh_0$ measuring roughly the level of evolutionary hierarchy [L40, L39] and by p-adic length scales. The larger the value of h_{eff}, the longer the relevant time and length scale is, and the more abstract the representation is. The "gist" would correspond to large values of h_{eff} to which one can assign largest maximum value of information content.

Neuroscientists read unconscious brain activity to predict decisions

The third link was to a popular article "*Neuroscientists read unconscious brain activity to predict decisions*" (see `http://tinyurl.com/yxgnr9x6`). The article tells about the work of Koenig-Robert and Person published in Scientific Reports as an article with title "*Decoding the contents and strength of imagery before volitional engagement*" [J85] (see `http://tinyurl.com/yyp6hugz`).

1. In the experiment the situation was following. The subject person looked at most $T = 20$ seconds two different pictures, decided to imagine either of them, and pushed immediately the knob. Then she tried to imagine the chosen picture. Subject person reported also the subjectively experienced intensity of imagination.

   Neural activity was detected in brain and it was found that it emerged $t = 11$ second before the decision. From the pattern of activity it was possible to predict the picture. Also the subjectively experienced intensity of imagination could be predicted. One could say that the sensory experience was re-created by imagination in the brain of past.

2. The imagination involved could be also regarded as an active memory recall. This interpretation suggests that the time t at which the neural activity appears must be within the $T = 20$ second interval during which the decision was made.

3. The authors leave open whether their finding excludes free will. The first interpretation is that the choice really occurred at unconscious level and for some reason subject person experienced illusion of choise. A real choice combined with illusion about real choice looks rather weird idea, and only shifts the problem of free will to a level unconscious to us. If there is no free will then all experiments involving choice are pseudo experiments: this would throw a large portion of neuroscience to trash bin.

These findings will be used to build TGD based model for memory recall based on TGD based vision about living systems described in the introduction.

7.7.2 TGD based model for what happens in imagination as active memory recall

The experiments discussed above give good hopes about a detailed model for what happens in imagination as active memory recall.

Background ideas

To develop this model some background ideas about TGD are needed.

1. I have developed a model for motor action as time reversal of sensory perception based on ZEO in an earlier article [L54] (see `http://tinyurl.com/ybe4vf3j`). This leads also to a model for remory recall as sending a signal to geometric past giving rise to time reflected signal as memory recall.

   Could memories correspond to mental images in standard time direction generated by time reflected dark photon beam as has been assumed hitherto or do they correspond to time reversed mental image in the geometric past at the opposite boundary of CD. The earlier assumption has been that time reversed mental images are not conscious to us.

2. There are several words to which one must give meaning: what do "re-experience in geometric past", "time reflection", "imagination as active memory recall" mean? Who is the imagining intentional agent? The above experiment inspired an attempt to give a more precise meaning for these words.

   The idea is to combine the model of memory with a decades old model of living matter as conscious hologram [K11] (see `http://tinyurl.com/y6lz3t3y`) (one more imprecisely defined word!) .

3. MB is the basic notion. MB acts as intentional agent using biological body (BB) as motor instrument and sensory receptor. In the recent case MB imagines and performs active memory recall by selecting the picture and directing its attention to it (still more words to be explained!).

   Dark matter hierarchy as hierarchy of phases of ordinary matter (also photons) assignable to the MB and labelled by the value of effective Planck constant $h_{eff} = n \times h_0$ is a further central element of the general picture. In particular, EEG photons are dark photons with very large value of Planck constant guarantewing that their energies are above thermal threshold. Bio-photons would with energies in visible and UV range would result as dark EEG photons with very large value of h_{eff} transform to ordinary photons.

4. Brain as a hologram is an old idea originally to Karl Pribram. The formation of hologram involves two waves with the same freqeuency: reference wave and the wave representing the target - typically a wave of same frequency reflected from the target. The reference wave is a simple plane wave with some frequency. These waves must interfere so that coherence is required. The interference pattern is stored by the modification of the hologram substrate. The transmission coefficient of the substrate is proportional to $T = |vert U_0 + U_R|^2$, where U_0 and U_R are complex amplitudes.

   If one illuminates the resulting hologram by reference wave U_R the image of the target is formed. If one illuminates the target with the phase conjugate $\overline{U}_R$ of the reference wave - its time reversal $\overline{U}_0$ - the phase conjugate of the image is formed. In ZEO time reversal has precise quantal meaning as also the time reversal of self and of mental image.

   This requires coherence in the length scales of hot and wet brain. Without non-standard large enough value value of h_{eff} makes this is not possible. The coherence for ordinary photons need not be quantum coherence, but is induced by quantum coherence of dark photons transforming to ordinary photons. Quite generally, the coherence of living matter would be induced in this manner from quantum coherence of dark matter at magnetic flux tubes.

TGD inspired model for memory retrieval

With these ingredients one can build a rather simple model for memory retrieval.

1. Memory and sensory mental images is generated as MB creates a reference wave in the formation of hologram as interference pattern of incoming ordinary light beam and dark reference beam. This induces the pattern of neural activity. Coherence is not quantum coherence but inherited from quantum coherence of dark photon beam from MB. Also phase

conjugate in active memory recall comes from MB. The ripples associated with the formation of sensory percept would correspond to the formation of conscious hologram.

2. Phase conjugate wave corresponds to time reversal of wave and would be created in ZEO in BSR reversing the arrow of time for self involved. The phase conjugate of the reference wave generated by MB acting as intentional agent trying to imagine would propagate to geometric past and scatter from the brain substrate acting as a hologram and generate the memory mental image in geometric past at the opposite boundary - the "re-experience", which need not be conscious-to-us. The ripples reported in the first article [J14] would correspond to the scattering of the phase conjugate wave from the hologram.

   This phase conjugate mental image need not be conscious-to-us: the assumption has indeed been that time reversed mental images are not conscious to us. The assumption will be kept also now.

   The next BSR would mean the "death" of the memory mental image and rebirth as a mental image in standard time direction. This would correspond to the "time reflection" generating a signal to the geometric future defining in the recent situation declarative, verbal memory of the mental image. This would be the outcome of imagination experienced by the subject person.

   Why these "normal" mental images are not usually genuine sensory mental images at our level of self hierarchy? A good reason for this is that they would interfere with the ordinary sensory perceptions. We can indeed have this kind of mental images during dreaming and hallucinations. During dreaming it is not a threat for survival as it is during hallucinations. I have discussed a detailed model for imagination as almost sensory mental images [L51] (see `http://tinyurl.com/ydhxen4g`). They would be created by feedback signals from MB via cortex to a level above sensory organs in the hierarchy so that no actual sensory percepts is obtained. Also imagined motor actions would be similar.

   An essential element of the model is that the sensory input is transformed to dark photons beams propagating along flux tubes parallel to axons and being responsible for the communications. The function of nerve pulses would be creation of communication channels by connecting flux tubes associated with axons to longer structures: neural transmitters and various information molecules would do this connecting. Situation would be very much analogous to that in mobile phone communications.

   The notion of re-incarnation is certainly the most controversial aspect of the proposed vision. TGD predicts self hierarchy and sub-selves are identified as mental images so that one can look whether re-incarnation hypothesis makes sense for them. After images appearing periodically would be examples of this kind of mental images: they would be conscious to us and correspond to the level of self hierarchy immediately below us. Since they are typically of different color than the original image, we know that they do not represent a real object. The periods without after image would correspond to the phase conjugates of these mental images and would be un-conscious to us. Essentially a sequence of re-incarnations of mental image would be in question.

3. How can subject person (identifiable as MB!) actively choose the target of the memory recall? In the experiment considered the two pictures were seen by the subject person for a time not longer than $T = 20$ seconds. Both generate a hologram like structure in visual cortex which in good approximation are disjoint patterns of neural activity - presumably regions of coherence induced by quantum coherence of the dark reference beam.

   A conscious choise associated with the memory recall requires that the two areas are labelled by some control parameter which MB can vary. Fixing this parameter directs the attention of MB to either picture. The frequency of the laser beam is the only parameter available. Incoming beam of light corresponds to the energies of visible light and for the ordinary value of Planck constant one cannot vary the frequency. There is however EEG frequency, which can be varied but its ratio to the frequency of visible light is of order 10^{-14} for 10 Hz! The energy $E = hf$ of EEG photons is extremely small and EEG photons should have absolutely no effects on brain or correlate with the contents of consciousness. We however know that it does!

In TGD framework this fact was the original motivation for the hierarchy of Planck constants for which adelic physics [L40, L39] provides a mathematical justification. The choice of the picture to be imagined/attended by MB would mean that the value of h_{eff} associated with it changes. The chosen picture naturally corresponds to a larger value of Planck constant since the maximal conscious information content of the system increases as h_{eff} increase. The increase of h_{eff} requires metabolic energy as directed attention certainly indeed does.

EEG also requires metabolic energy and it would be non-sensical to send information to outer space without any receiver: MB is the natural receiver of this information.

4. A more refined view about memory recall motivated by the second article described above [J71] involves a hierarchical structure in which memory recall is built up so that first the "gist" of the pattern is recalled and then come the details. This is the opposite of what happens in sensory perception in which features are identified first and the holistic view emerges later.

   TGD predicts self hierarchies labelled by the values of h_{eff} and by p-adic length scales. The higher the level of self hierarchy, the longer the corresponding length scale. The "gist" corresponds to large values of h_{eff} and low EEG frequencies whereas details correspond to smaller values of h_{eff} and higher EEG frequencies and smaller wavelengths for ordinary photons. The construction of the memory mental images would correspond to a cascade of state function reductions proceeding from long to short length scales and beginning from largest value of h_{eff} involved. The model for what happens in state function reduction in TGD framework assumes this cascade [K41] [L42] (see `http://tinyurl.com/yyv3v9u8` and `http://tinyurl.com/ycxm2tpd`).

5. It is essential that sensory input is transformed to dark photons at sensory organs propagating to the brain: this also makes the processing of sensory information fast and sensory mental images can be built as standardized mental images - pattern recognition - by forth-and-back signalling between brain and sensory organ combining artificial sensory input from brain with genuine sensory input. It is hard to imagine anything simpler!

6. Neural activity associated with the neural percept preserves the topography of the visual percept so that the shape of the firing pattern in cortex is same as that of object. This cannot be however used as an objection against holography since it is the reading of the neural hologram which generates the image of the object. The topography of the hologram has nothing to do with the shape of the object.

This mechanism should generalize to the case of sensory perception and motor action as its time reversal. MB as an intentional agent would be sending reference beams and their phase conjugates at various frequencies f and values of h_{eff} serving as control knobs! The details are however far from clear. At least to me, it is very difficult to gain detailed understanding. This is to be expected, since our standard intuition of time relies on preferred arrow of time and on the identification of the experienced and geometric time. The following is one particular humble attempt.

1. Are motor action and sensory perception really mirror images as has been assumed hitherto so? The differences between them would be only relative and they would change their roles as the arrow of time is changed?

   Or could it be that the difference is absolute? Motor actions would correspond to BSRs and change the arrow of time. Sensory percepts would correspond to SRSs and preserve the arrow of time. The latter interpretation looks more natural and is consistent with the earlier intuitive but not precise enough view deduced from Libet's findings that sensory percept and motor action correspond to different arrows of time. Let us assume the latter option.

2. Sensory representation, hologram H is formed using reference beam R and object beam O entering to the active boundary of CD. Sensory experience, "reading" of H, is achieved by applying R to H. Subsequent SRSs correspond to R.

It does not make sense to apply time reversal $\overline{R}$ to H: here the situation differs from that for the ordinary holograms. $\overline{R}$ can be applied only to $\overline{H}$ and would require BSR replacing H with its phase conjugate $\overline{H}$.

If this picture is correct, one would say that the basic activities are printing to make H and reading of H using R. The triplet $\{R, O, H\}$ would be characterize the situation.

The formation of H would be like printing and the application of R to it is like reading of the text. R must correspond to a SRS at the active boundary of CD.

3. Motor representation $\overline{H}$ formed using $\overline{R}$ and conjugate object beam $\overline{O}$ at opposite boundary of CD being now active would be sensory representation in our geometric past having opposite arrow of time. The hypothesis is that what is conscious $\overline{T}$ is unconscious-to-us.

   Our sensory percepts would reflect the motor actions of our temporal mirror image. This motor action has changed the arrow of time for sub-self to that for us and the signals coming from past are passively experienced by us.

4. Our (MB's) motor action - volitional act - involves BSR at some - presumably nearest - level of self hierarchy below us (MB) changing the roles of boundaries of sub-CD in question. At this level the receiver of sensory input is in the geometric past and memory is formed by $\overline{R}$ but as such is not conscious-to-us: this conforms with the findings of the articles. Only the next big state function reduction makes the memory conscious-to-us as sensory or possibly verbal memory and we can read it by making SRSs.

5. The application of $\overline{R}$ to time reversed mental image (conjugate sub-self) $\overline{H}$ would be unconscious memory for us. It would become conscious in BSR for it producing memory at our level: this conforms with the findings of the articles. The application of R to time mental image (sub-self) would be conscious-to-us precognition or sensory experience. Sensory experience are indeed known to be also predictions as is natural in ZEO in which quantum states are superpositions of entire deterministic classical time evolutions.

Needless to add that this view is only a sketch. It is good to list the key assumptions.

1. BSRs correspond to motor actions and SRSs to sensory percepts including precognition.

2. Sub-selves with same time orientation are conscious to use but not their conjugates. I do not have a really good argument for why time reversed mental images should be unconscious-to-us.

3. Only R can be applied to hologram but not $\overline{R}$ as for ordinary holograms.

Could one demonstrate experimentally that the standard view about time is wrong?

The prevailing view in neuroscience and physics identifies experienced time with geometric time despite the fact that these two times have very different properties. In TGD framework these times are not identified but are closely correlated. TGD inspired theory of consciousness based on zero energy ontology (ZEO) [L42, L52] [K7] allows to understand the relationship between the two times and leads to rather dramatic predictions.

TGD interpretation says that in the act of free will MB sends phase conjugate signal to the brain of geometric past or stating it otherwise: replaces the deterministic time evolution of brain (and also its past) with a new one (strictly speaking, replaces their quantum superposition with a new one). This should happen also in the choice of which picture is to be imagined.

Could a modification of the experiment of [J85] replacing imagination with an activity not requiring memory recall allow to demonstrate that the standard view about time is wrong?

1. Consider a thought experiment experiment in which the subject person receives a stimulus and makes a decision to do something - not imagine but something else - during some time interval T after it. Suppose that the decision is found to be preceded by neural activity before the stimulus appears.

   Standard view about time not does allow this since person could have decided about the reaction to the stimulus before it came (precognition would be the only explanation).

TGD view about the relationship between subjective and geometric time allows this since the decision sends signal to the brain of the past and there is no reason why the moment in past could be before the stimulus.

2. The modification of the above experiment in this manner could mean the reduction of $T = 20$ seconds to - say - $T = 9$ seconds. If the neural activity would appear say $t = 11$ second earlier it would emerge before person has seen the pictures and one would have paradox for standard view about time. However, if the imagined picture relies on memory, this should not happen.

Chapter 8

Quantum Statistical Brain

8.1 Introduction

The considerations of this chapter were inspired by two popular articles. The first popular article (`https://cutt.ly/1IM14xa`) told about findings [J47] (`https://cutt.ly/aIM0ajF`) of Li *et al* supporting the view that neural noise carries information in the sense that it represents the uncertainty of visual short term memories so that both the content of memory and its uncertainty are represesented.

Second inspiring popular article published in Science Times (`https://cutt.ly/iONjRI2`) had a long title "*Are We Living In the Past? New Study Shows Brain Acts Like A Time Machine That Brings Us 15 Seconds Back*". It caught my attention because the basic prediction of TGD inspired theory of consciousness is that the perceptive field is 4-dimensional rather than 3-D time=constant snapshot as in standard neuroscience.

The original article by Mauro Manassi and David Whitney, published in Science Advances [J74] (`https://cutt.ly/lONjIQn`), has a less provocative title "*Illusion of visual stability through active perceptual serial dependence*". The findings suggest that visual perception is a kind of temporal average over a time interval, which can be even longer than 15 seconds.

8.1.1 The findings of Li *et al*

Does neural noise carry information about the uncertainty of visual short term memories?

The highlights of Li *et al* are following:

- Humans know the uncertainty of their working memory and use it to make decisions.
- The content and the uncertainty of working memory can be decoded from so called BOLD signals.
- Decoding errors predict memory errors at the single-trial level.
- Decoded uncertainty correlates with behavioral reports of working memory uncertainty.

The abstract of the article provides an overall view about what has been done and found.

Neural representations of visual working memory (VWM) are noisy, and thus, decisions based on VWM are inevitably subject to uncertainty. However, the mechanisms by which the brain simultaneously represents the content and uncertainty of memory remain largely unknown. Here, inspired by the theory of probabilistic population codes, we test the hypothesis that the human brain represents an item maintained in VWM as a probability distribution over stimulus feature space, thereby capturing both its content and uncertainty.
We used a neural generative model to decode probability distributions over memorized locations from fMRI activation patterns. We found that the mean of the probability distribution decoded from retinotopic cortical areas predicted memory reports on a trial-by-trial basis. Moreover, in several of the same mid-dorsal stream areas, the spread of the distribution predicted subjective trial-by-trial uncertainty judgements. These results provide evidence that VWM content and uncertainty are jointly represented by probabilistic neural codes.

It is not surprising that the states of feature detector neurons should obey a statistical distribution. It is however not obvious that the reliability of the memory should correlate with the width of this distribution and that even the subjective estimate for the reliability should reflect this width.

Does the distribution in the feature space reflect quantum non-determinism?

Could the distribution in the feature space reflect quantum non-determinism rather than uncertainty of sensory perceptions and somehow also the uncertainty of memories.

1. If features as states of feature detector neurons or groups of them correspond to the outcomes of quantum measurements, they have a probability distribution. The real input to these neutron would have produced this distribution and could be estimated from the probability distribution.

   The outcomes are eigenstates of density matrix determined by the entanglement and determined apart from phase factors. For instance, in the measurement of spin of spin 1/2 particle the probabilities of spin 1/2 and spin -1/2 states can be deduced for an ensemble of identical particles but the relative phase of the spin 1/2 and spin -1/2 state cannot be deduced.

2. The interpretation of quantum measurement would differ from the classical one. Classically, and according to recent neuroscience, sensory perception means that brain, system A, detects the state of system B in the external world. Quantum mechanically, the entanglement between A and B is reduced in the measurement and entangled state becomes a tensor product of are eigenstates of the density matrix. The relationship between A and B is what is "measured". For an ensemble of outcomes, the probabilities of outcomes allow to deduce information about the entanglement before measurement.

3. If the reduction of the entanglement between sensory organ and external world can be measured repeatedly, it gives rise to a distribution of outcomes coding also the uncertainty caused by the quantum measurement. This however requires that the entanglement is regenerated between these measurements. Is this possible?

The distribution of features would not reflect uncertainty of memories but the non-determinism of the outcome in the reduction of entanglement. Interestingly, in quantum computation this kind of ensemble is produced and from the distribution of outcomes of the measurement halting the quantum computation, the outcome of the quantum computation is deduced. The method is essentually statistical.

In TGD framework the notion of magnetic body (MB) using biological body as sensory receptor and motor instrument emerges as a new notion. The entanglement between magnetic body and sensory organs could be reduced in sensory perception. There is a hierarchy of levels and entanglements at them and SFR is replaed with a cascade of SFRs proceeding from long to short scales.

Is the feature distribution realized as a temporal ensemble?

In sensory perception, the distribution of features should correspond to a distribution of states of feature detector neurons or their groups. How is this distribution realized? How does this distribution relate to the distribution of memories?

Let us consider the questions about sensory perceptions.

1. The neuroscience based answer to question in the case of sensory perceptions would be "As a spatial ensemble consisting of feature neurons". But how does this distribution relate to the distribution of memories?

2. In TGD framework, the answer would be "As a temporal ensemble". Zero energy ontology (ZEO) leads to a new view about quantum states as superpositions of deterministic time evolutions and modifies the view about quantum measurements allowing to circumvent the basic paradox of quantum measurement theory leading to various interpretations.

   The outcome is the notion of 4-D brain, which suggests a temporal ansemble formed by memory mental images of the feature. In ZEO, the sequences of "small" state function reductions (SSFRs) as counterparts of so called weak measurements would form temporal ensembles of memory mental images so that the connection with short term memory would be direct. The spatial ensemble would be replaed by temporal ensemble experienced consciously as memories.

8.1.2 The findings of Manassi and Whitney

"Why do the objects in the world appear to be so stable despite constant changes in their retinal images?" was the question that motivated the work of Manassi and Whitney [J74] (`https://cutt.ly/lONjIQn`). Retinal images continuously fluctuate because of sources of internal and external noise. Retinal image motion, occlusions and discontinuities, lighting changes, and perspective changes and many other sources of noise are present. However, the objects do not appear to jitter, fluctuate, or change identity from moment to moment. Why does the perceived world change smoothly over time although the real world does not?

This problem is also encountered in quantum consciousness theories. If conscious experience consists of a sequence of non-deterministic quantum jumps as moments of consciousness, it is not at all clear how a smooth stream of consciousness is possible.

One modern explanation for the smoothness of conscious experience is some kind of change blindness or inattentional blindness. The finite capacity of visual short-term memory is certainly a fact and forces a finite perceptive resolution and effectively eliminates too fast temporal gradients. This finite resolution poses limits in perceptual, decisional and memory processing. This would naturally apply also to other sensory memories.

In the standard view sensory percept corresponds to a time=constant snapshot of the physical world. The basic prediction is that the object at a given moment of time is the real object but in a finite perceptive resolution.

The alternative hypothesis studied in the article is that the visual system, and presumably also other sensory systems, use an active stabilization mechanism, which manifests as a serial dependence in perceptual judgments. Serial dependence causes objects at any moment to be misperceived as being more similar to those in the recent past. The serial dependence has been reported in the appearance of objects, perceptual decisions about objects, and the memories about objects. In all of these examples, serial dependence is found for random or unpredictable sequential images.

This raises the question whether one can understand the serial dependence by identifying the conscious perception at a given time as a weighted temporal average of preceding time= constant perceptions over some time interval T and what additional assumptions are needed to understand the other findings related to the phenomenon. This is what the model explaining the findings of Li *et al* indeed suggests.

8.1.3 TGD based view about sensations and short term memories

To develop a more detailed model based on the proposed ideas, one must answer several questions in the TGD framework. What sensory experiences, perceptions, and features are in TGD Universe? What could the phrase "statistical ensemble of features" mean? What does sensory perception as a quantum measurement and quantum measurement itself correspond to?

The notions of sensation, perception, and feature

Sensation as the core of sensory experience must be distinguished from perception. Sensation is just the sensory awareness with nothing added. Perception involves a cognitive representation providing an interpretation of perception and consists of objects and the associations and memories associated with them.

Brain is believed to analyze the sensory input from the sensory organs to features. Features are just those aspects of the input that are relevant to survival or target of attention. Neutrons serve as feature detectors (`https://cutt.ly/vIM0bqB`).

This deconstruction process is followed by reconstruction which proceeds upwards from features to objects of the perceptive field so that the perceptive field decomposes to standardized mental images representing objects with various attributes, orientation and motion are such attributes. This is basically pattern recognition. Features are basic building bricks of the sensory mental images and not necessarily conscious to us.

The reconstruction process is analogous to first drawing a simple drawing consisting of lines and then gradually filling the picture by adding colors with varying intensities. Something analogous happens also when the sound-scape of a movie is constructed. One starts from the actual sound-scape but the outcome is quite different and very far from the original. One could say that sensory perception is essentially an artwork.

In the mathematical modeling, one can speak of a feature space. Features have attributes and the claim of the article discussed is that one can assign to features a probability distribution. Brain would not only build features but also represent this probability distribution making it possible to estimate the reliability of the visual short memory. It is however not clear how the distribution gives rise to a conscious experience about reliability and how the short term memory relates to the sensory perception.

Ensemble of features as temporal ensemble of memory mental images?

The probability distribution for features should be realized somehow as a statistical ensemble. One can consider two alternative options.

1. In the standard physics framework spatial ensemble seems to be the only possible realization. The perception would be represented as a large number of copies. The fact that the inputs in the retina are mapped in a topographic way to various parts of the visual cortex poses strong constraints on the number and location of the copies. If there is a spatial ensemble its neurons should form groups of neary neurons. The problem is how the distribution of features in this ensemble can code for the reliability of sensory or memory mental images and this requires a theory of consciousness.

2. In the TGD framework, the brain is 4-D and it makes sense to speak of a temporal ensemble of memory mental images. These temporal ensembles would correspond to temporal sequences of memory mental images and the distribution aspect would be automatically realized. The variance of this distribution would provide conscious experience about the reliability of the mental images. The natural interpretation would be in terms of short term memory.

For the TGD option, the sensory input to the sensory organ, say retina, would generate a temporal ensemble of visual mental images making possible short term memory. This ensemble would be characterized by a probability distribution. The probability distribution for the states of feature neurons would be a neuronal level example of this kind of distribution. Variance would be one characteristic of this distribution and characterize the reliability of short term memory. Sensory perceptions would give rise to short term memories.

Many questions remain to be answered. How are these memory mental images generated in quantum measurements? How does the memory recall of long term memory generate a short term memory represented as a temporal ensemble of visual mental images?

1. For instance, in the memory recall of a phone number, long term memory is involved. Somehow the memory recall creates "almost" sensory, that is virtual, perception, which suggests that a virtual sensory input from MB is involved and creates a virtual sensory perception giving rise to a visual short term memory.

2. In the TGD framework, these virtual sensory perceptions would also make possible imagination. The virtual sensory input would come from MB to cortex and proceed to the lower levels of the brain but would not reach sensory organs except during dreams, hallucinatory states, and sensory memories (memory feats of idiot savants).

3. The sensation associated with the sensory experience would correspond to a state function reduction (SFR) occurring in quantum measurement. But what does SFR correspond to in TGD?

   In the zero energy ontology (ZEO), the notion of SFR generalizes. The are two kinds of SFRs: "big" SFRS (BSFRs) as analogs of ordinary quantum measurements in which a large change is possible and "small" SFRs (SSFRs) as analogs of so called weak measurements, which are assumed in quantum optics but are not very-well defined in the standard quantum theory and do not appear in the text books.

   SSFRs relate closely to the Zeno effect which states that the state of the physical system remains unaffected if the same measurement is repeated. In reality this is not quite true, and the sequence of SSFRs represents a generalization of a repeated quantum measurement allowing us to understand what really happens.

   Sensory perception would be repetition of SSFRs following analogs of unitary time evolutions and would produce an temporal ensemble of sensory mental images giving rise to short term memory. The system would be measured, it would return back to almost its original state and would be measured again. SSFR is almost a classical measurement.

In the sequel the above summarized view is discussed in more detail. Three sections are devoted to TGD inspired theory of consciousness, quantum biology and quantum brain. A more extensive discussion can be found in [L100]. In the next section a model for the generation of sensory perception and short term memory explaining the findings of Li *et al* [J47] is considered. The last section discusses the model explaining the findings of Manassi and Whitney [J74].

8.2 TGD inspired theory of consciousness briefly

TGD inspired theory of consciousness can be regarded as an extension of quantum measurement theory to a theory of consciousness that relies on Zero Energy Ontology (ZEO) [L96].

8.2.1 Conditions satisfied by the theory of consciousness

Any quantum theory of consciousness must be consistent with existing physics. Since existing physics cannot explain biological phenomena and consciousness, a theory explaining them is bound to predict some new physics.

The new theory must solve the basic problems intractable to current theoretical physics. Many of these problems are philosophical. This theory should also be applicable to quantum biology and neuroscience and answer at least the following questions.

1. In everyday life everyone, even a strict physicalist, will in their subjective experience, regard free will as real, but in the role of natural scientist, deny it since it is inconsistent with the determinism of classical physics. Could the underlying view of time be wrong? Could free will be consistent with deterministic field equations after all?

   It seems that behavior is built from deterministic time evolutions connecting initial and final states. Biological functions, behaviors, and computer programs represent good examples

of this. Could free will be in the selection between deterministic time evolutions. These questions suggest a new ontology in which a deterministic classical time evolution becomes the basic entity instead of the time=constant snapshot of time evolution central to the standard ontology.

2. A similar problem plagues quantum measurement theory. The state function reduction (SFR) is non-deterministic whereas the Schrödinger equation is deterministic. This has led to myriads of "interpretations". This problem is analogous to the conflict between free will and classical deterministic physics.

   It is easy to trace the origin of the problem. In standard quantum theory the observer can affect the measured system but still remains an outsider. A quantum theory of consciousness would generalize quantum measurement theory. The notion of "self" as part of a system would replace that of "observer".

   Quantum coherence is assumed to be possible only at very short scales. Coherence of biological systems, however, suggests this assumption is wrong. There is also the question whether there is some scale at which quantum behavior transforms to classical behavior. This question has not been answered. Could the quantum world actually prevail at all scales and only appear as classical? Could discontinuous quantum jumps somehow look like deterministic and smooth classical time evolutions?

3. Experienced time and the geometric time of the physicist are very different. Subjective time however correlates with geometric time: contents of sensory experience correspond to a moment of geometric time within an accuracy of .1 second: one can speak of a sensory chronon. How should one distinguish between these two times?

4. Are there physical correlates for cognition and imagination? Could they be realized at the level of space-time?

5. What do life, death, and aging mean? Could they be universal notions applicable at all scales? Does consciousness survive after the cessation of bodily function in some sense? If this were the case, universality might make it possible to provide indirect, and yet convincing, evidence for life after death.

8.2.2 ZEO based quantum measurement theory extends to a theory of consciousness

ZEO based quantum measurement theory [L96] leads to a quantum theory of consciousness. In particular, the theory predicts that the arrow of time (AT) changes in "big" (ordinary) SFRs (BSFRs) as opposed to "small" SFRs (SSFRs) as the counterparts of "weak" measurements (`http://tinyurl.com/zt36hpb`).

BSFR suggests that self-organization (SO) at all scales partially reduces to dissipation with a reversed AT implied by the generalization of the second law of thermo-dynamics (SL).

1. SO always involves an energy feed. The energies of quantum states increase with $h_{eff} = nh_0$ and h_{eff} tends to be reduced spontaneously. The energy feed prevents this and hence the reduction of the universal "Intelligence Quotient" (IQ) as the dimension n of EQ characterizing the algebraic complexity of EQ and of a space-time surface [L90, L91]. This prevents also the reduction of the scale of quantum coherence. In biology this corresponds to the metabolic energy feed.

2. In ZEO, the energy feed necessary for SO could be partially replaced with an extraction of energy from the environment by dissipation in a reversed direction of time. The self-organizing system could effectively send negative energy to the environment.

   The basic signature is a generation of gradients in conflict with SL in its standard form. This conforms with what happens in SO but does not of course prove that SO is based solely on time reversed dissipation. Both the energy feed and the extraction of energy from the environment are involved.

For time reversed dissipation no specific mechanisms are required and only metabolic energy storages - systems able to receive the negative energy dissipated in a reversed time direction - are enough. Even thermal energy could be used and there is evidence for this [L133]. This inspires a totally new vision, not only of living matter, but also in regards to possible energy technologies.

3. Time reversals occur at very short time scales at the elementary particle level and for ordinary matter with $h_{eff} = h$). For MBs controlling ordinary matter, time reversals would have long lasting effects on ordinary matter as well.

   MB has an onion-like layered structure implied by the p-adic length scale hypothesis [K46] and h_{eff} hierarchy [L71]. Layers have sizes even larger than the size of the Earth. The slaving hierarchy formed by the layers of MB carrying dark matter could control the dynamics by inducing time reversals at the lower levels as BSFRs interpreted as generalized motor actions (master and slave are standard notions in the theory of SO). A given layer of MB is characterized by its size determined by a p-adic length scale characterizing flux tube thickness and by the value of h_{eff}.

ZEO

The TGD based view of consciousness relies on ZEO solving the basic paradox of quantum measurement theory. First, a brief summary of ZEO [L96] is required.

1. The notion of a causal diamond (CD) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms (3-D balls). The half-cones are mirror images of each other. CD=$cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2. The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics [L40])via the M^8-H duality [L79, L90, L91].

2. In the ZEO, quantum states are not 3-dimensional, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. By holography time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving AT that give rise to an analog of the Zeno effect (`https://cutt.ly/yl7oIUy`) [L96].

To avoid confusion, one may emphasize some aspects of ZEO.

1. ZEO does not mean that the physical states identified in standard quantum theory as 3-D time= constant snapshots - and assigned in ZEO to the opposite boundaries of a causal diamond (CD) - would have zero energy. Rather, these 3-D states have the same conserved quantities, such as energy. Conservation laws allow us to adopt the convention that the values of conserved quantities are opposite for these states so that their sum vanishes.

   This is not new: in quantum field theories (QFTs), one speaks, instead of incoming and outgoing particles, external particles arriving from the geometric past and future and having opposite signs of energy. That conserved quantities vanish in the *4-D* sense, expresses only the content of conservation laws. A weaker form of this condition [L103] states that the total conserved Poincare charges are opposite only at the limit of infinitely large CD. CD would be an analog of quantization volume in QFTs, whose finiteness implies a small conservation of momentum.

2. ZEO implies *two* times: subjective time as a sequence of quantum jumps and geometric time as a space-time coordinate: for instance, the proper time of the observer. Since subjective time does not correspond to a real continuum, these times are not identifiable but are strongly correlated. This correlation has led to their identification although they are different.

BSFR as death and reincarnation in universal sense

In BSFRs, AT is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. The BSFRs can occur at all scales since TGD predicts a hierarchy of effective Planck constants h_{eff} with arbitrarily large values. There is empirical support for BSFRs.

1. The findings of Minev *et al* [L66] for atomic systems can be explained by the same mechanism [L74]. BSFR replaces the zero energy state with a new one and changes the roles of the 3-D states (active and passive state) at the boundaries of CD.

   For an observer with a standard AT, the final zero energy state is a superposition of deterministic, smooth time evolutions leading to a fixed 3-D state at the formerly active boundary of CD. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution. The ZEO based interpretation is that a second BSFR as a return back to the initial state occurs.

2. Libet's experiments on the active aspects of consciousness [J18] can be understood from this perspective. For instance, a test subject raises his index finger and neural activity starts *before* the conscious decision to do so. In a physicalistic framework, neural activity leads to the experience of making the decision so that free will would not be real.

   Libet himself proposed what he called a veto option: free will is in the decision to stop the action already initiated. The problem with the veto option [J12] is that the activity beginning .5 seconds earlier looks like dissipation with a reversed AT. In the standard direction of time this looks like self-organization which leads from a chaotic state to an ordered state at around .15 seconds before the raising of the finger. The ZEO explanation is that a macroscopic BSFR occurred and generated a signal proceeding backwards in time which generated neural activity and dissipated to randomness.

3. An example from a different scale comes from earthquakes and supports universality. Earthquakes involve a strange anomaly: they are *preceded* by ELF radiation. One would expect that ELF radiation would follow the earthquake. In the TGD framework, the identification as BSFR can explain the anomaly [L75, L63].

   In biology, the reversals of AT may occur routinely [J68] and indeed are a central element of biological SO in the TGD framework. Time reversal also explains self-organized quantum criticality (SOQC) identifiable as the basic mechanism of homeostasis [L78, L133]. Homeostasis would occur spontaneously rather than being a result of programming.

Sequence of SSFRs as life cycle

SSFRs are counterparts of "weak" measurements, which are much like classical measurements and do not involve any dramatic changes. The sequence of SSFRs gives rise to a conscious entity - self - as a sequence of moments of consciousness. Subjective time as a sequence of SSFRs correlates with the geometric time for which one identification is as the distance T between the tips of CD, whose size increases statistically.

1. In SSFRs [L94] members of states at the "passive" boundary (PB) of the CD are not changed and PB itself is not shifted although it increases in size. The active boundary (AB) recedes from PB and increases in size in a statistical sense. Also, the states at AB change by unitary time evolutions followed by SSFRs that do not affect the states at PB.

   SSFRs correspond to a measurement of observables whose action does not affect the states at PB. Cognitive measurements are excellent candidates for these kind of measurements [L94]. The time T identified as the temporal distance between the tips increases in a statistical sense and correlates with the subjective time identified as a sequence of SSFRs.

2. The identification of a "geometric now" as a correlate of "subjective now" is not unique. The most natural identification of the geometric time is as the linear M^4 time coordinate assignable with the line connecting the tips of CD. The "geometric now" would correspond to the $T_{now} = T/2$ which corresponds to a 3-D ball (not a 2-D sphere, which is its boundary)

at which the expansion of 3-ball with light-velocity changes to contraction - the analogy with the Big Bang followed by the Big Crunch is obvious. T_{now} increases in a statistical sense.

3. $M^8 - H$ duality predicts that the roots r_n of the real polynomial P define special moments $t = r_n$ of M^4 linear time: I have called them "very special moments in the life of self" [L34, L35, L36, L68, L90, L91]. If these moments correspond to the values of T_{now} for SSFRs, the size of CD increases in a step-wise manner.

4. The Lorentz invariant light-cone proper time "a" labeling the hyperboloids inside the lower and upper half-cones of the $CD \subset H = M^4 \times CP_2$ is the second natural candidate for the geometric time coordinate and is completely analogous to cosmic time. It reduces in a good approximation to "t" near the time axis connecting the tips of CD.

   This picture applies at the level of H. $M^8 - H$ duality [L90, L91] forces also consider the M^8 level. M^8 is analogous to momentum space: there is no time and space in the usual sense. Could the claims of timeless and spaceless states of consciousness correspond to the M^8 mode? In momentum space, time and spatial coordinates are replaced with energy and momenta.

$M^8 - H$ duality leads to a more detailed picture of the evolution of self. One may consider first what the evolution of self looks like geometrically.

1. A given space-time surface in M^8 is determined in terms of an octonionic polynomial $P(o)$ obtained by algebraically continuing a real polynomial $P(x)$ with rational coefficients (so that p-adic variants of the space-time surface exist). $P(o)$ is decomposed to quaternion valued "real" and "imaginary" parts and the space-time surface corresponds to a root for the real part of $P(o)$ [L68, L90, L91].

   The associativity of the normal space of the space-time surface is the number theoretical dynamic principle. It implies that space-time surfaces are minimal surfaces. Also their counterparts in $H = M^4 \times CP_2$ - obtained by $M^8 - H$ duality - are minimal surfaces geometrizing the massless wave equation.

2. One can assign to the half-cones of the CD distinct polynomials which must be identical at $t = T/2$. The condition is satisfied if the polynomials are $P(o)$ for the "lower" half-cone and $P(T - o)$ for the "upper" half-cone. The space-time surfaces associated with the half-cones are in well-defined sense mirror images glued together at $T_{geom} = T/2$. This is not however the case for the space-time surfaces assignable to sub-CDs of CD interpreted as correlates of the mental images of the self assignable to CD.

This proposal has strong implications.

1. The evolution by steps consisting of unitary time evolution+SSFR increases the size of CD in a statistical sense (the number of CDs larger than the given CD is infinitely larger than those smaller than it). PB remains unaffected apart from scaling. Hence the size of the region of space-time surface identified as a "root" of the real part of P, increases: more of the surface determined by P becomes visible in each SSFR. This is like opening a packet containing a gift. Each "very special moment" $t = r_n$ brings something new in light.

2. At $T_{now} = T/2$ the sensory input from the geometric past induces sensory mental images drifting to the geometric future and gives rise to memory mental images assignable to sub-CDs. Contrary to a naive expectation, memory mental images indeed drift to the geometric future of T_{now} as the size of CD increases rather than remaining in the geometric past. The emergence of these sub-CDs in shorter scales breaks the mirror symmetry between half-cones.

   This makes it possible to learn from experiences during a given life cycle and utilize that learning during the next life cycle with an opposite AT. In the BSFR, AB becomes passive and these memory mental images become the "silent wisdom" for the time reversed self representing what was learned during the previous life cycle.

ZEO and planned actions

ZEO also provides a model for planned actions. To understand the basic idea, it is good to first describe a strange finding by Armor and Sackett [J16] and its TGD based explanation.

1. Armor and Sackett made a surprising discovery: the prediction of what happens in a future event is more reliable if the person knows that the event will actually occur. The future event was a scavenger hunt and the participant had to predict her performance defined as the number of items to be found. The participants who knew that the event would actually take place, made better predictions.

   Did the participants precognize their performance as passive spectators of themselves in the geometric future so that free will would be an illusion? This need not be the case: the information was about the number of items found and rather abstract. This did not fix the detailed behavior of the participant in the hunt.

2. Reference [L137] shows that the finding actually fits with the vision in which BSFRs occur as cascades which proceed from long to short scales. MBs represent a hierarchy of abstractions about the lowest level. The higher the level, the less detailed the information [L89]. Only this abstract information can be pre-determined.

   The BSFR for MB_2 above MB_1 in the hierarchy - the "boss" - corresponds to a time scale $T_2 > T_1$ and determines the fate of MB_1 in the time scale T_2. MB_1 can apply its free will in the time scale T_1 in the limits posed by its fate. This paradoxical finding makes the distinction between subjective and geometric time very concrete. The fate of the subject person MB_1 is to some degree determined by BSFR of MB_2. With respect subjective (geometric) time, this BSFR occurred *before* (*after*)MB_1 made the prediction.

   This a supports the idea of the organizer of the experiment to perform the experiment was actually communicated by MB_2 to the experimenter. Thus she only actualized her fate.

Could most, if not all, planned actions be like this - induced by BSFR of MB_2 in the geometric future, but in the subjective past (of MB_1)? This would allow for more detailed planning at the level of MB_1. There would be the experience of planning and a realization induced by the signals from the geometric future sent by a higher level in the hierarchy of conscious entities! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than as agents with completely free will.

1. Ordinary matter is at the bottom of the master slave hierarchy and its coherence is forced by the quantum coherence at higher levels MB layers.

2. The BSFR for a higher level MB gives rise to what is experienced as a planned action at the lower levels of the hierarchy. Planned action at a given level induces a cascade of planned actions in shorter time scales which eventually proceed to the atomic level.

3. Sensory perceptions and motor actions would be universal. Sensory perceptions naturally correspond to SSFRs "weak" measurements (`http://tinyurl.com/zt36hpb`), and both BSFRs and SSFRs can occur with both arrows of time. Motor action is identifiable as a cascade of BSFRs, with each BSFR inducing sensory perceptions as SSFRs at lower levels. These would, in turn, induce motor actions as BSFRs in shorter time and length scales.

8.2.3 Negentropy Maximization Principle (NMP) as variational principle of consciousness

Negentropy Maximization Principle (NMP) defines the variational principle of consciousness in TGD [K41] [L105].

1. NMP replaces the second law (SL) and implies it for ordinary matter. SFR means a reduction of the entanglement for a pair $S_a - S_b$ of sub-system S_a and S_b, its complement in S. Instead of a single measurement, there is a measurement cascade, proceeding from long to short scales. At each step a system decomposes to a pair of unentangled subsystems. NMP states that the negentropy gain in each step is maximized and selects the pair $S_a - S_b$ at each step. This process can be visualized by a tree diagram.

2. In adelic physics [L39, L43] the entropy $N = -S_1 - S_2$ is the sum of real and various p-adic negentropies. p-Adic negentropies can be positive so that for non-trivial EQs one can have $N > 0$. Negentropic entanglement (NE) is stable against NMP so that the process stops. It is natural to assign positively colored emotions to NE. One can also say that NE distinguishes between living and inanimate matter and between dark and ordinary matter.

NMP as a generalization of the second law of thermo-dynamics

On the basis of empirical facts, Jeremy England [I24] has proposed that SL implies evolution. This statement seems to be in conflict with the standard thermodynamic view of biology [L22].

England's view that SL implies evolution, is clearly in error. NMP [L105] explains why England's paradoxical view is apparently true. A generalization of quantum measurement theory to a ZEO based theory of consciousness, and a number theory based view of cognition leading to adelic physics, is required to understand this misinterpretation.

1. SFR decomposes a given system (unentangled from the environment) to 2 subsystems in such a way that the negentropy gain is maximal for the "winning" decomposition. This corresponds to the quantum measurement of a universal observable, identified as the density matrix for the subsystem-complement pair.

2. TGD allows a genuine notion of negentropy assignable to entanglement and thus to the density matrix. The negative of the ordinary entanglement entropy $N = -S$ defines negentropy which at best is $N = 0$ since N is always non-positive.

   A genuine measure of information is needed. Since information is associated with cognition, one must expand the realm of physics to include cognition. One can also assign to the extensions of p-adic number fields an entanglement negentropy by the analog of a Shannon formula replacing logarithms of probabilities with the logarithms of their p-adic norms [K41] [L105].

   Remarkably, p-adic entropy can be negative and NMP mandates this. Furthermore, its magnitude is not smaller than that of real entropy. Therefore negentropy identified as the sum $N = -S_1 - S_2$ of real and p-adic entanglement negentropies can be positive for non-trivial EQs. N defines a genuine measure of information and, by NMP, increases during the life span of the conscious entity. This however implies the increase of real entanglement entropy [L22].

   p-Adic number fields, combining with real numbers to form an adele, are needed [L39, L43]. The algebraic extensions of p-adic number fields induced by EQs form an infinite hierarchy with increasing complexity which is identifiable as an evolutionary hierarchy. EQs emerge from $M^8 - H$ duality [L90, L91]. Space-time regions are determined by polynomials defining the EQs via their roots. Evolution as an increase of the dimension of EQ is unavoidable.

3. Consider now the connection with thermo-dynamics. When SFR occurs, entanglement entropy becomes zero, but ensemble entropy increases. That is, the outcome of measurement is not deterministic and reduction probabilities correspond to the eigenvalues of the density matrix. This means an increased thermo-dynamic entropy and generation of disorder.

   However, if the SFR cannot occur, entanglement is stable. For the negentropic states for which negentropy cannot decrease, NMP prevents SFR! The negentropic states approach cognitive fixed points and replace thermodynamic equilibria for which entanglement negentropy is maximum. The conscious entity maximizes its knowledge during its life-span quite universally: this applies to all systems at all scales, not only humans.

   For $h_{eff} = h_0$, NMP implies standard quantum measurement theory. Entanglement can be also non-negentropic for non-trivial EQs. In this case, NMP does not prevent complete de-entanglement from occurring and SL holds true. For dark matter with $h_{eff} > h$ NMP can, however, stabilize entanglement. This gives rise to a generation of conscious information. In summary, a pessimistic SL transforms to an optimistic NMP and implies SL for ordinary matter.

8.3 Some aspects of TGD inspired quantum biology

8.3.1 MB carrying dark matter as controller of ordinary biomatter

The TGD based quantum model for living matter relies heavily on the notions of MB carrying $h_{eff} > h$ phases behaving like dark matter and ZEO.

MB contains dark matter identified, as phases of ordinary matter characterized by EQ with a dimension $n = h_{eff}/h_0$ serving as a measure of the algebraic complexity of a given space-time region [L90, L91], and interpreted as a universal IQ. The scales of quantum coherence increase with h_{eff}. The layers of MB characterized by the value of n naturally form a master-slave hierarchy in which ordinary matter with the smallest Planck constant is at the bottom, and controlled by higher levels. The energies of systems increase with h_{eff} and since h_{eff} tends to be spontaneously reduced, an energy feed is needed to preserve the distribution of h_{eff}: the interpretation is as an analog of a metabolic energy feed.

MB acts as a "boss" controlling ordinary matter and induces self-organization [L78].

Anatomy of MB

MB has, as its body parts, magnetic flux quanta: flux tubes and flux sheets. There are two kinds of flux quanta. Flux can be vanishing, which corresponds to a Maxwellian regime. Flux can also be non-vanishing and quantized corresponding to a monopole flux. In the monopole case, the magnetic field requires no current for its creation. This option is not possible in the Maxwellian world. By fractality of the TGD Universe, these flux tubes play a key role at all scales [L76].

Also the Earth's magnetic field with nominal value of $B_E = .5$ Gauss has two parts.

1. The monopole flux part corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss and explains the strange effects of ELF EM radiation on the physiology and behavior of vertebrates [J24].

   The presence of this part explains the stability of the Earth's magnetic field. This field should have decayed long ago in a Maxwellian world since it is generated by currents which disappear.The contribution of the molten iron in the Earth's core to B_E decays but the changes of the orientation of B_{end} regenerate it [L87]. Also, magnetic fields that penetrate super-conductors as quantized fluxes and even those of permanent magnets (as opposed to electromagnets) may have a monopole part consisting of flux quanta.

2. The interaction of MB with the gravitational field of Earth is discussed in [L111]. Intriguingly, the metabolic energy currency with the nominal value of .5 eV is rather close to the energy for the escape velocity of a proton. Could the transfer of ions from the surface of the Earth to MB be a standard process?

Communications to and control by MB

Communication from the biological body (BB) to MB and its control by MB would rely on dark photons, which can transform to ordinary photons with a large h_{eff} and vice versa. Molecular transitions would represent one form of control.

1. Cell membranes could act as generalized Josephson junctions generating dark Josephson radiation with energies given by the sum $E_J + \Delta E_c$ of ordinary Josephson energy E_J and the difference ΔE_c of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential modulates the Josephson frequency and codes the sensory information at the cell membrane to a dark photon signal sent to MB.

2. The large effects of radiation at ELF frequencies observed by Blackman and others [J24] could be understood in terms of the cyclotron transitions in $B_{end} = .2$ Gauss if "h" in $E = hf$ is replaced with h_{eff}. h_{eff} should be rather large and possibly assignable to the gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. For the simplest model, M represents the Earth's mass coupling to the small mass m, and v_0 is a parameter with dimensions of velocity expected to have discrete spectrum. The energies $E = h_{eff}f$ of dark photons should be in the biophoton energy range (visible and UV) characterizing molecular transitions [K9, K14].

3. For the value $v_0/c \simeq 2^{-11}$, suggested by the Nottale's model for planetary orbits [E1], the predicted cyclotron energy scale is 3 orders of magnitude higher than the energy scale of visible photons. Several solutions of this problem were considered [L110, L101] . The most plausible solution is $\beta_0 = v_0/c = 1/2$ for living matter so that gravitational Compton length $\Lambda_{gr} = GM/\beta_0$ equals to Schwartschild radius at the surface of Earth. and brings nothing new to the original Nottale hypothesis.

By its higher level of "IQ", MB would naturally be the master controlling BB by cyclotron radiation - possibly via a genome accompanied by dark genome at flux tubes parallel to the DNA strands.

1. Cyclotron Bose-Einstein condensates (BECs) of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear as dark matter in living systems and the $h_{eff} = h_{gr}$ hypothesis predicts a universal cyclotron energy spectrum in the range of bio-photon energies.

2. Dark photons may transform to bio-photons [L7, L6] with energies covering the visible and UV energies associated with the transitions of bio-molecules. This control of biomolecules implies that remote mental interactions are routine in living matter. EEG signals would represent a particular instance of these communications: without the presence of MB it is difficult to understand why the brain would use such large amounts of energy to send signals to outer space.

3. In ZEO, the field body (FB) and MB correspond to 4-D rather than 3-D field patterns and quantum states correspond to quantum counterparts of behaviors and biological functions. Conscious holograms could be generated as a result of interference of a dark photon reference beam from MB and a dark photon beam carrying the sensory information. This hologram would be read by MB using the conjugate of the reference beam.

   In ZEO time reversals of these processes also take place. This makes it possible to understand memory as a result of communications with memory mental images (see section 8.2.2).

8.3.2 Adelic physics, cognition, and biology

$M^8 - H$ duality [L79, L90, L91] concretizes the number theoretic vision.

1. $M^8 - H$ duality states that space- times are representable as 4-D surfaces in either complexified M^8 (complexified octonions O_c) or $H = M^4 \times CP_2$. $n = h_{eff}/h_0$ has an interpretation as a dimension of EQ identifiable as the degree n of the polynomial determining the space-time surface in M^8. Roots correspond to different sheets of n-sheeted space-time surface, and the Galois group G of EQ permutes the sheets with each other and act as a number theoretic symmetry group. Dark matter states at the flux tubes define representations of G.

2. The wave functions in the set of space-time surfaces obtained by the action of G may be interpreted as functions in G defining the group algebra $L(G)$ of G. They define quantal cognitive representations. Also their fermionic counterparts make sense. Galois group G would thus act as the symmetry group of cognition. The notion of cognitive measurement in $L(G)$ makes sense and leads to a model of cognitive process as a cascade of cognitive SSFRs [L94, L105].

3. Galois confinement [L88] would force n-particle states to behave as coherent units like hadrons do as color-confined states.

4. The model makes rather far-reaching predictions. The decomposition of EQ to an extension of an extension of an extension ... of rationals defines a *finite* hierarchy of normal subgroups which in turn makes it possible to express the element of $L(G)$ as entangled products of states in the group algebras associated with the normal subgroups. Simple groups, whose classification is known, are groups which have no normal subgroups [L105, L103] so that this decomposition is trivial. Cognitive processes such as SSFR cascades are impossible for simple Galois groups - thus thinking as analysis is impossible. Could simple groups classify meditative states (or irreducible ideas as analogs of axioms)?

8.3.3 Genetic code (GC)

The model of bio-harmony [L15, L16, L77, L86, L102] is essential for the TGD based understanding of what might be called emotional intelligence (whose reality is accepted) and its relations with ordinary intelligence. The surprising outcomes are the connection with GC and the key role of bioharmony in quantum information processing in living matter.

1. The notion of bioharmony relies on icosahedral and tetrahedral geometries. The representation of the 12-note scale as a sequence of quints, reduced by an octave equivalence (notes differing by octave are experienced as equvalent) to the basic octave, defines the harmony for a given Hamiltonian cycle: the 20 allowed 3-chords of the icosahedral harmony correspond to the 20 triangular faces. The symmetries of the harmony are defined by some subgroup (Z_6,Z_4, or Z_2) of the icosahedral group.

2. Genetic codons correspond to dark photon triplets (3-chords of light) defined by the triangular faces of an icosahedron and tetrahedron. The counterparts of amino-acids are identified as orbits of 3-chords under the symmetries of a given harmony.

   Any combination of 3 icosahedral harmonies with 20 chords with symmetries Z_6, Z_4 and Z_2 and of the tetrahedral harmony with 4 chords gives a particular bioharmony with 20+20+20+4=64 chords assignable to DNA codons. DNA codons coding for a given amino acid correspond to the chords at the orbit of the symmetry group. Rather remarkably, the numbers of DNA codons coding for a given amino acid come out correctly.

3. Music expresses and creates emotions. Musical harmony codes for moods and emotions as holistic aspects of music. Bio-harmony with 64 3-chords, would assign the binary, local, aspects of information to the 6 bits of the codon and its holistic, emotional aspects to the bio-harmony. A chemical representation of the genetic code can thus correspond to several moods represented by bioharmony. In contrast with physicalism, emotions would appear already at the molecular level, and would have physical effects that are not reducible to bio-chemistry. This understanding is not possible without using the notion of MB.

   The model of bio-harmony requires that the values of B_{end} correspond to those associated with the Pythagorean scale definable by the quint cycle. These frequencies correspond to energies that a molecule must have in order to serve as a basic biomolecule. This criterion could select DNA, RNA, tRNA, and amino-acids.

In the second model of GC [L58], codons are represented as dark proton triplets.

1. The numbers of dark proton triplets turn out to correspond to numbers of DNA, RNA, tRNA codons, and amino acids. The numbers of DNA and RNA codons assignable to a given amino-acid in the vertebrate GC are correctly predicted. Genes would correspond to sequences of dark proton triplets [L77].

2. Dark proton triplet - dark codon - would be analogous to baryon and Galois confinement [L88] behaving like a single quantum unit. The N dark codons of a dark gene would, in turn, bind to Galois confined states of the Galois group of an EQ associated with the sequence of codons. An entire hierarchy of confinements is possible.

3. Galois confinement can be realized also for dark photon triplets and the sequences of N dark-photon triplets representing genes as dark $3N$-photon states. Genes could serve as addresses for communications based on dark $3N$-photon resonances.

   For communications between levels with the same value of h_{eff} there would be both energy and frequency resonance and for levels with different values of h_{eff} only the energy resonance. It is an open question whether dark $3N$-photons transforms to single ordinary photon or $3N$ ordinary photons (biophotons) in dark-ordinary communications.

4. The basic hypothesis is that both DNA, RNA, tRNA, and amino acids are paired with their dark analogs, and that energy resonance mediates the interaction between the members of pairs.

How could the icosahedra and tetrahedra be realized? Why must one glue them together? This looks aesthetically unappealing. However, surprisingly, both icosahedrons and tetrahedrons appear in, perhaps the simplest honeycomb of the hyperbolic 3-space H^3 (cosmic time = constant hyperboloid). H^3 is also central to special relativity and cosmology [L102]. Dark GC can be realized in terms of both dark protons and photons using this particular tessellation and would be universal. This master tessellation would induce sub-tessellations at the space-time surface, in particular representations of GC at magnetic flux tubes. Also 2-D and even 3-D representations of GC can be considered (i.e. cell membrane and microtubules) [L104].

8.4 TGD based view of brain

The TGD based view of the brain differs in several ways from the standard neuro-scientific model relying on materialism and reductionism [K38, K37]. The notion of MB as a controller of BB (biological body) forces us to abandon the idea of the brain as the sole seat of consciousness. Also the view of the role of nerve pulses is radically different.

8.4.1 MB and brain

In the TGD framework, the onion-like hierarchical structures of the MB of the brain would correspond to brain regions and provide an abstract map of the brain. The structure of MB with levels labelled by EQs partially characterized by $n = h_{eff}/h_0$ measuring the scale of quantum coherence, would also reflect the geometric and topological structure of the brain.

MB as a hierarchy of abstractions

There is evidence that functionally similar neurons can be modelled using statistically determined hyperbolic geometry [J38]. Functionally similar neurons not necessarily physically near to each other would be near to each other in the effective hyperbolic geometry.

MB could realize this hyperbolic geometry quite concretely as an abstract representation of the hierarchical functional structure of the brain [L89]. That is, functionally similar neurons and also higher level brain structures not near to each other in the brain would be connected to nearby points at MB by flux tubes. Classification, visualizable as putting similar things in the same box, is a basic cognitive function and the hierarchy of MBs could realize classification geometrically.

An astonishing finding supports this view. In the lab, the neurons of the brain of a salamander were shuffled like a pack of cards. The salamander however recovered and preserved its memories (identified as learned behaviors) [J83]. In [K55, K57] this finding was considered as a support for the view that the brain is analogous to a hologram (The TGD Universe can be seen as a conscious hologram [K10]). It seems, however, clear that a single neuron cannot represent the information content of the entire brain. However, if memories are represented by the images of neurons at the level of the MB, the shuffling of neurons has no effect on memories as the experiment indeed demonstrated. Neurons would be analogous to RAM in computer science.

Dark photons and communications and control

Communications both inside the central nervous system (CNS) and also from ordinary cells, could occur by dark cyclotron photon signals with $h_{eff}/h = n$ and light velocity. The value of h_{eff} could be considerably smaller than for the EEG communications from CNS to the large part of the MB. The value of h_{eff} could be estimated from the scaling up of cell length scale to a typical scale found in CNS. This iteration of back-and-forth communications makes pattern completion and recognition possible.

Dark photons could transform in an energy conserving manner to biophotons with energies in the visible and UV range (at least) and thus above thermal energy and therefore have effects that are not masked by thermal radiation. The brain is known to emit biophotons and they are also associated with axons [K14, K9].

Dark Josephson radiation would make information transfer to MB possible whereas the control signals from the MB would be as dark cyclotron photons.

1. Nerve pulse patterns modulate generalized Josephson frequencies for the flux tubes associated with the membrane proteins (such as ion channels and pumps) which act as generalized Josephson junctions. The sensory input is encoded by the Josephson radiation sent to the "big" part of MB [K24].

2. The frequency modulated Josephson radiation generated by nerve pulses would give rise to EEG (and perhaps also to its scaled variants) as a communication of information from the brain to MB via Josephson frequency modulation. In sharp contrast with the brain-centered neuroscience orthodoxy, the size scale of this layer of the MB would be rather large (i.e. of the order of c/f_c and given by the circumference of the Earth for the Schumann frequency $f_c \sim 7.8$ Hz). The structure of the Earth's magnetosphere suggests that both EEG bands and regions of BB correspond to regions of the magnetosphere [L101].

3. Nerve pulse patterns would code for information communicated to various layers of MB assignable to the EEG bands as a frequency modulated generalized Josephson radiation. Generalized Josephson frequency would be the sum of the ordinary Josephson frequency $f_J = ZeV/h_{eff}$ and the difference Δf_J of the cyclotron frequencies $f_c = ZeB/2\pi m$ for flux tubes at different sides of the neuronal membrane and transverse to it. The modulation of f_J by the nerve pulse patterns [K59, K24, K60] would code for sensory and cognitive information.

4. The frequency modulated dark photon radiation absorbed in cyclotron transitions at MB would generate a sequence of cyclotron resonances at MB, which code for sensory input.

   Already the modulation of the membrane potential at the basal ganglia of sensory receptors could communicate sensory information in this manner. If so, nerve pulse patterns could be a secondary representation of sensory information induced by the sequence of resonance peaks from MB back to the brain. This picture also applies to other forms of information (there are also basal ganglia inside the brain).

5. The dual representations of sensory information as resonance peaks and continuous Josephson radiation would be analogous to the local representation of a function provided by its values for a discrete sequence of time values, and to the holistic representation provided by its Fourier transform for a discrete set of frequencies.

MB controls BB and the motor output generated by the control signals from MB would act as "negative energy" signals with a reversed AT: two BSFRs are required to re-establish the original AT. The motor output of MB could take place via genes and induce gene expression as proteins.

Also other forms of gene expression such as as dark photon signals to the cell-/neuronal membranes could induce nerve pulse patterns.

The number theoretic vision suggests a considerable generalization of the idea of resonant communications [L136]. The model of Galois confinement (GC) based on the notion of bio-harmony [L15, L16, L86, L102] and the notion of GC [L94] suggests that dark $3N$-photon states, analogous to BECs, function as coherent dynamic units.

This inspires the notion of $3N$-resonance. Genes could be represented as sequences of N dark photon "3-chords" serving as addresses in dark $3N$-photon communications [L86, L102]. This picture leads to a model of human language [L134, L135].

8.4.2 General TGD view of sensory perception

The identification of sensory organs as seats of sensory qualia and a new view of the role of nerve pulses distinguish between the standard view of neuroscience and the TGD view.

Sensory organs as seats of sensory qualia

According to the TGD view, sensory perception generates sensory mental images at sensory organs rather than in the brain [L59]. This could solve some of the basic problems in neuroscience due to the similarity of neural tissue in various sensory areas. The basic objection is phantom limb

syndrome. The new view of time and memory implied by ZEO would solve this problem: the pain in the phantom limb would be a sensory memory of pain.

This view could solve several mysteries in neuroscience. The stimulation of temporal lobes indeed generates sensory memories, and people with cognitive impairment are known for memory feats such as being able to draw a building, seen in the past, in fine detail, or to learn entire works of music from a single listening.

1. These feats can be understood if the sensory memories and memories in general correspond to "seeing" in time direction.

2. The "obvious" interpretation would be that a beam of dark photons travels to the geometric *past*, is reflected back and produce memories as an analog of ordinary vision. Memories would be in the geometric past. However, on further consideration, the process seems to be more complex.

3. It is possible to build a rather detailed model for sensory memories [L92, L93] based on three ZEO and the notion of CD as a perceptive field of self at the level of embedding space. A crucial element is the identification of the geometric correlate of the "subjective now" (T_{now}) as the 3-D ball along which the half-cones of CD are glued together.

   Memories as mental images would correspond to sub-selves assigned to sub-CDs residing in the *geometric future* of T_{now} and shifting to the geometric *future* (!) during the sequence of SSFRs defining self and increasing the size of the CD and value of T_{now}. In the BSFR, identified as the death of self in a universal sense, these memories would become "silent wisdom" for the next life cycle with an opposite AT. Computer scientists would refer to this function as construction of log files.

New view of the role of nerve pulse transmission

Since perception is not mere passive reception of sensory input, but involves pattern recognition building standardized mental images, the TGD based view of sensory organs requires back and forth signaling between the brain and sensory organs. There should be a virtual sensory input from the sensory areas of the brain, or from MB via the brain, to sensory organs.

A sensory perception would be an actively constructed work of art, a standardized mental image, which is as near as possible to the sensory input. Pattern recognition would occur when the constructed pattern is sufficiently close to a standardized mental image.

The velocity of nerve pulse conduction is too slow to build a standardized sensory mental image by back and forth signalling. Nerve pulse duration of order of 1 ms defines the lower bound for the duration of the synaptic "bridge" making possible the propagation of dark photon signals. For a 10 cm long neural pathway this duration allows about 10^6 forth and back paths of light for a signal between the sensory cortex and retina.

The TGD view of sensory perception and the function of the nerve pulse transmission differs from the standard view. Nerve pulse conduction would not be communication between parts of the CNS but construction of "waveguides" for dark photons as connected flux tubes from axonal units [L59] [K59]. Nerve pulse patterns at the level of the brain would build standardized cognitive representations by decomposing the sensory input into "named" objects of a perceptive field from which associations could be built.

Sensory organs are seats of sensory qualia and sensory perception. This model explains REM dreams, hallucinations, and psychedelic experiences as experiences involving only the virtual input. Imagination can be understood as an "almost sensory" experience.

More concretely:

1. Sensory mental images at the level of sensory organs are generated by an iteration involving the virtual sensory input from the brain to the sensory organs [L59]. Pattern recognition is realized as a carving of a 4-D work of art representing a standardized mental image as near as possible to the original sensory input.

2. Nerve pulses would connect existing flux tubes parallel to axons to form longer flux tubes: neurotransmitters at synaptic contacts would act as relays. There is an obvious analogy with

an old fashioned telephone network. It would requiree too energy to keep all connections on all the time.

The meridians assigned with acupuncture network could correspond to a permanent flux tube network and would not require nerve pulses, transmitters, nor information molecules as relays. For CNS, this flux tube network would be dynamic. Plants would only have the meridian system.

3. The standard view of learning as a strengthening of synaptic connections translates into a gradual build-up of long-lived flux tube connections, which make possible dark photon communications. The sender and receiver neuron groups can also fuse to a single, quantum entangled, system.

4. Actually all information molecules (neural transmitters, hormones, and messenger molecules) could be connection builders. An alternative view is that information molecule such as hormone is attached to the end of a flux tube, which stretches as the molecule travels to the target.

   The same theory applies to water memory [K31], which remains a dismissed concept in mainstream science although the research performed outside the confines of institutional support has revealed much about the involved mechanisms.

Dreams, hallucinations, and imagination

TGD makes it possible to understand sensory imagination as virtual sensory inputs from MB via the brain, which do not reach sensory organs. Imagined motor actions as virtual motor actions would not reach muscles.

Virtual sensory inputs would be received by virtual sensory organs inside the brain. A good candidate is the basal ganglia. Ganglions are also associated with sensory receptors. The input from MB or brain would be represented as dark photons.

The notions of virtual sensory and motor input are central to the understanding of speech comprehension and also inner speech. Hallucinations, psychedelic experiences and REM dreams (motor activities during sleep) could be understood as virtual sensory (motor) inputs reaching the sensory organs (muscles). Memory recall could involve virtual (real in the case of sensory memories) sensory input from MB at which memory mental images are realized [L96, L68].

8.4.3 Memories

To understand what memories and memory recall could be in ZEO one must specify what the geometrical correlate of "subjective now" is.

"Geometric now" corresponds to the $T_{now} = T/2$ slice of CD with maximal size located in the middle of the CD. If one accepts $M^8 - H$ duality [L79] "geometric now" corresponds to a "special moment in the life of self" [L79, L95] identifiable as intersection of the space-time surface and a 6-sphere which is a brane-like entity (in the sense of branes encountered in M-theory) appearing as a universal special solution to algebraic equations determining the space-time surfaces in M^8_c. The special values of T_{now} would correspond to the roots of the real polynomial defining the space-time surface.

2. During the sequence of SFRs, AB shifts towards the geometric future and the size of CD increases (in the statistical sense). The sub-CDs accompanying sensory and other mental images shift in the direction of the geometric future as CD increases during the SFR sequence and become potential memory mental images experiencing BSFRs in a shorter time scale.

   The time=constant snap-shots at the upper half of CD assignable to the memory mental images are ordered with respect to Minkowski time t but the order is opposite to the order of subjective experiences. This makes possible for the time-reversed re-incarnate to have these memories as "silent wisdom". Snapshots correspond to subselves to which memory recall builds a connection by entanglement or by sending a signal, reflected back in a BSFR of the memory mental image.

How are episodic memories recalled in ZEO?

1. Spontaneous memory recall could correspond to the death of a memory mental image (sub-self/sub-CD) having the same AT as self (CD) followed by re-incarnation with an opposite AT. This would be accompanied by an emission of a past directed "negative energy" signal received by the self associated with the "geometric now". The interpretation is as an extraction of metabolic energy: memory recall indeed requires metabolic energy.

   Active memory recall could correspond to the receipt of a future directed "positive energy" signal by memory mental image arriving from the "geometric now", and allow interpretation as a metabolic energy feed. Reflection of the signal in opposite time direction requires BSFR. Why should BSFR happen? Could the metabolic energy feed induce (by NMP) rapid evolution and aging of the memory mental images leading to its death by BSFR.

2. The prediction is that in an active memory recall by a "positive energy" signals received by the memory sub-CDs, the order of recalled memories is opposite to that of the original experience. There is evidence for this kind of change [J71] (see also the popular article at `http://tinyurl.com/y7hbqmug`).

8.5 TGD inspired model for sensory perception and short term memory

The findings of [J47] suggesting a statistical representation of short memories allowing a conscious estimate of the reliability of the memories allow to develop a more detailed form about sensory perceptions based on the interpretation of short term memories as sequence of "small" state function reductions (SSFRs) following analogs of unitary time evolutions.

The identification of SSFRs as cognitive measurements is discussed in [L85] in the number theoretic vision about TGD. In [L98] the possibility that all SFRs, including also "big" SFRs (BSFRs) and even particle scattering events, could be interpreted as cognitive SFRs, is considered. This involves the notion of $M^8 - H$ duality meaning that space-time surfaces in H are images of 4-surfaces in M^8 analogous to momentum space under $M^8 - H$ duality. At the level of M^4 the physics is purely number theoretic.

1. The first implication is cognitive representation defined by points of 4-surface in M^8 for which coordinates representing components of momentum are algebraic integers for the extension of rationals defined by the polynomial defining the 4-surface in M^4. As a matter of fact, the points of cognitie representation belong to a mass shell of M^4 and active points of cognitive representation contain quark.

2. Second key implications is Galois confinement prividing a purely number theoretic mechanism for the formation of bound states [L109, L108]. In this article these aspects will not be discussed.

This picture leads to a highly detailed identification of scattering amplitudes [L98].

1. The interaction region of particle reaction can be interpreted as a cognitive process in which quarks of Galois singlets move freely and only re-organize to new Galois singlets. One might say that Nature is performing recombinatorics [L98].

2. Scattering interaction corresponds theoretically to a formation of a quantum superposition of functional composites of the polynomials associated with the external particles and a natural proposal is that the outgoing state corresponds to a product of the polynomials. Allowed functional compositions can differ only by a cyclic permutations of composite, which in dual string models and twistor Grassmann approach corresponds to allowance of only planar diagrams.

3. The cognitive measurement is identified as a cascade of measurements for a representation of a Galois group decomposing to a product of representations of its subgroups defined by its decomposition to an inclusion hierarchy of normal subgroups. Due to the inclusion hierarchy,

the quantum entanglements involved are directed and the natural interpretation is in terms of directed attention.

In [L107] a model of spin glasses is discussed and the proposal is made that the time evolution of spin glass corresponds to a sequence of analogs of unitary time evolutions followed by SSFRs.

1. The analog of unitary time evolution would correspond to a scaling rather than time translation as in standard quantum theory. This effectively replaces Minkowski time with its logarithm and predicts that decay rates obey power law rather than being exponential. The relaxation processes in spin glasses, which have a lot in common with living matter, indeed obey power law.

2. BSFRs would naturally correspond to time evolution as time translation and would give rise to exponential decay rates. If short term memory and sensory perception involves SSFRs, the prediction is that the decay of memories is not exponential but obeys power law.

8.5.1 How the sensory perception is formed?

The following represents a simple model for what might happen in sensory perception.

1. Sensory perception means a reduction of entanglement. This reduction is usually interpreted as quantum measurement but one could also say that it gives information about the relationship between A and B rather than state of A, or equivalently B. In a sequence of SSFRs, this measurement is carried out repeatedly for the regenerated entanglement. What this regeneration could mean in the TGD framework is discussed in the general number theoretical model for interactions based on $M^8 - H$ duality [L98]. The original entanglement need not be generated faithfully but could do so in a good approximation.

   What is essential is that Nature would replace single SFR with a sequence of cognitive SSFRs, which would be measurement cascades proceeding from long to short p-adic scales: the p-adic length scale is determined by largest ramified prime of the extension and decreases in the cascade defining SSFR [L98]. This sequence of SSFRs would produce a sequence of sensory mental images giving rise to a temporal statistical ensemble of mental images characterizing the unentangled state, which in the ideal case would be the same after all SFR cascades.

   The situation is analogous to that in quantum computation in which unitary time evolution determined by Hamiltonian produces a state of observables measured as the program halts. In quantum computation, one must produce a spatial ensemble of final states. One can also run the programs several times to build this kind of ensemble. The statistical distribution for the outcomes codes for the solution of the problem that the quantum computer program is supposed to solve, say factorization of an integer. I have considered two decades ago the possibility that living systems, for instance DNA-nuclear membrane system, could act like topological quantum computers: the braiding of magnetic flux tubes would code the quantum computer program [K3, K4, K79].

2. Quantum entanglement would be naturally between magnetic bodies (MBs) of the systems involved [L136, L84, L100]. The sensory input comes from the external world but it is unclear in what scales it can be quantum entangled with sensory receptors. The hierarchy of Planck constants predicts quantum coherence in all scales for MBS so that the entanglement could be macroscopic.

   What seems clear is that the MB of the sensory organ entangles with the MB of the conscious perceiver. The MB of the sensory organ would quantum entangle with the MBs of the receptor neurons and perhaps these in turn quantum entangle in the same scale with the MBs of the external world.

3. Sensory organs and their receptor neurons should entangle with the nearby neurons able to generate nerve pulses in order to communicate the information to brain. The sensory input could be communicated to MB from the neuronal membrane of sensory receptor neuron (which does not generate nerve pulses) to MB as frequency - and amplitude modulated (generalized) Josephson radiation generating a sequence of resonance peaks, which defined

feedback from MB to the neurons, which in turn give rise to nerve pulses from the sensory organ to the brain [K24, K60, L101, K59] [L97].

4. The SFR generating the sensation at our level of self hierarchy should occur in the scale of the sensory organ at least. The pair MB-sensory organ would be a natural pair to consider if generalized Josephson radiation communicates the sensory information to MB.

8.5.2 Models for the sensory input from the sensory organ to MB and vice versa

The basic objection against communications from the sensory organ to MB and vice versa is that the input from the sensory neurons to MB is expected to decompose to non-correlated inputs from separate neurons. If they are non-correlated, it is very difficult to understand how a macroscopic SFR giving rise to unitary conscious experience can take place. This problem is actually the key problem of all theories of consciousness and standard QM does not seem to be enough to overcome this problem.

Sensory input from the sensory organ to MB

What is required would be a large number of simultaneous dark cyclotron transitions as a quantum analog of a phase transition. The (generalized) Josephson radiation from the sensory neurons with the same receptive field should be in synchrony and somehow fuse to a kind of Bose-Einstein condensate. Here the number theoretic vision comes into rescue.

1. The hierarchy of Planck constants is the first prediction of the number theoretic vision. The second prediction is Galois confinement, which provides a universal number theoretic mechanism for the formation of bound states of quarks. All elementary particles and also their bound states would be formed by Galois confinement. Even particle reactions would be at the fundamental number theoretic level recombinations of Galois singlets formed from free quarks to new Galois singlets [L98].

2. For the 4-surface of M^8 determined by a polynomial P, quarks have momenta, which are algebraic integers in an extension of rationals determined by P. For instance, periodic boundary conditions require that the total momentum has integer valued components in units defined by the p-adic mass scale assignable to the Galois singlet is therefore formed.

   Galois confinement would bind Galois-non-singlets to singlets in all scales. In particular, dark N-photons are predicted as also dark N-protons and ions. Dark N-photons would be analogous to Bose-Einstein condensates and could induce N-cyclotron resonances at MB for N-ion Galois singlets. Dark genetic codons would be Galois singlets formed by dark proton triplets and dark genes would be Galois singlets formed from these triples but with momentum which does not have integer components.

Consider now a more detailed model for the secondary sensory input from sensory organ to MB.

1. Generalized Josephson radiation [K24, K60] from neural membranes produces the sensory input to MB. The Josephson radiations from different sensory receptors form a Galois confined state as dark N-photon.

2. Frequency modulation of the generalized Josephson radiation is possible and transforms the information coded by the membrane potential modulation to a sequence of cyclotron resonances at MB. This sequence is communicated back to the sensory organ to neurons able to generate nerve pulses, most naturally neighbors of the sensory receptor neurons. Therefore the communication of sensory input to the brain occurs via the loop sensory receptor $\rightarrow$ MB $\rightarrow$ neuron able to fire.

3. The intensity of the generalized Josephson radiation radiation can be modulated by varying the density of the dark Cooper pairs of electrons, protons and fermionic ions and of bosonic ions at the cell membrane acting as a collection of Josephson junctions formed magnetic flux

tubes associated with ion channels and pumps. If the intensity is too low, the signal from MB is weak and no nerve pulses are generated. This would be the case during sleep and unconscious states in general.

As the intensity of the sensory input increases, also the intensity of Josephson radiation and therefore also nerve pulse response increases. The period for the amplitude modulation determines the rate of nerve pulses bursts.

4. Biological high temperature superconductors are open systems. The increase of h_{eff} for electrons giving rise to Cooper pairs requires energy and since the Cooper pairs have tendency to decay by the reduction of h_{eff}, the maintenance of the Cooper pair condensate requires a continual energy feed. Either sensory input or metabolic energy feed can provide the needed energy. The latter case the sensory input would mean amplification of the sensory input.

Model for the virtual sensory input from MB to brain

A virtual sensory input from MB to the brain is needed to generate memory mental images associated with short term memory. This input would also make possible imagination and dreams and hallucinations.

It is difficult to imagine a detailed mechanism for the generation of the virtual sensory input to the brain at the level of MB. ZEO however allows us to consider an option requiring no new mechanisms at the level of MB . This option would be based on a time reversal occurring BSFR at the level of MB. From the point of view of an observer with the standard arrow of time, time reversed communications from the sensory organ to MB would look like communications from MB to sensory organ!

The counterpart of the time reverse period following BSFR is analogous to death and is followed by a time-reversed period analogous to reincarnation. Sleep and hibernation would be examples of this time reversed period [L133]. Also at the level of fundamental biomolecules, periods analogous to sleep are a rule. In the case of a neuronal membrane, nerve pulse is followed by a dead time, which would be also analogous to a sleep period as a time reversed period.

8.6 Are we living in the past?

The original article by Mauro Manassi and David Whitney [J74] (`https://cutt.ly/lONjIQn`) with title "*Illusion of visual stability through active perceptual serial dependence*" suggests that visual perception is a kind of temporal average over a time interval, which can be even longer than 15 seconds.

8.6.1 The findings of Manassi and Whitney

"Why do the objects in the world appear to be so stable despite constant changes in their retinal images?" was the question that motivated the work of Manassi and Whitney. Retinal images continuously fluctuate because of sources of internal and external noise. Retinal image motion, occlusions and discontinuities, lighting changes, and perspective changes and many other sources of noise are present. However, the objects do not appear to jitter, fluctuate, or change identity from moment to moment. Why does the perceived world change smoothly over time although the real world does not?

This problem is also encountered in quantum consciousness theories. If conscious experience consists of a sequence of non-deterministic quantum jumps as moments of consciousness, it is not at all clear how a smooth stream of consciousness is possible.

One modern explanation for the smoothness of conscious experience is some kind of change blindness or inattentional blindness. The finite capacity of visual short-term memory is certainly a fact and forces a finite perceptive resolution and effectively eliminates too fast temporal gradients. This finite resolution poses limits in perceptual, decisional and memory processing. This would naturally apply also to other sensory memories.

In the standard view sensory percept corresponds to a time=constant snapshot of the physical world. The basic prediction is that the object at a given moment of time is the real object but in a finite perceptive resolution.

The alternative hypothesis studied in the article is that the visual system, and presumably also other sensory systems, use an active stabilization mechanism, which manifests as a serial dependence in perceptual judgments. Serial dependence causes objects at any moment to be misperceived as being more similar to those in the recent past. The serial dependence has been reported in the appearance of objects, perceptual decisions about objects, and the memories about objects. In all of these examples, serial dependence is found for random or unpredictable sequential images.

This raises the question whether one can understand the serial dependence by identifying the conscious perception at a given time as a weighted temporal average of preceding time= constant perceptions over some time interval T and what additional assumptions are needed to understand the other findings related to the phenomenon.

8.6.2 The experiments demonstrating the serial illusion

Article describes 5 experiments related to serial illusion. The experiments are described in detail in [J74] with illustrations (`https://cutt.ly/lONjIQn`) and in the sequel I summarize them only very briefly. The reader is strongly encouraged to read the original article providing illustrations and references to literature related to serial illusion.

Experiment 1: shift of the perception to past

In Experiment 1 the shift of the perception to the past was demonstrated.

1. 2 separate groups of 44 and 45 participants rated the age of a young or old static face embedded in a blue frame (13 and 25.5 years, respectively). This gave a distribution of ratings around some mean identified as the real age of the face. The rating of the static face alone is referred to as the reference face .

2. A third group of 47 independent participants were presented with a movie of a face that morphed gradually, aging from young to old. These observers then rated the age of the old face. The rating of the static face preceded by the movie is referred to as the test face . The last frame of the video was identical to the reference face.

3. The age ratings between physically identical static faces, either alone (reference face) or with a preceding video (test face) were compared. Although the test and reference faces were identical, the old test face, seen after the video, was rated as 5 years younger than the old reference face, seen without the video (20.2 versus 25.5 years).

4. One can argue that the stability illusion is due to a simple unidirectional bias in age ratings. Therefore a fourth group of 45 new participants watched a movie of a face that gradually morphed from old to young. Following the movie, observers rated the age of a young static test face embedded in a blue frame. The young face was rated as 5 years older than its actual age (18.4 versus 13 years). Therefore the stability illusion can cause faces to appear younger or older depending on the previously seen faces.

   These findings are consistent with the temporal averaging hypothesis.

Experiment 2: the effect of noise

The noise is known to increase the serial dependence. Whether this is the case also in the case of illusion stability was tested. Stimuli with and without noise were represented to separate groups of observers. As a measure of the stability illusion strength, *attraction index* as the bias in age ratings toward the beginning of the movie was introduced.

1. A measure of the stability illusion strength, *attraction index* was introduced. *Attraction index* is defined as $\Delta T/T$, $\Delta T = |T_r - T_p|$, where T_r is the real and T_p the perceived age of the test face, and T is the total age range T. Real age refers to the average perceived age in the Experiment without preceding video.

2. When the movie and test face were presented alone or with superimposed dynamic noise, the static test face ratings were attracted by 28 and 42 % of the movie.

3. When the movie was presented with increasing dynamic noise and a test face with high noise, the attraction was around 48 %.

   The results conform with the earlier finding that serial dependence in perception increases with noise and uncertainty. As the increasing dynamical noise yielded the strongest illusory effect, it was used across subsequent experiments.

Why should the increase of the noise increase the strength of the illusion stability? Suppose that the perception is average over time=constant perceptions from a time interval T. For instance, one could think of a Gaussian distribution for the weights of the contributions over the interval T. It would seem that T gets longer in the presence of noise in order to achieve reliability.

Experiment 3: Central tendency bias not involved

It might be argued that the results are due to a central tendency bias, i.e., the tendency to rate test faces as being close to middle age, independent of movie content.

To test this, Experiment 3 replicated the same conditions Experiment 1 but linear increase/decrease in the age of the face was replaced with a more complex increase/decrease using staircase functions leaving intact the starting and ending points of the movies (young and old).

1. Attraction index gradually decreased with decreasing the number of age steps in the movie, thus showing that our illusion is not only due to a simple response or central tendency bias but also strongly depends on the whole content of the face morphing movie

2. The attraction index was computed with the last 6, 18, and 30 seconds of the video preceding the test face. Attraction linearly increased with increasing video duration, thus showing that the attraction effect involves all parts of the preceding video.

These results seem to be consistent with the averaging hypothesis. If Gaussian distribution can be used to model the averaging, the parameter T characterizing the locus of the distribution was at least of order $T = 30$ seconds and that the distribution was rather flat in this range.

Experiment 4: Temporal strength/range of illusion

If our illusion is due to the proposed active mechanism of perceptual serial dependence, it should occur on a broad temporal range in accordance with previous findings.

In experiment 4 the temporal strength of the stability illusion with an interstimulus interval (I.S.I.) of 0, 1, 5, 10, and 15 seconds between the movie and test face was measured.

Test face age ratings were attracted toward the movie at all intervals, thus showing that stability illusion extends across a large period of time . These results also show that, without intervening trials, serial dependence magnitude extends over a larger period of time than previously shown.

Experiment 5: Face feature similarity

The previous serial dependence literature on face stimuli suggests that stability illusion should be determined by face feature similarity and should occur only when the face morphing movie and test face are similar (belong to the same person, and even more, have very nearly the same age).

Unlike previous passive change blindness based explanations, any modulation of the illusion respecting feature similarity should be consistent with serial dependence and would make it possible to make predictions about the perceived age T_p of the test face.

In experiment 5, a movie of a face that morphed from young to old was represented, and after an interval of 1 second, the age of the static test face was varied by making it younger or older than the original test old face. On the basis of the known tuning of serial dependence for face similarity, three predictions were formulated.

1. Stability illusion should occur only with faces similar in age to the test face and not between dissimilar faces. It was found that the old test face was rated as younger (attraction effect) only for a few similar identities that were most similar to the old face; the attraction disappeared for more dissimilar identities.

2. As the old test face was perceived as being $\sim$ 20 years old after watching the movie, it was predicted that, when a reference face that is 20 years old is used as a test face after the movie, the degree of attraction for that face should be zero. No attraction for a test face of 20 years of age was found.

3. Test faces younger than $\sim$ 20 years old should be perceived as older, because the movie content contains older identities across the duration of the morph movie and, hence, should bias test face perception toward older ages. When the test face was younger, it was rated as older than it actually was.

The results and predictions were very well captured by a two-parameter derivative of a Gaussian model, in accordance with previous results, and ideal observer models proposed in the serial dependence literature.

8.6.3 TGD based explanation for the findings

TGD inspired quantum theory of consciousness as a generalization of quantum measurement theory allowing to overcome its basic problem caused by the conflict between determinism of unitary time evolution and non-determinism of state function reduction (see for instance [K74, K72, K73]). Zero energy ontology (ZEO) as an ontology of quantum theory [L72] [K87] plays a crucial role and leads to the proposal that the perceptive field is 4-dimensional so that one can speak of 4-D brain. This leads to a general vision about sensory perception and memory.

In the TGD framework, the question why the perceived world looks smooth is encountered already at quantum level. ZEO predicts two kinds of state function reductions (SFRs).

1. In "Big" SFRs (BSFRs) the arrow of time changes. In ZEO this explains in all scales why the world looks classical for the observer having arrow of time opposite to that for a system produced in BSFR [L66].

2. Sensory perceptions correspond naturally to "small" SFRs (SSFRs) and since SSFRs are the TGD counterparts of weak measurements of quantum optics and their sequences define what in the wave mechanics would correspond to a repetition of the same measurement (Zeno effect). Therefore one can hope that the problem disappears at quantum level.

   One must however understand why the perceived world seems to evolve smoothly although it does not.

The TGD based explanation for stability illusion and serial dependence relies on the general assumptions of TGD inspired theory of consciousness.

1. TGD inspired theory of consciousness predicts the notion of self hierarchy [K74]. Self has subselves, which in turn have subselves which correspond to particular sub-subselves of self. Self experiences its subselves as separate mental images determined as averages of their subselves. There are therefore three levels involved: self, subself, and sub-sub-self. Self hierarchy is universal and appears in all scales and one can ask whether the super-ego–ego–Id triple of Freud could be interpreted in terms of this hierarchy.

   The correspondences are therefore "We" $\leftrightarrow$ self; mental image $\leftrightarrow$ subself; subself as mental images of self $\leftrightarrow$ average over sub-subselves.

2. In accordance with the vision of the 4-D brain, ZEO makes possible the temporal ensemble of mental images as a basic element of quantum consciousness. No separate neural mechanism for forming the temporal ensemble is needed: its generation is a basic aspect of the quantum world.

3. The perception (subself) as a mental image is identified as a kind of temporal average over time=constant perceptions (sub-subselves), which basically correspond to quantum measurements and can in ZEO be identified as "small" state function reductions (SSFRs) in ZEO. Continuous stream of consciousness would replace the Zeno effect.

   The averaging smooths out various fluctuations (to which also SSFRs contribute at quantum level) and subselves as temporal averages over sub-subselves give rise to an experience of a smoothly changing world. The conscious sensory perception at "our" level is not about time=constant snapshot but an average over this kind of snapshots.

Consider now a model for the stability illusion and various aspects of serial dependence. In the following T_r *resp.* T_p denotes the real *resp.* perceived age (after seeing the video) of the face. T denotes the total age range. t_k denotes the time associated with k^{th} video picture and t the total duration of the video.

1. Sub-subselves in the experiments of [J74] correspond to $t = t_k < t$ video snapshots. Subself at $t = t_k$ corresponds to a statistical average M_k of $0 \leq r \leq k$ video snapshots at t_r. At $t = t_k$, "we" experiences M_k . The averaging over time gives rise to experience, which is biased towards earlier perceptions. The averaging creates the smoothing of the perception and generates the illusion that the perceived mental image is shifted to the past.

   If the perceived ages $T_{p,k}$, to be distinguished from t_k corresponding to real ages $T_{r,k} = T_0 + k\Delta T_r$ contribute with the same weight in the age interval T, the average corresponds to the central value of $T = T_0 + T/2$. In the general case, the average depends on the details of the distribution for $T_{r,k}$ and on the distribution of weights for t_k in accordance with the results of Experiment 3.

2. The higher the noise level, the longer the maximal time interval t_M over which the averaging takes place in order to gain reliability. This requires active response by changing t_M for M_k. t_M must increase with the noise level. For instance, if the weights in the average are Gaussian, the width of the Gaussian distribution must increase with the noise level. This explains the findings of Experiment 2 relating to the effects of noise.

Experiment 5 provides the information needed to formulate a model for what could happen in the addition of a new face at $t = t_N$.

1. The test face F_{N+1} is first experienced as a different person. After that it is checked whether F_{N+1} corresponds to any memory mental image M_k in the ensemble $\{M_k|k = 1, ..., N\}$. This involves memory recall besides time=constant snapshot perception.

   If F_{N+1} is similar to some M_k in $\{M_k|k = 1, ..., N\}$, it is added to M_N and defines a new memory mental image M_{N+1} and there is a stability illusion.

   If it does not correspond to any M_k, it is not recognized as an already perceived face, and is not added to M_N as a new memory M_{N+1} so that there is no stability illusion.

2. This model explains the results of 3 sub-experiments of Experiment 5 relating to the face feature similarity. The second experiment however deserves a detailed comment since it involves criticality in the sense that a small variation of the real age of $F(N+1)$ should lead to a disappearance of the stability illusion.

   Let $T_{p,A}$ be the perceived age of the test face in experiment A and $T_{r,B}$ the real age in the next experiment. For $T_{B,r} = T_{A,p}$ the stability illusion is absent whereas for $T_{B,r} \leq T_{A,p}$ it is present. The situation is therefore critical.

   The proposed model explains the presence of the illusion. One can however argue that $T_{B,r} \geq T_{A,p}$ rather than $T_{B,r} = T_{A,p}$ should actually hold true, or more precisely, there was no memory mental image M_k with $T_p \leq T_r$. A small variation of $T_{B,r}$ makes it possible to test whether the situation is really critical.

Chapter 9

Taos hum, stochastic resonance, and sensory perception

9.1 Introduction

Taos hum (see this) is an experimentally well-established anomalous phenomenon which has escaped rational explanations (in the article [I17] a thorough review about nocturnal taos hum is given and the following representation relies on this article). Very concisely, taos hum seems is apparently a subjective experience without identifiable objective counterpart and could thus provide an application for the sensory canvas hypothesis.

The TGD based model for EEG [K24] is based on dark Josephson radiation generated by cell membrane Josephson junctions in the energy range of visible and UV light and covering a wide frequency range. The model explains bio-photons and EEG photons as manifestations of one and same thing. Taos hum might be perhaps understood in terms of this kind of Josephson radiation at microwave frequencies generated by living matter during night-time and possibly providing some organisms with an active vision. The emission of negative energy dark photons could also make it possible for plants to suck metabolic energy from environment in the absence of solar radiation.

Also other interpretations might be considered and the most recent idea suggests a connection with quantum gravitation which plays a key role in TGD inspired quantum biology.

9.1.1 Basic facts

Taos hum is perceived in and around Taos, New Mexico but similar phenomena are experienced also in Northern America and Northern Europe. The hum is mostly heard during night time. Most people experience the hum as irritating and it causes nocturnal disturbances. From the tests based on psychophysical matching the frequency range of the hum has been deduced to be 40-80 Hz and whereas amplitude is around 60 dB. The hum is a regional phenomenon. The hum does not usually appear between sunrise and sunset. The pitch and intensity of the hum varies inside house and finds the largest magnifications on lower floors. Rooms modify the hum by adding distinctive harmonics to it. The pitch of the hum changes when one moves from outer wall to the interior rooms. Hallways and small alcoves raise the pitch considerably. The wavelengths involved vary between 3.9-7.8 meters for 40-80 Hz frequency range which suggests that resonance effects could be involved. It has been however impossible to identify any acoustic origin for the phenomenon. The presence of effectively acoustic effects suggests that gigantic amplification by the physical (and em!) body of the patient is involved.

Hum can involve also an experience about whirling or roaring wind, kind of vortex although nothing moves around, and coming from all directions. Also a strange amplification of distant sounds can be experienced. White light in the horizon in the direction where hum comes from can be also perceived. Experiences analogous to hum have been reported also in past, even in antique ("Aeolian wind"), but nowadays the number of victims of the hum has increased, which suggests a connection with the emergence of electronics and computers. The direction which hum is experienced to come from seems to be random.

The hum can be accompanied by irritating tactile sensations and neuralgic pain. The unfortunate individual who suffers of extreme HUM disturbances, seems to be controlled by very fundamental and autonomic response-reflexes when in its grips. Such sufferers may behave in semiconscious modes, modelling behavioral patterns seen only in animals. Typically the victim tends to get underground believing that this allows to get him rid of the hum. The victims of hum indeed tend to wake up with the realization that they have very strong and painful muscle tenure.

An important hint as regards to mechanism of hum is the fact that the temporal patterns of the shortwave radio static detectable by shortwave receivers correlate strongly with those associated with the hum. It is also known that the static has a biological origin: the warbling sounds characterizing the static resemble those produced by plants and galvanic skin response sensors. And most importantly, the statics is present during night time.

All attempts to detect the hum instrumentally and to identify its source have failed. This has inspired various kinds of conspiracy theories about the nature of the phenomenon, for instance, the proposal the strong ELF power feed by submarine radars alone could explain the phenomenon.

9.1.2 Phenomena possibly related to taos hum

It is appropriate to discuss first some phenomena possibly related to the taos hum before considering the model for the phenomenon itself.

Microwave hearing

During the collaboration with Joaquim Fernandez related to the construction of a a model for so called Fatima miracle [H1] I learned about the phenomenon of microwave hearing [I12] in which microwaves generate an audible sensation. There is evidence that microwave hearing does not involve ears as receivers of the primary signal [I6] and that the sensation of hearing could result as back-projection from cortex to ears.

This, and the correlation with microwave static suggest that taos hum could be a particular case of microwave hearing. The model of sensory representations implies that brain acts as a sending microwave antenna: a natural implication is that brain can act also as a receiving microwave antenna. The size of the brain hemisphere corresponds to a microwave frequency of order 3 GHz and smaller structures inside brain correspond to higher radio frequencies. If primary sensory organs are the seats of the sensory qualia and that back-projections cannot induce physical pain, the presence of the painful tactile sensations means that microwaves must interact also with the sensory receptors at the skin.

Why taos hum? Could animals use microwaves for "seeing" in absence of sunlight? But for what purpose plants would use microwaves? Could organisms send negative energy $h_{eff} = n \times h$ [**?**] microwaves to environment and suck metabolic energy quanta with energy around .5 eV in this manner? Remote metabolism! Or maybe time reversed photosynthesis in dark! Biophotons indeed have energy spectrum in visible and UV as also sunlight does. This would require non-standard value of Planck constant.

This hypothesis would explain why the microwaves causing taos hum not hum are not observed directly. And if something is sucking metabolic energy from you, it is would be rather natural to experience very unpleasant feelings and try to find a place to hide as many sufferers of taos hum try to do!

Physiophonic effect

Physiophonic effect is a phenomenon accidentally discovered by Antonio Meucci in 1842, in which vocal signals are electrically transmitted directly into the neurology of listeners [I17]. Physiophonic sound can be often amplified to an enormous volume. A possible interpretation is as externally stimulated internal sound but one can of course wonder whether the transduction to sound is necessary.

Since the body (especially collagen network) is liquid crystal allowing piezoelectric effect in which mechanical vibrations are transformed to electric signal, external sounds could be transformed to electric fields. On course, LC property implies that also genuine sound is generated so that both ELF em fields and ELF sounds can act as amplified signals. One can ask whether

strong back-projection to the ears is generated so that sound percept results. This would imply oto-acoustic sounds directly detectable by microphones not found in the case of taos hum.

Microwave static and taos hum

It is known that the temporal patterns of the shortwave static detectable by shortwave receivers correlate strongly with those associated with the hum. It is also known that the static has a biological origin: the warbling sounds characterizing the static resemble those produced by plants and galvanic skin response sensors. And most importantly, the fact that the static is present during night time would explain why hum is experienced at night time.

9.2 Possible ingredients for the model for taos hum

The facts about the role of the musculature, shortwave radio noise, and the role of acoustic environment combined with the model of microwave hearing based on the notion of dark photons [K36] pose strong constraints on the model of taos hum.

9.2.1 Taos hum as sensitivity to alien control commands

Magnetic bodies control biological body by sending control commands to brain and body where they are transformed to nerve pulse patterns and various physiological waves. Also the lower levels of self hierarchy should control the respective levels of the hierarchy, in particular muscle cells, in a similar manner. In the case of hum patient the normal control signal could be replaced by a control signal from some external biological source, say plants, and would be responsible for the muscular vibrations amplified to the hum. In the worst situation the behavior of hum patients reduces to simple reflex actions: these reflex actions would be initiated by fake control signals.

The fact that the taos hum begins after the sunset would conform with the interpretation as sucking of metabolic energy with energy quanta in visible and UV range. The loss of metabolic energy could explain why the experiences of patients are so unpleasant. Since motor action is based on negative energy signals affecting directly neuronal membranes by the same mechanisms as ordinary motor actions the signals would also induce reflex actions.

The situation would be due to the failure of the em (or rather, electro-weak) immune system of the patient. In order to understand what is involved a brief discussion of model of motor control based on charge entanglement induced by W MEs is necessary: a detailed model is discussed in [K31, K36].

1. The exotic ionization of dark matter induced by W MEs generates dark plasma oscillations inducing electric fields which by many-sheeted variant of the Faraday law induce electric fields also at the space-time sheets where ordinary matter resides. Various ionic waves, in particular Ca^{2+} waves and nerve pulse are examples of the physiological responses resulting in this manner.

2. Dark plasma frequency corresponds to a microwave photon with energy above the thermal threshold and the system must be able to provide dark photons with this energy to generate plasma oscillation patterns serving as control commands.

The electro-weak immune system could fail in the following manner.

1. In the healthy situation em immune system takes care the body is tuned to the personal dark plasma frequencies and does not respond to control commands from alien magnetic bodies associated with say plants.

2. In an un-healthy situation persons plasma oscillation frequencies are tuned to some frequencies in the microwave static and microwave static provides the energy needed to generate plasma wave patterns and thus to realize control commands from the alien magnetic bodies. The plasmoids would induce microwave hearing and generalized motor actions at cellular level exhausting the personal metabolic sources and leading to the painful experiences and fatigue.

9.2.2 Taos hum and microwave hearing

The identification of the audible sensation associated with taos hum is in terms of microwave hearing explains the failure of the attempts to identify the source for taos hum. Amplitude modulation by ELF frequencies naturally associated with motor control would give rise to sensation of sound.

Concerning the model for microwave hearing, a good guideline is that the effect is expected to be possible as quantum effect only if the energies of the microwave photons are above the thermal threshold. This would require dark microwave photons for which 5 GHz photons have energy above thermal threshold (6 cm wavelength). Same applies to other effects caused by dark microwave photons.

Microwave hearing itself would rely on hearing of dark microwave photons at visible and UV frequencies. These dark microwave photons could accompany the microwave signal automatically or could be generated by cells via a phase transition increasing the value of Planck constant.

9.2.3 Taos hum and microwave seeing

The de-coherence of microwave photons to ordinary photons would produce the biological effects. This could explain also the reported perception of white light as resulting from the de-coherence of the microwave photons at the upper end of the spectrum: 1 mm microwave wavelength would correspond to 2.5 eV photon energy.

The de-coherence of dark microwave static to ordinary visible photons could make possible microwave vision during night time. This could explain why the static emerges after the sunset. Plants could also generate negative energy dark microwave photons with energies in the frequency bands of visible photons involved with photosynthesis to satisfy their metabolic needs when they do not receive sunlight. One can of course wonder whether the quartz in the rock heated during day-time could generate dark microwave photons during night-time serving as a metabolic source.

9.2.4 Taos hum as a failure of the electromagnetic immune system

Taos hum starts immediately after the sunrise and stops after the sunset and seems to have a biological origin. The magnetic bodies of (say) plant cells could send dark energy photons at microwave frequencies above 5 GHz: one reason is that they become visible in this manner.

Negative energy W MEs in the same frequency range and responsible for quantum bio-control in the time scale of microwaves could be involved. Due to the failure of the electro-weak immune system the surrounding biosphere could induce generalized motor actions and these would exhaust the metabolic energy resources of the victim. This would explain why the hum is intolerable and the extreme fatigue caused by it.

The radio noise generated by computers and other sources of radio waves should not cause troubles if these radio waves correspond to ordinary photons. If not, then the microwaves in question could provide the energy needed to realize alien control commands based on ELF modulation.

9.2.5 An explanation for 40-80 Hz modulation

The model of biological evolution and evolution of nervous system based on dark matter hierarchy [K24] leads to sa detailed identification of the values of Planck constant associated with EEG identified as of dark Josephson radiation with energies in visible and UV range and EEG frequencies. This level is involved with all life forms capable of genetic expression, in particular plants. Therefore the ELF modulation of microwave frequencies could be due to the control commands from the levels of the magnetic body normally meant to control the genetic expression of say plants. The modulation of the microwaves with EEG frequencies, in particular with the frequencies in the $37-44$ Hz thalamo-cortical resonance band, could force the patient to stay awake by not allowing the dominant EEG frequencies to drop down to theta and delta region of EEG as occurs during sleep.

9.2.6 Is stochastic resonance involved?

One could also ask whether the microwave static of victims of taos hum is anomalously amplified by some mechanism so that control commands from alien magnetic bodies can be realized. The

transduction of weak microwave signals to mechanical oscillations by piezo-electric body liquid crystals, and the amplification of this signal in the presence of a metabolic energy feed to the musculature, could lead to this kind of situation.

Stochastic resonance with white noise generated by body provides one possible amplification mechanism. Micro-wave frequency would correspond to the amplified frequency. If so, one could perhaps understand why only some persons experience the hum and why the effect is strong at night time. White noise would be generated by body. White noise induces jumps between the states of the 2-state system with an average frequency f_K (Kramers frequency) which depends on the autocorrelation function of the white noise and the properties of the 2-state system [K60]. If the Kramers frequency satisfies $f_R = 2f$, where f is the frequency of the signal, a resonant amplification occurs. The dependence $f_K \propto exp(-\Delta V/D)$, where $\Delta V > 0$ is the height of the potential barrier separating the states of the 2-state system, implies and exponential sensitivity of f_K on $1/D$, where D is the intensity of the white noise. Hence the failure of the em immune system could be due to the too intense white noise produced by the body of the victim or due a too low height of the potential barrier.

9.2.7 Are electronic systems involved with the hum?

The fact that the number of victims of hum has rapidly increased during the era of radio communications and computers and suggests that both radio noise and computers might be actively involved with the hum. Also ELF noise from electronic systems might be important if these systems generate dark ELF photons.

Electronic instruments generate also frequencies in the range $40 - 80$ Hz, in particular the 50 Hz frequency associated with the household electricity. Also submarine radars generate very strong ELF signals. The liquid crystal character of human body implies that besides weak sound signals also these ELF signals can contribute to the signal amplified by musculature. If these signals correspond to the lowest level of dark matter hierarchy, they should not have biological effects but whether this is the case is not all clear.

The strong coupling between magnetic flux tube structures associated the with computer networks and sensory canvases might be created by the magnetic reconnection process during night time when the shape of the flux tube structures changes. Also whole-daily use of a computer could generate magnetic mirror bridges between the computer and user's musculature and allow computer to feed fake control signals to muscles.

9.2.8 Is hum possible in other sensory modalities?

The model of hum based on magnetic sensory canvas suggests that the effect is involved with all sensory modalities. Tactile sensations, in particular pain, are certainly involved. It was already mentioned that hum experiences can involve also perceptions of white light in the horizon in the direction from which hum came. In the model explaining the sensation of hum as being caused by the muscular sound, this sensation could result as a kind of cross-modal association accompanying very intense auditory sensation. In the model explaining the effect as ESP the presence light sensation could be understood as visual aspect of the ESP.

My personal experiences provide a candidate for the counterpart of taos hum in visual field. While closing eyes in a calm state of mind, I see a strange and complex flow consisting of small dots: for the first time I had this experience during my great experience roughly 15 years ago. The effect is easiest to achieve with lightly closed eyes but appears after some time also with tightly closed eyes. For lightly closed eyes the flow is more complex whereas for tightly closed eyes there is just a sink in the middle representing what I would call "third eye", which is present practically always. Vortices and spiral vortices (compare with the whirling winds associated with hums) are typically involved and flow can have also weak coloring.

Could this flow be the visual counterpart of the taos hum? The very fact that the experience is pleasant and the appearance of diffuse white light during taos hum suggests that this interpretation need not be quite correct.

1. The effect is caused by the de-coherence of dark microwave photons or perhaps dark EEG photons above alpha band to visible photons (during calm states of mind alpha band is very strong).

2. This effect is strongest when the eyes are only lightly closed. Perhaps ELF em waves from some source could provide the input to the retina which is magnetic structure and generate the visual sensation somehow (note that rotating non-colored Benham top can generate sensations of color). The de-coherence of dark ELF photons to ordinary visible photons could be the mechanism.

3. I have proposed an interpretation for the flow in terms of the magnetic flux tube structure emerging from the retina. One can however wonder why just single central vortex rather than two? Could it be that pineal gland, which is also a magnetic structure and contains retinal pigments and is "third eye" in rather literal sense, could be responsible for the "third eye" component of the flow, and that during eyes lightly closed conditions turbulent retinal and single vortex like pineal contributions superpose? Could pineal vision be based on the de-coherence of EEG waves above alpha band to ordinary visible photons?

What is perhaps remarkable that the ability to have the flow experience has stabilized during last year or two, which is also the period during which various hum symptoms have developed. However, I experience the flow also when the computer is off: as a matter fact, I experienced the flow for 15 years ago when I did not work with computers.

9.3 The recent TGD view of Taos hum

9.3.1 Personal experiences about Taos hum

While learning about taos hum, I suddenly realized that I am perhaps not an objective outsider at all! I cannot tolerate the humming noise of the refrigerator: in order to sleep at all I try to insulate myself from the kitchen by cloth (I do not have door between) and use pillows on my ears in order to get rid of this extremely irritating sound. Even this is not enough and I wake-up very often during night-time. I also used to have terrifying experiences in which the noise of the refrigerator started to increase in volume and my body started to float and was attracted by the refrigerator as if it were a conscious creature wanting to fuse with, or rather steal, my consciousness (by the way this suggests that magnetic selves strongly interacting with my magnetic body might be really involved). I can also hear sounds, such as cracks from wall, as amplified to completely abnormal intensity (in fact I have always had abnormally sensitive ears).

I suffer also from almost intolerable hum of my computer at day-time and only while learning about taos hum, I realized that similar mechanism might be at work also here (note however that taos hum is strongest during night time, between 9 P.M. and 9 A.M.). Remarkably, the hum amplifies when I become conscious of it: I can work long times without noticing its presence at all. Neither am I aware of the refrigerator at daytime. To complete the picture, two years ago I began to suffer from chronic pain in head, neck and back which are due to strong muscle tensions. These pains correlate very strongly with working at the computer terminal. I have believed that this is due to the bad working ergonomy and poor quality of eye glasses. However it turned out that this was not the reason of pains. I have even suffered from temporal dizziness when pains have been worst and even lost my consciousness once: strangely enough, I heard before the loss of consciousness a strange whirling wind to blow (sic!), and realized only later that weather had been completely calm.

It seems that all these symptoms fit with those of a hum patient. Now only the source of radio waves would be my own computer and would act also at daytime via direct radio wave magnetic mirror bridges connecting the oscillating circuits of the computer to my musculature. When I am not aware of the noise, my brain does not project sensory input from muscles to the auditory canvas and I am saved from the hum sensation. I however feel the pain coming from the body all the time.

On basis of what has been said, it would seem that there is high time to consider the possibility that the electric pollution of environment is gradually making our life increasingly intolerable. One cannot even exclude demon like conscious virus like entities generated by the electronics and computers and fighting for survival with us.

This was however not the full story yet. I suffered from taos hum in my previous hometown. After I moved to my recent hometown, I believed that I had got rid of this problem. But also here

I have been tormented from time to time by an unpleasant sensation of sound. Always at night and summertime. The sound source did not move. As if someone were keeping the car idling or even screaming the car engine to drive his fellow men to the brink of rage.

What gave the stimulus to write an article was that after a long period the experience came back at winter time and lasted for several hours. Once again I tried to figure out what it could be. The interpretation as hallucinations didn't seem likely. Another interpretation was as sensory memories. Such are possible and can be induced by electrically stimulating the temporal lobes. For example, some previously experienced pain due to some real cause can be chronically repeated as a sensory memory.

Then I suddenly realized that it was my old friend Taos hum! The reason why I had not realized this from the beginning was that in my new hometown my friend has been much more aggressive and created the impression of intentional bullying so that the unavoidable first impression was that some-one is terrorizing his neighbors by gassing his car at night-time.

9.3.2 Taos hum and quantum gravitation

The latest experiences with taos hum led to an identification of new pieces, which seem to fit the puzzle of taos hum.

If taos hum corresponds to microwave hearing, the natural question is what the range of the carrier frequencies is and whether there are some special carrier frequencies.

1. In quantum biology based on TGD quantum gravity is essential [L116, L114]. Nottale's hypothesis [E1] is generalized and assigns macroscopic and even astrophysical quantum coherence to classical gravitational fields created by astrophysical objects.

   In the Earth's gravitational field, the gravitational Compton wavelength is $\Lambda_{gr} = GM_E/\beta_0$, where the velocity parameter satisfies $\beta_0 = v_0/c < 1$. Λ_{gr} and the corresponding frequency f_{gr} do not depend on the mass of the particle (Equivalence Principle). For $\beta_0 = 1$ one has $\Lambda_{gr,E} = .45$ cm. It corresponds to the microwave frequency $f_{gr,E} = 67$ GHz. This would be some kind of universal clock frequency of quantum biology.

2. I have considered also the possibility that computers [L124, L123, L127] could acquire some characteristics of a biological organism, if their clock frequency is higher than this frequency, because then the statistical determinism would no longer apply. In fact, the corresponding wavelength associated with the Sun is half the radius of the Earth and corresponds to the frequency $f_{gr,S} = 50$ Hz which is EEG frequency, which inspires many questions.

3. For biomolecules, microwave frequencies play an essential role. Microwaves are associated with many strange effects such as ball lightning and light balls that have often been interpreted as UFOs. The creation of crop circles [K22, K23] [L127] could be based on the same mechanisms as the explosion of a tomato in a microwave oven, which can be also used to produce this kind of light balls. There are also reports of lightballs in the act of building a crop circle.

4. Could the amplitude modulation of the radiation with gravitational Compton frequency $f_{gr,E}$ of the Earth produce the taos hum?! The modulating frequencies are in the EEG range and quite low, which brings in mind the gravitational magnetic body of the Sun with $f_{gr,S} = 50$ Hz.

5. What would give rise to the impression of an idling diesel engine? Could it correspond to some kind of random noise but what about the impression of deliberate gassing? What comes to mind is a boxer who is in a state of maximal alertness ready to attack at any moment. This suggests a quantum critical state in which bursts of metabolic energy are randomly occurring. Note that the carrier frequencies would be microwave frequencies and by a factor of 67 higher than in the Frey effect, which has been associated with the microwave hearing.

There is also another important microwave frequency. The maximum for the frequency distribution of the cosmic microwave background is at the frequency 160 GHz and to wavelength .2 cm. This frequency is roughly twice the gravitational Compton frequency for Earth. This is close to the upper limit of microwave frequencies of 300 GHz. Is it a coincidence that these two frequencies are so near to each other?

9.3.3 Taos hum and TGD based generalization of stochastic resonance

Stochastic resonance [D1] [J42] occurs in the brain [D4] and its quantum analog serves as a candidate for the mechanism behind the perception of taos hum.

Consider first the classical variant of the stochastic resonance, which I have considered in [K60].

1. Classical stochastic resonance is an amplification mechanism for a signal represented as an amplitude modulation of a carrier wave with a basic frequency f acting as a harmonic perturbation of a bistable system, which is also subject to a white noise. In the recent case the message could correspond to the amplitude modulated signal with frequency f in the microwave range. $f = f_{gr}$ is an interesting option. One might say that the system manages to extract the energy of the noise, which creates the question whether the mechanism conforms with the second law of thermodynamics.

2. In the resonance, the signal frequency f must be one half of the average frequency $f(spont)$ for the jumps between two states of the bistable system: $f = f(spont)/2$. This condition has a simple physical interpretation: the height of the potential barrier separating the two potential wells varies periodically with a period which is half of the period defined by f, and the best opportunity to get to another potential well is to hop when the potential barrier is lowest possible.

3. For the mechanical analog system the rate $f(spont) = r_0 A$ is proportional to an "Arrhenius factor" $A = exp(-\Delta V/D)$, where ΔV is the height of the potential barrier and D characterizes the intensity of the white noise. $f(spont)$ is also proportional to a factor $r_0 = \omega\omega_b/\gamma$ where ω is the frequency of small oscillations at either bottom of the symmetric potential well, ω_b is the analogous quantity at the top of the barrier (for harmonic oscillator potential one would have $\omega = \omega_b$), and γ characterizes the linear dissipative force (overcritical damping is assumed).

4. Thus, when the white noise has a correct intensity, a weak harmonic perturbation with a given frequency is amplified in the sense that the Fourier expansion of the system's time development regarded as jumps between the two states contains a peak at the multiples of the frequency of the amplitude modulated harmonic perturbation. Neuroscientists refer to this phenomenon as phase locking. The peaks for the higher multiples of the input frequency f are exponentially suppressed. The notion of stochastic resonance makes sense also in the quantum context: now quantum tunnelling would replace the jumps induced by the stochastic noise.

In stochastic resonance the system extracts energy from the environment to amplify the signal. Does this really conform with the second law of thermodynamics: it would seem that the second law temporarily fails but is true with an opposite arrow of time. The TGD view of stochastic resonance could be motivated by this question.

Could stochastic resonance generalize to a quantum situation but with the ordinary ontology of quantum theory replaced with the zero energy ontology (ZEO) of TGD [K87]? What would be new is the identification of the ordinary quantum jump as a "big" state function reduction (BSFR) in which the arrow of time changes. One can consider two interpretations.

1. Consider first the TGD analog of the standard interpretation. The jump between the potential wells corresponds to a quantum tunnelling as a transition of states with the same arrow of time and therefore involves two subsequent BSFRs. In stochastic resonance, the frequency $f(spont)$ for these tunnellings should satisfy $f = f_{spont}/2$. Each period $T = 1/f$ would correspond to two pairs of BSFRs. In the TGD framework, this interpretation looks too complicated.

2. For the second option, a single BSFR defines the counterpart for the hopping between two potential wells and 2 BSFRs define quantum tunnelling. Bistability has nothing to do with the details of the dynamics and is universal and corresponds to the two arrows of time. $f(spont)$ is identified as the rate for BSFRs rather than their pairs and characterizes external perturbations.

In the stochastic resonance, the rate $f(spont)/2$ for a pair of BSFRs would be equal to the carrier frequency f so that quantum tunnelling is in synchrony with the driving frequency f and each period corresponds to a quantum tunnelling. The intensity of the noise could be used to induce this synchrony.

This synchronization mechanism applies to all transitions and to all frequencies f but $f = f_{gr,E}$ would be in a special role since $f_{gr,E}$ defines a universal gravitational Compton frequency of the Earth. For instance, EEG with frequencies in the range 1-100 Hz could involve this mechanism and the halves of the EEG period would correspond to different arrows of time as I have indeed proposed in [K60] on basis of observations of brothers Fingelkurts [J41]. As already noticed, the gravitational Compton frequency $f_{gr,S} = 50$ Hz of Sun is EEG frequency and EEG frequencies appear as modulation frequencies in Taos hum.

9.3.4 Stochastic resonance and sensory perception

In the TGD framework, subjective existence corresponds universally to the sleep-wakeup cycle defined by the periods of wake-up with opposite arrows of time defined by a sequence of "big" state function reductions (BSFRs) changing the arrow of time. In BSFR, a self with a given arrow of time dies (or falls asleep) and reincarnates as a self with an opposite arrow of time.

The TGD view, the stochastic resonance would synchronize the signals realized as amplitude modulated carrier waves with the sleep-wakeup cycle. The wakeup period would correspond to $T(spont) = 1/f(spont)$. Stochastic resonance would correlate the rhythms of subjective and physical existence.

The basic prediction is that this synchrony is optimal when the noise level is optimum. Taking the ordinary sleep-wake-up cycle as an example, one can understand what this means. If the stimulus level is too high, concentration to a given task is difficult and problems with sleep appear. If the stimulus level is too low, drowsiness becomes the problem and the resonance with the circadian rhythm tends to be lost.

Concerning the identification of the counterpart of the white noise, there are several guidelines.

1. White noise could correspond to any signal for which the frequency distribution is constant in the time scale of modulations. The rate of BSFRs should be $f(spont) = 2f$. In stochastic resonance, the white noise would keep the system in optimal wakeup state.

2. Many neuroscientists believe that the rate of nerve pulses codes for the sensory input. This need not be quite true but inspires the question whether the nerve pulses define the white noise and whether a single nerve pulse wakes up the neuron. If so, then the rate of nerve pulses could correspond to $f = f(spont)/2$ since only the nerve pulses with a standard arrow of time are observed.

   Nerve pulse duration is about 1 ms and defines the maximum rate of nerve pulses. On the other hand, $f = 1$ kHz frequency is a resonance frequency of the brain synchrony and also the average mechanical resonance frequency of the skull.

3. This observation brings to mind an interesting old observation. For electrons with mass .5 eV the secondary p-adic time scale $T_2(e)$ corresponds to frequency 10 Hz, alpha frequency. The mass estimates for the light quarks u and d vary in the range 2-20 MeV. T_2 scales like mass scale squared so that the mass scale estimate for quarks is $T_2 \sim$ kHz.

   The TGD inspired quantum biology indeed predicts that QCD allows dark variants with same masses but Compton length scaled up by $\hbar_{eff}/\hbar$. Does this mean that the kHz frequency scale of nerve pulses corresponds to T_2 for quarks and 10 Hz EEG frequency scale corresponds to T_2 for electrons? If this is the case, secondary p-adic length scales for electrons and quarks are fundamental for the brain.

   This raises some questions.

1. It would seem that cyclotron pulses inducing BSFRs correspond to the white noise behind stochastic resonance. The rate of the detected nerve pulses would correspond to

$f = f(spont)/2$ and to a frequency of modulated carrier wave. Can one imagine a general mechanism for producing the noise realized as nerve pulses?

2. One can also ask whether a system could keep itself awake and in stochastic resonance in presence of the necessary metabolic energy feed. Could the system itself produce the white noise as pulse patterns and stay in a stochastic resonance with it. If so, the amount of metabolic energy could control the level of noise in turn controlling the presence of the stochastic resonance.

3. A nontrivial question is what one means with a system. In TGD, the system involves both the biological body and the magnetic body (MB) carrying dark matter associated with it. MB has a hierarchical structure with levels labelled by the values of h_{eff}.

The model for the communication of sensory input from the cell membrane to the magnetic body and for the control of the biological body suggests itself as a mechanism transforming sensory input at the cell membrane to pulse patterns.

1. At the level of the cell membrane, sensory input corresponds to the oscillations of the membrane potential and to nerve pulses.

2. This sensory input is communicated to the MB as a generalized Josephson radiation modulated by the variation membrane potential representing sensory input. The generalized Josephson frequency is the sum of two parts. The first part corresponds to the ordinary Josephson frequency $f_J = ZeV/h_{eff}$. The second, usually dominating, part corresponds to the difference of the cyclotron frequencies of monopole flux tubes at the two sides of the cell membrane and transverse to it. The energies involved are of the order of ZeV and just above the thermal energy as required by the minimal consumption of metabolic energy. Josephson frequencies are in the EEG range.

3. At the MB, the dark Josephson radiation generates cyclotron resonance, which transforms the frequency modulated Josephson radiation to a sequence of pulses, which define a feedback to the brain. A natural proposal is that the cyclotron pulse sequences generate nerve pulse patterns serving as the white noise.

   The rate of nerve pulses would dictate the resonant frequency f which can vary from its maximum value of kHz down to 1 Hz and even below it. The cyclotron frequencies for the body parts of the MB would thus select, which frequencies from the frequency spectrum of the Josephson radiation are amplified. Essentially, a Fourier analysis of the sensory input is performed and the spectrum would be represented at the MB.

4. The nerve pulse patterns would in turn generate a response as modulations of geneneralized Josephson frequency sent to the MB. There the response of the system to the white noise generates the white noise. This feedback loop would define a nearly autonomous system staying in a stochastic resonance in presence of a suitable metabolic feed.

5. Only the frequency modulation by the sensory input appears in this mechanism. Frequency modulation however reduces to the amplitude modulation for the membrane potentials.

6. The generalized Josephson frequency must be equal to the cyclotron frequency at a given body part of the MB. It can control by a variation of the flux tube thickness whether it receives information from the cell membrane at a given generalized Josephson frequency.

7. The failure of the communication line between the brain and the MB could cause various disorders since the MB cannot anymore take care of BB. Since the cyclotron frequencies of the biologically important ions in $B_{end} = .2$ Gauss are in a key role, the concentration of these ions in biomatter is an important factor. Lithium ions serve as a basic example. Its cyclotron frequency is 50 Hz, which corresponds to $f_{gr,Sun}$. The depletion of lithium ions in the soild is known to induce depression and even suicides.

How does sensory perception relate to the stochastic resonance in the proposed sense? The stochastic resonance would be associated with the communications with the MB and the information representable as a modulation of the carrier wave.

1. Sensory qualia would be labelled by quantum numbers measured repeatedly during the sequences of "small" state function reductions (SSFRs) between BSFRs. Primary sensory qualia would be associated with the sensory organs and the feedback from the MB of the brain to the sensory organs could generate virtual sensory input explaining hallucinations and dreams. This picture fits nicely to vision, olfaction and tactile senses, which are spatial.

2. The generation of sensory qualia at the level of sensory organs could involve stochastic resonance amplifying the primary sensory input. The sensory input would be transformed to dark Josephson radiation to the MB of the sensory organ and returned back as a pattern of cyclotron resonance pulses in turn generating BSFRs and a modified Josephson radiation but without modification due to nerve pulses.

   When the membrane potential is reduced below the critical value, a nerve pulse would be generated and lead to a processing of the signal at the higher levels of the hierarchy. The rate of the nerve pulses would determine the intensity of the signal at the higher levels of the hierarchy. Similar feedback loops with the local magnetic bodies would take place at the higher levels of the hierarchy and generate higher level representations of the sensory input. The virtual sensory input from MB would lead to the generation of standardized mental images as a pattern completion and recognition.

3. Stochastic resonance for the sensory receptors would allow code for various characteristics of the sensory input (such as colors, intensity and frequency of light or sound,...) to cyclotron frequencies characterizing parts of the MB. Essentially a generalized Fourier analysis of the sensory input locating Fourier components to different parts of MB would be in question.

   Hearing is an exceptional sense in that the temporal aspect is essential.

1. It would be natural to identify the intensity and frequency of auditory qualia with the cyclotron frequencies labelling the magnetic body parts. In the case of speech and "almost heard" internal speech, the meaning of the speech represents a higher level element related to the temporal aspects, and could be associated with the communications to the MB rather than being purely spatial quale.

2. If the heard sound frequencies correspond to Josephson frequencies, why are the other qualia not accompanied by an auditory experience? A partial answer is that hearing involves the sensation of the pitch and intensity of the sound as non-temporal qualia at the neuronal level.

   The temporal aspects of hearing responsible for the meaning of the speech would naturally correspond to the modulations of the membrane potential and of Josephson frequencies. But also other senses involve this aspect. Could these aspects correspond to internal speech providing a cognitive interpretation of the experience, its naming? Could this aspect be universal and accompany all experiences? This would also conform with the fact that the oscillations of magnetic flux tubes are analogous to acoustic waves.

The 12-note scale defines a set of very special frequencies in that these frequencies have a deep emotional meaning. Also octave equivalence is a fascinating phenomenon. Could this be due the fact that these audible frequencies appear as resonance frequencies in the spectra of the cell membrane Josephson frequencies and cyclotron frequencies for the magnetic flux tubes? If this is the case magnetic flux tubes would define an analog of an organ played by the sensory input to MB. How do these special frequencies relate to the gravitational Compton frequencies?

1. The model for bioharmony, leading to a model for the genetic code [L9] [L83, L121], leads to a proposal that Pythagorean scale defines a spectrum of preferred cyclotron frequencies and thus a spectrum of strengths of the endogenous magnetic field B_{end}. Quint cycle $(3/2)^n$ of fundamental frequency and octave equivalence would yield the 12-note scale.

2. $\beta_0 \simeq 1$ has been assumed for the Earth and $\beta_0 \simeq 2^{-11}$ for the inner planets of the Sun. Could $\beta_0 \leq 1$ have a spectrum? Could this spectrum explain in the case of the Sun the EEG spectrum below 50 Hz frequency spanning 7 octaves (DNA corresponds to 1 Hz), and in the case of the Earth the microwave spectrum in the range .5-67 GHz?

3. I have considered the possibility that β_0 is for number-theoretical reasons quantized as an inverse integer: $\beta_0 = 1/n$ [L47]. Number theoretical constraints allow a more general quantization as rational numbers: $\beta_0 = m/n$. The spectrum of the gravitational Compton frequencies would resonate with the spectrum of the cyclotron frequencies if β_0 in $f_{gr} = \beta_0/GM$ obeys a quantization producing the 12-note scale. It would be interesting to check whether EEG exhibits 12-note scale as a finite structure realized as preferred frequencies.

Consider next the microwave hearing as a possible explanation of taos hum.

1. In microwave hearing the carrier wave amplitude, modulated in the frequency scale of audible frequencies with typical frequency in the range of EEG frequencies and therefore below 100 Hz, creates a sensation of sound. The electromagnetic signal would be amplified by stochastic resonance to a variation of neuronal membrane potentials in turn generating an acoustic signal by piezoelectric effect.

   This acoustic signal could serve as a virtual auditory input to the ear and generate a sensation with auditory qualia. The mechanism would be the same as in the case of hallucinations and dreams.

2. Assume that the frequency spectrum associated with the gravitational body of Earth ($f_{gr} =$ 67 GHz) spans as many octaves as that for the Sun. Assume that the frequency spectrum for Sun ($f_{gr} = 50$ Hz) corresponds to that for EEG assumed to span 7 octaves (1-128 Hz). The scaling gives in the case of the Earth for the microwave scaled variant of EEG realized at biomolecular level the range .5-149.5 GHz: the upper bound corresponds to energy 1.5 meV and is somewhat below the maximum frequency 160 GHz for the frequency distribution of CMB. Note that miniature membrane potentials correspond to meV energy scale.

   If one replaces EEG range with the range of frequencies 20 Hz-20 kHz audible for humans spanning 10 octaves the upper bound for scale frequency spectrum would be 12 THz which corresponds to energy of .1 eV which is the energy of Cooper pair for cell membrane Josephson function with voltage .05 V. For bats the audible frequencies extend to 110 kHz and the upper bound would be now .510 THz and correspond to energy of .5 eV which is the nominal value of the metabolic energy quantum.

3. There are indications that also the gravitational body of Moon (with mass 1/83 times that of Earth) [L122, L127] could play a key role in quantum biology. The proposed analog of the EEG range for the Earth would be scaled up by factor 83 with an upper bound corresponding to .12 eV, which corresponds to the energy of the Cooper pair for the cell membrane. For the range of audible frequencies the upper bound would scale up to 8.3 eV covering visible and UV frequencies.

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 [L39, L40]. In the recent view of quantum TGD [L119], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L80, L81] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L72] [K87] 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) [L72, L106] [K87] 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 [A16] 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 [A11] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it \ , \\ \xi^2 &= x + iy \ . \end{aligned} \tag{A-2.2}$$

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi+\Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= rexp(i\frac{(\Psi-\Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{A-2.3}$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second $b = 1$.

Fig. 4. CP_2 as manifold. `http://tgdtheory.fi/appfigures/cp2.jpg`

Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \to exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i \bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.4}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-2.5}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= log(F) \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-2.6}$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r, \phi) = (tan(\theta/2), \phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \tag{A-2.7}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ . \end{aligned} \tag{A-2.8}$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A \ , \tag{A-2.9}$$

are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , \quad e^1 = \tfrac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \tfrac{r\sigma_2}{\sqrt{F}} \ , \quad e^3 = \tfrac{r\sigma_3}{F} \ . \end{aligned} \tag{A-2.10}$$

The explicit representations of vierbein vectors are given by

$$\begin{aligned} e^0 &= \frac{dr}{F} \ , & e^1 &= \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\ e^2 &= \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 &= \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ . \end{aligned} \tag{A-2.11}$$

The explicit representation of the line element is given by the expression

$$ds^2/R^2 = \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2) \ . \tag{A-2.12}$$

From this expression one finds that at coordinate infinity $r = \infty$ line element reduces to $\frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2)$ of S^2 meaning that 3-sphere degenerates metrically to 2-sphere and one can say that CP_2 is obtained by adding to R^4 a 2-sphere at infinity.

The vierbein connection satisfying the defining relation

$$de^A = -V^A_B \wedge e^B \ , \tag{A-2.13}$$

is given by

$$\begin{aligned} V_{01} &= -\frac{e^1}{r} \ , & V_{23} &= \frac{e^1}{r} \ , \\ V_{02} &= -\frac{e^2}{r} \ , & V_{31} &= \frac{e^2}{r} \ , \\ V_{03} &= (r - \frac{1}{r})e^3 \ , & V_{12} &= (2r + \frac{1}{r})e^3 \ . \end{aligned} \tag{A-2.14}$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{aligned} R_{01} &= e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} &= e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} &= e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} &= -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\ R_{03} &= 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} &= 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{aligned} \tag{A-2.15}$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -is_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.16}$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$J^k_{\ r} J^{rl} = -s^{kl} \ . \tag{A-2.17}$$

The condition states that J and g give representations of real unit and imaginary units related by the formula $i^2 = -1$.

Kähler form is expressible locally in terms of Kähler gauge potential

$$J = dB \ , \tag{A-2.18}$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

$dJ = ddB = 0$ gives the topological half of Maxwell equations (vanishing of magnetic charges and Faraday's induction law) and self-duality $*J = J$ reduces the remaining equations to $dJ = 0$. Hence the Kähler form can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling).

The magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$\begin{aligned} B &= 2re^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2} dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F} sin\Theta d\Theta \wedge d\Phi \ . \end{aligned} \tag{A-2.19}$$

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1, 1).

Useful coordinates for CP_2 are the so called canonical (or symplectic or Darboux) coordinates in which the Kähler potential and Kähler form have very simple expressions

$$\begin{aligned} B &= \sum_{k=1,2} P_k dQ_k \ , \\ J &= \sum_{k=1,2} dP_k \wedge dQ_k \ . \end{aligned} \tag{A-2.20}$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$\begin{aligned} P_1 &= -\frac{1}{1+r^2} \ , \\ P_2 &= -\frac{r^2 cos\Theta}{2(1+r^2)} \ , \\ Q_1 &= \Psi \ , \\ Q_2 &= \Phi \ . \end{aligned} \tag{A-2.21}$$

Spinors In CP_2

CP_2 doesn't allow spinor structure in the conventional sense [A9]. 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 [A20] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-2.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2.2 CP_2 geometry and Standard Model symmetries

Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [B10] and in particular that the right handed neutrinos decouple completely from the electro-weak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e = \pm 1$, CP_2-chirality l, r and M^4-chirality L, R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \tag{A-2.23}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \otimes \gamma_5$, $1 \otimes \gamma_5$ and $\gamma_5 \otimes 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electro-weak group: $SO(4)$ having as its covering group $SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \tag{A-2.24}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{array}{lllllll} V_{01} & = & -\frac{e^1}{r} \ , & & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} \ , & & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r - \frac{1}{r})e^3 \ , & & V_{12} & = & (2r + \frac{1}{r})e^3 \ , \end{array} \tag{A-2.25}$$

and

$$B = 2re^3 \ , \tag{A-2.26}$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of $SO(4)$, one finds that the charged part of the spinor connection is given by

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 \ , \tag{A-2.27}$$

where one have defined

$$\begin{array}{lll} I_L^1 & = & \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 & = & \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{array} \tag{A-2.28}$$

A_{ch} is clearly left handed so that one can perform the identification of the gauge potential as

$$W^\pm = \frac{2(e^1 \pm ie^2)}{r} \ , \tag{A-2.29}$$

where $W^\pm$ denotes the charged intermediate vector boson.

The covariantly constant curvature tensor is given by

$$\begin{array}{l} R_{01} = -R_{23} = e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} = -R_{31} = e^0 \wedge e^2 - e^3 \wedge e^1 \ , \\ R_{03} = 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , \\ R_{12} = 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{array} \tag{A-2.30}$$

The charged part of the curvature tensor is left handed.

This is to be compared with the Weyl tensor, which defines a representation of quaternionic imaginary units.

$$
\begin{aligned}
W_{03} = W_{12} &\equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\
W_{01} = W_{23} &\equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\
W_{02} = W_{31} &\equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 \ .
\end{aligned}
\tag{A-2.31}
$$

The charged part of the Weyl tensor is right-handed and that the relative sign of the two terms in the curvature tensor and Weyl tensor are opposite.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$
\begin{aligned}
X &= re^3 \ , \\
Y &= \frac{e^3}{r} \ ,
\end{aligned}
\tag{A-2.32}
$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$
\begin{aligned}
\bar{\gamma} &= aX + bY \ , \\
\bar{Z}^0 &= cX + dY \ ,
\end{aligned}
\tag{A-2.33}
$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$
\begin{aligned}
A_{nc} &= [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+ 1_+ + n_- 1_-)]\bar{\gamma} \\
&+ [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+ 1_+ + n_- 1_-)]\bar{Z}^0 \ .
\end{aligned}
\tag{A-2.34}
$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5 \Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c = -d \ . \tag{A-2.35}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0 (I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.36}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$
\begin{aligned}
Q_{em} &= \Sigma^{12} + \frac{(n_+ 1_+ + n_- 1_-)}{6} \ , \\
I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ .
\end{aligned}
\tag{A-2.37}
$$

The fields γ and Z^0 are defined via the relations

$$
\begin{aligned}
\gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\
Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) \ .
\end{aligned}
\tag{A-2.38}
$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \tag{A-2.39}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of the Weinberg angle is a dynamical problem. The original approach was based on the assumption that it makes sense to talk about electroweak action defined at fundamental level and introduce a symmetry breaking by adding an additional term proportional to Kähler action. The recent view is that Kähler action plus volume term defines the fundamental action.

The Weinberg angle is completely fixed if one requires that the electroweak action contains no cross term of type γZ^0. This leads to a definite value for the Weinberg angle.

One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle. As a matter fact, color gauge action identifying color gauge field as proportional to $H^A J_{\alpha\beta}$ is proportional to Kähler action. A possible interpretation would be as a sum of electroweak and color gauge interactions.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+ 1_+ + n_- 1_-) \ , \tag{A-2.40}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \tag{A-2.41}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.42}$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{A-2.43}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \tag{A-2.44}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + f J^{\alpha\beta} J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2} Tr(F^{\alpha\beta} F_{\alpha\beta}) \ , \end{aligned} \tag{A-2.45}$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$\begin{aligned} X &= -\frac{K}{2g^2} + \frac{fp}{18} \ , \\ K &= Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ , \end{aligned} \tag{A-2.46}$$

This parameter can be calculated by substituting the values of quark and lepton charges and weak isospins.

In the general case the value of the coefficient K is given by

$$K = \sum_i \left[-\frac{(18 + 2n_i^2)sin^2\theta_W}{9} \right] \ , \tag{A-2.47}$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18 + n_i^2))} \ . \tag{A-2.48}$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \ . \tag{A-2.49}$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is not far from the typical value 9/24 of GUTs at high energies [B1]. 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 [L128] 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

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) = J + 2e^0 \wedge e^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) = 3J - 2e^0 \wedge e^3 \ , \end{aligned} \tag{A-2.50}$$

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} = 2(J + 2e^0 \wedge e^3) \end{aligned} \tag{A-2.51}$$

$$per. \tag{A-2.52}$$

The condition $\langle Z^0 \rangle = 0$ gives $2\langle e^0 \wedge e^3 \rangle = -2J$ and this in turn gives $\langle R_{12} \rangle = 4J$. The average over γ would be

$$\langle \gamma \rangle = (3 - 4sin^2\theta_W)J \ .$$

For $sin^2\theta_W = 3/4$ $langle\gamma\rangle$ would vanish.

The quantum averages of classical weak fields quite generally vanish. What about correlation functions?

1. One expects that the correlators of classical weak fields as color invariants, and perhaps even symplectic invariants, are non-vanishing below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as hadron.

2. The intuitive picture is that in longer length scales one has disjoint 3-surfaces with a size scale of Compton length. If the states associated with two disjoint 3-surfaces are separately color invariant there are no correlations in color degrees of freedom and correlators reduce to the products of expectations of classical weak fields and vanish. This could also hold when the 3-surfaces are connected by flux tube bonds.

   Below the Compton length weak bosons would thus behave as correlated massless fields. The Compton lengths of weak bosons are proportional to the value of effective Planck constant h_{eff} and in living systems the Compton lengths are proposed to be even of the order of cell size. This would explain the mysterious chiral selection in living systems requiring large parity violation.

3. What about the averages and correlators of color gauge fields? Classical color gauge fields are proportional to the products of Hamiltonians of color isometries induced Kähler form and the expectations of color Hamiltonians give vanishing average above Compton length and therefore vanishing average. Correlators are non-vanishing below the hadron scale. Gluons do not propagate in long scales for the same reason as weak bosons. This is implied by color confinement, which has also classical description in the sense that 3-surfaces have necessarily a finite size.

   A large value of h_{eff} allows colored states even in biological scales below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as dark hadron.

Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:

1. Symmetries must be realized as purely geometric transformations.

2. Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [B2] .

   The action of the reflection P on spinors of is given by

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0 \Psi \ . \tag{A-2.53}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \ , \\ \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \ . \end{aligned} \tag{A-2.54}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \Psi^\dagger \gamma^2\gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.55}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Induction procedure and many-sheeted space-time

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induction procedure for gauge fields and spinor connection

Induction procedure for gauge potentials and spinor structure is a standard procedure of bundle theory. If one has embedding of some manifold to the base space of a bundle, the bundle structure can be induced so that it has as a base space the imbedded manifold, whose points have as fiber the fiber if embedding space at their image points. In the recent case the embedding of space-time surface to embedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the embedding space to the space-time surface (see `http://tgdtheory.fi/appfigures/induct.jpg`).

Induction procedure makes sense also for the spinor fields of embedding space and one obtains geometrization of both electroweak gauge potentials and of spinors. The new element is induction of gamma matrices which gives their projections at space-time surface.

As a matter fact, the induced gamma matrices cannot appear in the counterpart of massless Dirac equation. To achieve super-symmetry, Dirac action must be replaced with Kähler-Dirac action for which gamma matrices are contractions of the canonical momentum currents of Kähler action with embedding space gamma matrices. Induced gamma matrices in Dirac action would correspond to 4-volume as action.

Fig. 9. Induction of spinor connection and metric as projection to the space-time surface. `http://tgdtheory.fi/appfigures/induct.jpg`.

A-3.2 Induced gauge fields for space-times for which CP_2 projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP_2 projection, only vacuum extremals and space-time surfaces for which CP_2 projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r = \infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \quad .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

$Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

A-3.3 Many-sheeted space-time

TGD space-time is many-sheeted: in other words, there are in general several space-sheets which have projection to the same M^4 region. Second manner to say this is that CP_2 coordinates are many-valued functions of M^4 coordinates. The original physical interpretation of many-sheeted space-time time was not correct: it was assumed that single sheet corresponds to GRT space-time and this obviously leads to difficulties since the induced gauge fields are expressible in terms of only four embedding space coordinates.

Fig. 10. Illustration of many-sheeted space-time of TGD. `http://tgdtheory.fi/appfigures/manysheeted.jpg`

Superposition of effects instead of superposition of fields

The first objection against TGD is that superposition is not possible for induced gauge fields and induced metric. The resolution of the problem is that it is effects which need to superpose, not the fields.

Test particle topologically condenses simultaneously to all space-time sheets having a projection to same region of M^4 (that is touches them). The superposition of effects of fields at various space-time sheets replaces the superposition of fields.This is crucial for the understanding also how GRT space-time relates to TGD space-time, which is also in the appendix of this book).

Wormhole contacts

Wormhole contacts are key element of many-sheeted space-time. One does not expect them to be stable unless there is non-trivial Kähler magnetic flux flowing through then so that the throats look like Kähler magnetic monopoles.

Fig. 11. Wormhole contact. `http://tgdtheory.fi/appfigures/wormholecontact.jpg`

Since the flow lines of Kähler magnetic field must be closed this requires the presence of another wormhole contact so that one obtains closed monopole flux tube decomposing to two Minkowskian pieces at the two space-time sheets involved and two wormhole contacts with Euclidian signature of the induced metric. These objects are identified as space-time correlates of elementary particles and are clearly analogous to string like objects.

The relationship between the many-sheeted space-time of TGD and of GRT space-time

The space-time of general relativity is single-sheeted and there is no need to regard it as surface in H although the assumption about representability as vacuum extremal gives very powerful constraints in cosmology and astrophysics and might make sense in simple situations.

The space-time of GRT can be regarded as a long length scale approximation obtained by lumping together the sheets of the many-sheeted space-time to a region of M^4 and providing it with an effective metric obtained as sum of M^4 metric and deviations of the induced metrics of various space-time sheets from M^4 metric. Also induced gauge potentials sum up in the similar manner so that also the gauge fields of gauge theories would not be fundamental fields.

Fig. 12. The superposition of fields is replaced with the superposition of their effects in many-sheeted space-time. `http://tgdtheory.fi/appfigures/fieldsuperpose.jpg`

Space-time surfaces of TGD are considerably simpler objects that the space-times of general relativity and relate to GRT space-time like elementary particles to systems of condensed matter physics. Same can be said about fields since all fields are expressible in terms of embedding space coordinates and their gradients, and general coordinate invariance means that the number of bosonic field degrees is reduced locally to 4. TGD space-time can be said to be a microscopic description whereas GRT space-time a macroscopic description. In TGD complexity of space-time topology replaces the complexity due to large number of fields in quantum field theory.

Topological field quantization and the notion of magnetic body

Topological field quantization also TGD from Maxwell's theory. TGD predicts topological light rays ("massless extremals (MEs)") as space-time sheets carrying waves or arbitrary shape propagating

with maximal signal velocity in single direction only and analogous to laser beams and carrying light-like gauge currents in the generi case. There are also magnetic flux quanta and electric flux quanta. The deformations of cosmic strings with 2-D string orbit as M^4 projection gives rise to magnetic flux tubes carrying monopole flux made possible by CP_2 topology allowing homological Kähler magnetic monopoles.

Fig. 13. Topological quantization for magnetic fields replaces magnetic fields with bundles of them defining flux tubes as topological field quanta. `http://tgdtheory.fi/appfigures/field.jpg`

The imbeddability condition for say magnetic field means that the region containing constant magnetic field splits into flux quanta, say tubes and sheets carrying constant magnetic field. Unless one assumes a separate boundary term in Kähler action, boundaries in the usual sense are forbidden except as ends of space-time surfaces at the boundaries of causal diamonds. One obtains typically pairs of sheets glued together along their boundaries giving rise to flux tubes with closed cross section possibly carrying monopole flux.

These kind of flux tubes might make possible magnetic fields in cosmic scales already during primordial period of cosmology since no currents are needed to generate these magnetic fields: cosmic string would be indeed this kind of objects and would dominated during the primordial period. Even superconductors and maybe even ferromagnets could involve this kind of monopole flux tubes.

A-3.4 Embedding space spinors and induced spinors

One can geometrize also fermionic degrees of freedom by inducing the spinor structure of $M^4 \times CP_2$.

CP_2 does not allow spinor structure in the ordinary sense but one can couple the opposite H-chiralities of H-spinors to an $n = 1$ ($n = 3$) integer multiple of Kähler gauge potential to obtain a respectable modified spinor structure. The em charges of resulting spinors are fractional (integer valued) and the interpretation as quarks (leptons) makes sense since the couplings to the induced spinor connection having interpretation in terms electro-weak gauge potential are identical to those assumed in standard model.

The notion of quark color differs from that of standard model.

1. Spinors do not couple to color gauge potential although the identification of color gauge potential as projection of $SU(3)$ Killing vector fields is possible. This coupling must emerge only at the effective gauge theory limit of TGD.

2. Spinor harmonics of embedding space correspond to triality $t = 1$ ($t = 0$) partial waves. The detailed correspondence between color and electroweak quantum numbers is however not correct as such and the interpretation of spinor harmonics of embedding space is as representations for ground states of super-conformal representations. The wormhole pairs associated with physical quarks and leptons must carry also neutrino pair to neutralize weak quantum numbers above the length scale of flux tube (weak scale or Compton length). The total color quantum numbers or these states must be those of standard model. For instance, the color quantum numbers of fundamental left-hand neutrino and lepton can compensate each other for the physical lepton. For fundamental quark-lepton pair they could sum up to those of physical quark.

The well-definedness of em charge is crucial condition.

1. Although the embedding space spinor connection carries W gauge potentials one can say that the embedding space spinor modes have well-defined em charge. One expects that this is true for induced spinor fields inside wormhole contacts with 4-D CP_2 projection and Euclidian signature of the induced metric.

2. The situation is not the same for the modes of induced spinor fields inside Minkowskian region and one must require that the CP_2 projection of the regions carrying induced spinor field is such that the induced W fields and above weak scale also the induced Z^0 fields vanish in order to avoid large parity breaking effects. This condition forces the CP_2 projection to be 2-dimensional. For a generic Minkowskian space-time region this is achieved only if the

spinor modes are localized at 2-D surfaces of space-time surface - string world sheets and possibly also partonic 2-surfaces.

3. Also the Kähler-Dirac gamma matrices appearing in the modified Dirac equation must vanish in the directions normal to the 2-D surface in order that Kähler-Dirac equation can be satisfied. This does not seem plausible for space-time regions with 4-D CP_2 projection.

4. One can thus say that strings emerge from TGD in Minkowskian space-time regions. In particular, elementary particles are accompanied by a pair of fermionic strings at the opposite space-time sheets and connecting wormhole contacts. Quite generally, fundamental fermions would propagate at the boundaries of string world sheets as massless particles and wormhole contacts would define the stringy vertices of generalized Feynman diagrams. One obtains geometrized diagrammatics, which brings looks like a combination of stringy and Feynman diagrammatics.

5. This is what happens in the the generic situation. Cosmic strings could serve as examples about surfaces with 2-D CP_2 projection and carrying only em fields and allowing delocalization of spinor modes to the entire space-time surfaces.

A-3.5 About induced gauge fields

In the following the induced gauge fields are studied for general space-time surface without assuming the preferred extremal property (Bohr orbit property). Therefore the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0, or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r, Θ, Ψ, Φ) for CP_2, the expression of Kähler form reads as

$$\begin{aligned} J &= \frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta) d\Phi) + \frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-3.1}$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3+2p)\frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta) d\Phi) + (3+p)\frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ p &= sin^2(\Theta_W) \ , \end{aligned} \tag{A-3.2}$$

where Θ_W denotes Weinberg angle.

1. The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi \ , \\ (3+2p)\frac{1}{r^2 F}(d(r^2)/d\Theta)(k + cos(\Theta)) &+ (3+p) sin(\Theta) = 0 \ , \end{aligned} \tag{A-3.3}$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$\begin{aligned} r &= \sqrt{\frac{X}{1-X}} \ , \\ X &= D\left[|\frac{k+u}{C}|\right]^{\epsilon} \ , \\ u &\equiv cos(\Theta) \ , \ C = k + cos(\Theta_0) \ , \ D = \frac{r_0^2}{1+r_0^2} \ , \ \epsilon = \frac{3+p}{3+2p} \ , \end{aligned} \tag{A-3.4}$$

where C and D are integration constants. $0 \leq X \leq 1$ is required by the reality of r. $r = 0$ would correspond to $X = 0$ giving $u = -k$ achieved only for $|k| \leq 1$ and $r = \infty$ to $X = 1$ giving $|u + k| = [(1 + r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$sign(u+k) \times [\frac{1+r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \leq k+1 \ ,$$

where $sign(x)$ denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$\begin{aligned} J &= -\frac{p}{3+2p} X du \wedge d\Phi \ , \\ Z^0 &= -\frac{6}{p} J \ . \end{aligned} \tag{A-3.5}$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

2. The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F} du \wedge d\Phi$ is useful.

3. The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$\begin{aligned} Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u} du \wedge d\Phi = (k+u) du \wedge d\Phi \ , \\ r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\ \gamma &= -\frac{p}{2} Z^0 \ . \end{aligned} \tag{A-3.6}$$

For a vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em,Z^0, or Kähler field is of practical value in the case of vacuum extremals and is given by

$$\begin{aligned} ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta}d\Theta^2 + s^{eff}_{\Phi\Phi}d\Phi^2] \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ , \end{aligned} \tag{A-3.7}$$

and is useful in the construction of vacuum embedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\begin{aligned} \Psi &= \omega_2 m^0 + k_2 m^3 + n_2\phi + \text{Fourier expansion} \ , \\ \Phi &= \omega_1 m^0 + k_1 m^3 + n_1\phi + \text{Fourier expansion} \ . \end{aligned} \tag{A-3.8}$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global embedding for, say a constant magnetic field. Although global embedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteeing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \ , \tag{A-3.9}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

A-4 The relationship of TGD to QFT and string models

The recent view of the relationship of TGD to QFT and string models has developed slowly during years and it seems that in a certain sense TGD means a return to roots: instead of QFT like description involving path integral one would have wave mechanics for 3-surfaces.

A-4.1 TGD as a generalization of wave mechanism obtained by replacing point-like particles with 3-surfaces

The first vision of TGD was as a generalization of quantum field theory (string models) obtained by replacing pointlike particles (strings) as fundamental objects with 3-surfaces.

The later work has revealed that TGD could be seen as a generalization of the wave mechanism based on the replacement of a point-like particle with 3-D surface. This is due to holography implied by general coordinate invariance. The definition of the metric of the "world of classical worlds" (WCW) must assign a unique or at least almost unique space-time surface to a given 3-surface. This 4-surface is analogous to Bohr orbit so that also Bohr orbitology becomes an exact part of quantum physics. The failure of strict determinism forces to replace 3-surfaces with 4-surfaces and this leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K34, K18, K63] [L109, L119].

Fig. 5. TGD replaces point-like particles with 3-surfaces. `http://tgdtheory.fi/appfigures/particletgd.jpg`

A-4.2 Extension of superconformal invariance

The fact that light-like 3-surfaces are effectively metrically 2-dimensional and thus possess generalization of 2-dimensional conformal symmetries with light-like radial coordinate defining the analog of second complex coordinate suggests that this generalization could work and extend the super-conformal symmetries to their 4-D analogs.

The boundary $\delta M^4_+ = S^2 \times R_+$- of 4-D light-cone M^4_+ is also metrically 2-dimensional and allows extended conformal invariance. Also the group of isometries of light-cone boundary and of light-like 3-surfaces is infinite-dimensional since the conformal scalings of S^2 can be compensated by S^2-local scaling of the light-like radial coordinate of R_+. These simple facts mean that 4-dimensional Minkowski space and 4-dimensional space-time surfaces are in a completely unique position as far as symmetries are considered.

In fact, this leads to a generalization of the Kac-Moody type symmetries of string models. $\delta M^4_+ \times CP_2$ allows huge supersymplectic symmetries for which the radial light-like coordinate of δM^4_+ plays the role of complex string coordinate in string models. These symmetries are assumed to act as isometries of WCW.

A-4.3 String-like objects and strings

String like objects obtained as deformations of cosmic strings $X^2 \times Y^2$, where X^2 is minimal surface in M^4 and Y^2 a holomorphic surface of CP_2 are fundamental extremals of Kähler action having string world sheet as M^4 projections. Cosmic strings dominate the primordial cosmology of the TGD Universe and the inflationary period corresponds to the transition to radiation dominated cosmology for which space-time sheets with 4-D M^4 projection dominate.

Also genuine string-like objects emerge from TGD. The conditions that the em charge of modes of induces spinor fields is well-defined requires in the generic case the localization of the modes at 2-D surfaces -string world sheets and possibly also partonic 2-surfaces. This in Minkowskian space-time regions.

Fig. 6. Well-definedness of em charge forces the localization of induced spinor modes to 2-D surfaces in generic situations in Minkowskian regions of space-time surface. `http://tgdtheory.fi/appfigures/fermistring.jpg`

A-4.4 TGD view of elementary particles

The TGD based view about elementary particles has two key aspects.

1. The space-time correlates of elementary particles are identified as pairs of wormhole contacts with Euclidean signature of metric and having 4-D CP_2 projection. Their throats behave effectively as Kähler magnetic monopoles so that wormhole throats must be connected by Kähler magnetic flux tubes with monopole flux so that closed flux tubes are obtained.

2. At the level of H Fermion number is carried by the modes of the induced spinor field. In space-time regions with Minkowski signature the modes are localized at string world sheets connecting the wormhole contacts.

Fig. 7. TGD view about elementary particles. a) Particle orbit corresponds to a 4-D generalization of a world line or b) with its light-like 3-D boundary (holography). c) Particle world lines have Euclidean signature of the induced metric. d) They can be identified as wormhole contacts. e) The throats of wormhole contacts carry effective Kähler magnetic charges so that wormhole contacts must appear as pairs in order to obtain closed flux tubes. f) Wormhole contacts are accompanied by fermionic strings connecting the throats at the same sheet: the strings do not extend inside the wormhole contacts. `http://tgdtheory.fi/appfigures/elparticletgd.jpg`

Particle interactions involve both stringy and QFT aspects.

1. The boundaries of string world sheets correspond to fundamental fermions. This gives rise to massless propagator lines in generalized Feynman diagrammatics. One can speak of "long" string connecting wormhole contacts and having a hadronic string as a physical counterpart. Long strings should be distinguished from wormhole contacts which due to their superconformal invariance behave like "short" strings with length scale given by CP_2 size, which is 10^4 times longer than Planck scale characterizing strings in string models.

2. Wormhole contact defines basic stringy interaction vertex for fermion-fermion scattering. The propagator is essentially the inverse of the superconformal scaling generator L_0. Wormhole contacts containing fermion and antifermion at its opposite throats behave like virtual bosons so that one has BFF type vertices typically.

3. In topological sense one has 3-vertices serving as generalizations of 3-vertices of Feynman diagrams. In these vertices 4-D "lines" of generalized Feynman diagrams meet along their 3-D ends. One obtains also the analogs of stringy diagrams but stringy vertices do not have the usual interpretation in terms of particle decays but in terms of propagation of particles along two different routes.

Fig. 8. a) TGD analogs of Feynman and string diagrammatics at the level of space-time topology. b) The 4-D analogs of both string diagrams and QFT diagrams appear but the interpretation of the analogs stringy diagrams is different. `http://tgdtheory.fi/appfigures/tgdgraphs.jpg`

A-5 About the selection of the action defining the Kähler function of the "world of classical worlds" (WCW)

The proposal is that space-time surfaces correspond to preferred extremals of some action principle, being analogous to Bohr orbits, so that they are almost deterministic. The action for the preferred extremal would define the Kähler function of WCW [K34, K63].

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 [L41] [L109, L112, L113] 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 [A16] 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 [L119]. 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 [L119] 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 [L119] 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 [L119] 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 [L115] 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 [K42, K43]). 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 [L115], 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 [L115], 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 [L115].

3. p-Adic length scale hypothesis [L120] 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 [L119] 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 $\delta M^4_+ \times CP_2$ [K34, K18]. 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 [L118].

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 [K46, K39, K15]. The fusion of the various p-adic physics leads to what I call adelic physics [L39, L40]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K19, K20, K21, 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 [L80, L81] 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 [L115, L118]. Also the ordinary $3 \rightarrow 4$ holography is needed to assign 4-surfaces with these 3-D mass shells. The number theoretic dynamics is based on the condition that the normal space of the 4-surface in M^8 is associative (quaternionic) and contains a commutative complex sub-space. This makes it possible to assign to this surface space-time surface in $H = M^4 \times CP_2$.

At the level of H the space-time surfaces are by holography preferred extremals and are assumed to be determined by the twistor lift of TGD [L41] 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 [A8]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k \geq k_0} x(k) p^k, \; x(k) = 0, ..., p-1 \; . \tag{A-6.1}$$

The norm of a p-adic number is given by

$$|x| \;=\; p^{-k_0(x)} \;. \tag{A-6.2}$$

Here $k_0(x)$ is the lowest power in the expansion of the p-adic number. The norm differs drastically from the norm of the ordinary real numbers since it depends on the lowest pinary digit of the p-adic number only. Arbitrarily high powers in the expansion are possible since the norm of the p-adic number is finite also for numbers, which are infinite with respect to the ordinary norm. A convenient representation for p-adic numbers is in the form

$$x \;=\; p^{k_0}\varepsilon(x) \;, \tag{A-6.3}$$

where $\varepsilon(x) = k + ...$ with $0 < k < p$, is p-adic number with unit norm and analogous to the phase factor $exp(i\phi)$ of a complex number.

The distance function $d(x,y) = |x-y|_p$ defined by the p-adic norm possesses a very general property called ultra-metricity:

$$d(x,z) \;\leq\; max\{d(x,y), d(y,z)\} \;. \tag{A-6.4}$$

The properties of the distance function make it possible to decompose R_p into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \;\leq\; D \;. \tag{A-6.5}$$

This division of the metric space into classes has following properties:

1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.

2. Distances of points x and y inside single class are smaller than distances between different classes.

3. Classes form a hierarchical tree.

Notice that the concept of the ultra-metricity emerged in physics from the models for spin glasses and is believed to have also applications in biology [B8]. The emergence of p-adic topology as the topology of the effective space-time would make ultra-metricity property basic feature of physics.

Canonical correspondence between p-adic and real numbers

The basic challenge encountered by p-adic physicist is how to map the predictions of the p-adic physics to real numbers. p-Adic probabilities provide a basic example in this respect. Identification via common rationals and canonical identification and its variants have turned out to play a key role in this respect.

1. Basic form of the canonical identification

There exists a natural continuous map $I : R_p \to R_+$ from p-adic numbers to non-negative real numbers given by the "pinary" expansion of the real number for $x \in R$ and $y \in R_p$ this correspondence reads

$$\begin{aligned} y \;&=\; \sum_{k>N} y_k p^k \to x = \sum_{k<N} y_k p^{-k} \;, \\ y_k \;&\in\; \{0,1,..,p-1\} \;. \end{aligned} \tag{A-6.6}$$

This map is continuous as one easily finds out. There is however a little difficulty associated with the definition of the inverse map since the pinary expansion like also decimal expansion is not unique ($1 = 0.999...$) for the real numbers x, which allow pinary expansion with finite number of pinary digits

$$\begin{aligned} x &= \sum_{k=N_0}^{N} x_k p^{-k} \ , \\ x &= \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1)p^{-N} + (p-1)p^{-N-1} \sum_{k=0,..} p^{-k} \ . \end{aligned} \tag{A-6.7}$$

The p-adic images associated with these expansions are different

$$\begin{aligned} y_1 &= \sum_{k=N_0}^{N} x_k p^{k} \ , \\ y_2 &= \sum_{k=N_0}^{N-1} x_k p^{k} + (x_N - 1)p^{N} + (p-1)p^{N+1} \sum_{k=0,..} p^{k} \\ &= y_1 + (x_N - 1)p^N - p^{N+1} \ , \end{aligned} \tag{A-6.8}$$

so that the inverse map is either two-valued for p-adic numbers having expansion with finite pinary digits or single valued and discontinuous and non-surjective if one makes pinary expansion unique by choosing the one with finite pinary digits. The finite pinary digit expansion is a natural choice since in the numerical work one always must use a pinary cutoff on the real axis.

2. The topology induced by canonical identification

The topology induced by the canonical identification in the set of positive real numbers differs from the ordinary topology. The difference is easily understood by interpreting the p-adic norm as a norm in the set of the real numbers. The norm is constant in each interval $[p^k, p^{k+1})$ (see **Fig. A-6.1**) and is equal to the usual real norm at the points $x = p^k$: the usual linear norm is replaced with a piecewise constant norm. This means that p-adic topology is coarser than the usual real topology and the higher the value of p is, the coarser the resulting topology is above a given length scale. This hierarchical ordering of the p-adic topologies will be a central feature as far as the proposed applications of the p-adic numbers are considered.

Ordinary continuity implies p-adic continuity since the norm induced from the p-adic topology is rougher than the ordinary norm. p-Adic continuity implies ordinary continuity from right as is clear already from the properties of the p-adic norm (the graph of the norm is indeed continuous from right). This feature is one clear signature of the p-adic topology.

Fig. 14. The real norm induced by canonical identification from 2-adic norm. `http://tgdtheory.fi/appfigures/norm.png`

The linear structure of the p-adic numbers induces a corresponding structure in the set of the non-negative real numbers and p-adic linearity in general differs from the ordinary concept of linearity. For example, p-adic sum is equal to real sum only provided the summands have no common pinary digits. Furthermore, the condition $x +_p y < max\{x, y\}$ holds in general for the p-adic sum of the real numbers. p-Adic multiplication is equivalent with the ordinary multiplication only provided that either of the members of the product is power of p. Moreover one has $x \times_p y < x \times y$ in general. The p-Adic negative -1_p associated with p-adic unit 1 is given by $(-1)_p = \sum_k (p-1)p^k$ and defines p-adic negative for each real number x. An interesting possibility is that p-adic linearity might replace the ordinary linearity in some strongly nonlinear systems so these systems would look simple in the p-adic topology.

These results suggest that canonical identification is involved with some deeper mathematical structure. The following inequalities hold true:

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |x|_p|y|_R \leq (xy)_R &\leq x_R y_R \ , \end{aligned} \tag{A-6.9}$$

where $|x|_p$ denotes p-adic norm. These inequalities can be generalized to the case of $(R_p)^n$ (a linear vector space over the p-adic numbers).

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |\lambda|_p|y|_R \leq (\lambda y)_R &\leq \lambda_R y_R \ , \end{aligned} \tag{A-6.10}$$

where the norm of the vector $x \in T_p^n$ is defined in some manner. The case of Euclidian space suggests the definition

$$(x_R)^2 = (\sum_n x_n^2)_R \ . \tag{A-6.11}$$

These inequalities resemble those satisfied by the vector norm. The only difference is the failure of linearity in the sense that the norm of a scaled vector is not obtained by scaling the norm of the original vector. Ordinary situation prevails only if the scaling corresponds to a power of p.

These observations suggests that the concept of a normed space or Banach space might have a generalization and physically the generalization might apply to the description of some non-linear systems. The nonlinearity would be concentrated in the nonlinear behavior of the norm under scaling.

3. Modified form of the canonical identification

The original form of the canonical identification is continuous but does not respect symmetries even approximately. This led to a search of variants which would do better in this respect. The modification of the canonical identification applying to rationals only and given by

$$I_Q(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \tag{A-6.12}$$

is uniquely defined for rationals, maps rationals to rationals, has also a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$. It has turned out that it is this map which most naturally appears in the applications. The map is obviously continuous locally since p-adically small modifications of r and s mean small modifications of the real counterparts.

Canonical identification is in a key role in the successful predictions of the elementary particle masses. The predictions for the light elementary particle masses are within extreme accuracy same for I and I_Q but I_Q is theoretically preferred since the real probabilities obtained from p-adic ones by I_Q sum up to one in p-adic thermodynamics.

4. Generalization of number concept and notion of embedding space

TGD forces an extension of number concept: roughly a fusion of reals and various p-adic number fields along common rationals is in question. This induces a similar fusion of real and p-adic embedding spaces. Since finite p-adic numbers correspond always to non-negative reals n-dimensional space R^n must be covered by 2^n copies of the p-adic variant R_p^n of R^n each of which projects to a copy of R_+^n (four quadrants in the case of plane). The common points of p-adic and real embedding spaces are rational points and most p-adic points are at real infinity.

Real numbers and various algebraic extensions of p-adic number fields are thus glued together along common rationals and also numbers in algebraic extension of rationals whose number belong to the algebraic extension of p-adic numbers. This gives rise to a book like structure with rationals and various algebraic extensions of rationals taking the role of the back of the book. Note that Neper number is exceptional in the sense that it is algebraic number in p-adic number field Q_p satisfying $e^p \ mod \ p = 1$.

Fig. 15. Various number fields combine to form a book like structure. `http://tgdtheory.fi/appfigures/book.jpg`

For a given p-adic space-time sheet most points are literally infinite as real points and the projection to the real embedding space consists of a discrete set of rational points: the interpretation in terms of the unavoidable discreteness of the physical representations of cognition is natural. Purely local p-adic physics implies real p-adic fractality and thus long range correlations for the real space-time surfaces having enough common points with this projection.

p-Adic fractality means that M^4 projections for the rational points of space-time surface X^4 are related by a direct identification whereas CP_2 coordinates of X^4 at these points are related by I, I_Q or some of its variants implying long range correlates for CP_2 coordinates. Since only a discrete set of points are related in this manner, both real and p-adic field equations can be satisfied and there are no problems with symmetries. p-Adic effective topology is expected to be a good approximation only within some length scale range which means infrared and UV cutoffs. Also multi-p-fractality is possible.

The notion of p-adic manifold

The notion of p-adic manifold is needed in order to fuse real physics and various p-adic physics to a larger structure which suggests that real and p-adic number fields should be glued together along common rationals bringing in mind adeles. The notion is problematic because p-adic topology is totally disconnected implying that p-adic balls are either disjoint or nested so that ordinary definition of manifold using p-adic chart maps fails. A cure is suggested to be based on chart maps from p-adics to reals rather than to p-adics (see the appendix of the book)

The chart maps are interpreted as cognitive maps, "thought bubbles".

Fig. 16. The basic idea between p-adic manifold. `http://tgdtheory.fi/appfigures/padmanifold.jpg`

There are some problems.

1. Canonical identification does not respect symmetries since it does not commute with second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map arithmetic operations which requires pinary cutoff below which chart map takes rationals to rationals so that commutativity with arithmetics and symmetries is achieved in finite resolution: above the cutoff canonical identification is used

2. Canonical identification is continuous but does not map smooth p-adic surfaces to smooth real surfaces requiring second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map requiring completion of the image to smooth preferred extremal of Kähler action so that chart map is not unique in accordance with finite measurement resolution

3. Canonical identification violates general coordinate invariance of chart map: (cognition-induced symmetry breaking) minimized if p-adic manifold structure is induced from that for p-adic embedding space with chart maps to real embedding space and assuming preferred coordinates made possible by isometries of embedding space: one however obtains several inequivalent p-adic manifold structures depending on the choice of coordinates: these cognitive representations are not equivalent.

A-6.2 Hierarchy of Planck constants and dark matter hierarchy

Hierarchy of Planck constants was motivated by the "impossible" quantal effects of ELF em fields on vertebrate cyclotron energies $E = hf = \hbar \times eB/m$ are above thermal energy is possible only if $\hbar$ has value much larger than its standard value. Also Nottale's finding that planetary orbits migh be understood as Bohr orbits for a gigantic gravitational Planck constant.

Hierachy of Planck constant would mean that the values of Planck constant come as integer multiples of ordinary Planck constant: $h_{eff} = n \times h$. The particles at magnetic flux tubes characterized by h_{eff} would correspond to dark matter which would be invisible in the sense that only particle with same value of h_{eff} appear in the same vertex of Feynman diagram.

Hierarchy of Planck constants would be due to the non-determism of the Kähler action predicting huge vacuum degeneracy allowing all space-time surfaces which are sub-manfolds of any $M^4 \times Y^2$, where Y^2 is Lagrangian sub-manifold of CP_2. For agiven Y^2 one obtains new manifolds Y^2 by applying symplectic transformations of CP_2.

Non-determinism would mean that the 3-surface at the ends of causal diamond (CD) can be connected by several space-time surfaces carrying same conserved Kähler charges and having same values of Kähler action. Conformal symmetries defined by Kac-Moody algebra associated with the embedding space isometries could act as gauge transformations and respect the light-likeness property of partonic orbits at which the signature of the induced metric changes from Minkowskian to Euclidian (Minkowskianb space-time region transforms to wormhole contact say). The number of conformal equivalence classes of these surfaces could be finite number n and define discrete physical degree of freedom and one would have $h_{eff} = n \times h$. This degeneracy would mean "second quantization" for the sheets of n-furcation: not only one but several sheets can be realized.

This relates also to quantum criticality postulated to be the basic characteristics of the dynamics of quantum TGD. Quantum criticalities would correspond to an infinite fractal hierarchy of broken conformal symmetries defined by sub-algebras of conformal algebra with conformal weights coming as integer multiples of n. This leads also to connections with quantum criticality and hierarchy of broken conformal symmetries, p-adicity, and negentropic entanglement which by consistency with standard quantum measurement theory would be described in terms of density matrix proportional $n \times n$ identity matrix and being due to unitary entanglement coefficients (typical for quantum computing systems).

Formally the situation could be described by regarding space-time surfaces as surfaces in singular n-fold singular coverings of embedding space. A stronger assumption would be that they are expressible as as products of n_1 -fold covering of M^4 and n_2-fold covering of CP_2 meaning analogy with multi-sheeted Riemann surfaces and that M^4 coordinates are n_1-valued functions and CP_2 coordinates n_2 -valued functions of space-time coordinates for $n = n_1 \times n_2$. These singular coverings of embedding space form a book like structure with singularities of the coverings localizable at the boundaries of causal diamonds defining the back of the book like structure.

Fig. 17. Hierarchy of Planck constants. `http://tgdtheory.fi/appfigures/planckhierarchy.jpg`

A-6.3 $M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix **??**) has changed considerably towards the end 2021 [L109] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \to m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L109] 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 [L109] 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 [L80, L81]. 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 $X^4 \subset M^8$ [L68]. 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 [L109]. 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 [L99] 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 [L109]. 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 [L72] [K87].

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 [L72].

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 [L66] in atomic scale can be explained by the same mechanism [L66]. 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 [L67]. 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 [L71, L133].

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 [L71, L133]. 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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