The recent view of TGD inspired theory of consciousness and quantum biology

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Abstract

This chapter is a summary of TGD inspired theory of consciousness as it is towards the end of 2025 and of its applications to biology. This article gives a summary of TGD inspired theory of consciousness as it is towards the end of 2025. In the TGD framework, it is not possible to discuss consciousness without the TGD view of space-time and quantum. Also the applications to quantum biology and neuroscience have been essential in the development of ideas. The basic inspiration has come from the deep philosophical problems of recent day physics and philosophy of consciousness. The TGD view of consciousness can be seen as a generalization of quantum measurement theory: the observer as an outsider becomes a part of the system.

The basic new elements are zero energy ontology (ZEO) as a new quantum ontology forced by the new view of space-time as 4-surfaces analogous to Bohr orbits of particles as 3-D surfaces. The dynamics of the classical space-time obeys holography = holomorphy principle. The failure of a strict classical determinism provides geometric correlates of intention and cognition. ZEO allows us to solve the basic problem of quantum measurement theory, allows free will, and provides a new view of the relation between geometric time and subjective time.

Physical existence, identified as the mathematical existence of quantum states: one can speak of quantum Platonia. Conscious existence is identified as quantum jumps between them and can be seen as two different kinds of existence. The classical non-determinism gives rise to quantum jumps giving rise to conscious entities, selves, and the ordinary quantum jumps are predicted to change the arrow of time. This means death and reincarnation of self with an opposite arrow of time.

Also the number theoretic visions of TGD is central. A key implication of the number theoretic vision is a hierarchy of Planck constants h_{eff} making possible quantum coherence in arbitrarily long scales crucial for the coherence of living matter. p-Adic length scale hierarchy is the second number theoretic prediction. The applications to quantum biology and neuroscience rely on these hierarchies.

In this chapter, the key notions and ideas of TGD, especially those relevant to consciousness and quantum biology, are summarized. The TGD view of consciousness emphasizing recent progress is summarized. The basic ideas and applications to quantum biology are also described. Also the number theoretic visions of TGD is central. A key implication of the number theoretic vision is a hierarchy of Planck constants h_{eff} making possible quantum coherence in arbitrarily long scales crucial for the coherence of living matter. p-Adic length scale hierarchy is the second number theoretic prediction. The applications to quantum biology and neuroscience rely on these hierarchies.

1 Introduction

Topological GeometroDynamics (TGD) [L90, L91] was born as a proposal for a unified theory of fundamental interactions. The basic idea came in 1977 and my thesis was published in 1982. Around 1995 I started a systematical development of TGD inspired theory of consciousness and quantum biology (for a material about TGD see this).

1.1 What TGD inspired theory of consciousness is?

TGD inspired theory of consciousness solves the problem of free will. Free will is in conflict with the determinism of classical physics and with the statistical determinism of quantum physics. Also the basic problem of quantum measurement theory is due to the conflict between non-determinism of state function reduction and determinism of unitary time evolution.

The logical steps of the proposed solution are as follows.

1. In TGD space-time of general relativity is replaced with a 4-D space-time surface X^4 in 8-D space $H = M^4 \times CP_2$ [L90, L91]. This solves the conflict of general relativity with classical conservation laws: since the M^4 factor of H realizes Poincare invariance.

2. The realization of general coordinate invariance requires holography since path integral approach solving it formally does not allow a renormalizable quantum theory. One must be able to assign to a given 3-surface as analog of a particle a 4-surface as its "orbit" obeying

holography. Holography = holomorphy (H-H) principle allows this [L84, L93, L86]. The space-time surface is a minimal surface and analogous to a 4-D Bohr orbit but is not strictly deterministic. This forces us to take the 4-D Bohr orbits as basic objects instead of 3-surfaces. This gives rise to zero energy ontology (ZEO) [K16] [L33, L74].

3. Quantum states correspond to wave function in the space of Bohr orbits ("world of classical worlds" (WCW)) and quantum jump occurring in state function reduction occurs between these states. Hence TGD could be seen as a generalization of wave mechanics by replacing point-like particles, not with 3-surfaces, but with their Bohr orbits. Classical field equations and the analog of Schrödinger equation are not violated and the non-determinism of state function reduction (SFR) is not in violation with classical field equations. This solves the quantum measurement problem [L33, L74].

4. The slight failure of classical determinism, predicted by holography = holomorphy vision (H-H) [L86], forces to replace the sequence of repeated quantum measurements, having no effect in standard quantum theory (Zeno effect), with a sequence of "small" SFRs (SSFRs) in which the observables assignable with the discrete degrees of freedom assignable to the classical non-determinism, interpreted in terms of cognition, are measured. This sequence defines a conscious entity, self. Subjective time corresponds to a sequence of SSFRs and geometric time correlates but is not identical with it.

5. Ordinary SFRs correspond to "big" SFRs (BSFRs) and in these the arrow of time changes and the system reincarnates with an opposite arrow of geometric time (to be distinguished from the subjective time). Falling asleep and biological death are familiar examples of BSFR.

1.2 What phenomena TGD inspired theory of consciousness explains that materialism fails to explain?

1. Free will: Free will ceases to be a mystery and in conflict with physics.

2. Life: TGD also predicts a hierarchy of Planck constants h_{eff} meaning the possibility of quantum coherence in arbitrarily long scales. This quantum coherence at the field body of the system as a TGD analog for its classical em fields, induces the coherence of the ordinary biomatter, which is difficult to understand in the standard biology. The universality of quantum coherence together with the fractality of the TGD Universe suggests that consciousness and life are universal phenomena.

3. Death: BSFR gives rise to a death of self as a sequence of SSFRs. Death in this sense would be universal and take place on all scales. Death means reincarnation with an opposite arrow of geometric time. A sequence of reincarnations with a given arrow of geometric time is predicted [L55].

4. Evolution: The value of effective Planck constant h_{eff} is a measure for the algebraic complexity of the space-time surface and serves as a kind of IQ predicted to increase during evolution as an increase of complexity [L32, L66, L70]. It is natural to assign a value of effective Planck constant to classical gravitational and electric fields. The values of $\hbar_{gr}$ and $\hbar_{em}$ can be very large and characterize interacting particle pairs connected by monopole flux tubes [L32, L66, L70].

5. Basic aspects of conscious experience:

   (a) The slight non-determinism of the classical dynamics, inducing similar non-determinism in fermionic degrees of freedom, predicts the presence of discrete degrees of freedom assignable to the space-time surface: cognitive/internal degrees of freedom (IDF) might be the proper term. Intention can be also assigned to these degrees of freedom.

   IDF could be responsible for cognitive consciousness. IDF can entangle with the ordinary physical degrees of freedom (ODF) associated with the system itself or with another system. Also the entanglement between the IDF of two separate systems is possible.

(b) Quantum measurements reducing these entanglements provide a model for sensory perception and motor action [L9] and IDF-ODF entanglement provides a model for various exotic phenomena of consciousness such as telepathy, psychokinesis, and hypnosis. Also intentions and intentional actions can be understood in terms of IDF-ODF coupling.

(c) I have also discussed TGD based models of sensory qualia [K8] as related to the measurements of ordinary observables and proposed that emotions might be sensory qualia at the level of magnetic/field bodies. IDF-ODF entanglement could assign cognitive representations to the sensory perceptions.

(d) Zero energy ontology and the 4-D character of the "Bohr orbits" allows us to understand memories as conscious experiences [L87]: this is something different than memories as conditioned behaviors. Entire 4-D space-time surface would serve as a memory storage quantum entanglement between the 3-D loci of non-determinism would make possible conscious memories as an outcome of the reduction of this entanglement.

1.3 What predictions can it make, and what experiments can test them?

Most predictions relate to neuroscience and quantum biology. ZEO [K16]; the number theoretic vision predicting evolution [L14] and generalizing the second law to Negentropy Maximization Principle [L74]; the notion of field/magnetic body carrying large h_{eff} phases of the ordinary matter with long range quantum coherence implying ordinary coherence [K10]; the survivors in the evolution as systems able to communicate with each other; and universal genetic code [L69] play key roles in the model.

1. The new view of time provided by ZEO allows us to understand the strange findings of Libet [J2, J4]. Also detailed models for EEG and nerve pulse emerge [K7, K14] [L80]. A general model for the sensory perception emerges [L9]. In this model the field/magnetic body of the brain and organism play a key role and a universal communication mechanism based on frequency modulation of dark Josephson radiation from the cell membrane emerges. Also the findings of Levin [I4] about the role of electric fields of cell membrane can be modelled in the TGD framework [L82, L85].

2. The dark matter at field/magnetic bodies with a large value of h_{eff} has higher "IQ" and controls the ordinary biomatter and receives information from it (say by EEG). Pollack effect [I2, L3, I8, I6] plays a key role in the transfer of ordinary particles to dark phases at the field bodies [L3, L7, L77, L43, L78, L70]. p-Adic length scale hypothesis [L68, L95], for which the number theoretic vision provides a justification, makes possible quantitative predictions.

3. Biology has a long list of unanswered questions. What does evolution mean at the fundamental level?; What makes possible the coherence of biosystems??; What is behind morphogenesis??; What makes biocatalysis so effective??; What is the precise role of metabolism??; What is the essence of homeostasis?; What ageing means?; How to solve various hen-and egg problems of biology.

   Second list of questions relates to the molecular level. How the biomolecules were chosen?; What happens in the replication of DNA and cells?; What happens in DNA replication, transcription and translation; What is the origin of the genetic code?

   The TGD view of consciousness and quantum theory allows a possible answer to these questions [L21].

4. TGD predicts a universal genetic code realized in terms of a unique tessellation of hyperbolic 3-space [L57, L69], which is in a central role in TGD. Genetic code should have realizations in all scales and very many different realizations. One example, in terms of dark photons.

5. Also new lifeforms are predicted. In particular, plasmoids [L70] are such a lifeform and NASA has reported about evidence for this kind of lifeforms in the ionosphere. TGD also allows us to consider the possibility of conscious computers as hybrids of ordinary and quantum computers using topological qubits realized in the TGD framework [L89, L99].

1.4 How the model expands human knowledge and supports a postmaterialist paradigm?

One must be cautious with what one means with the notion of "post materialistic paradigm". TGD does not propose that this paradigm should be based on idealism. The ontology behind TGD differs from both the materialistic ontology denying subjective existence and idealistic ontology denying material existence. The "objective reality" is replaced with "objective realities" identified as quantum states identified as mathematical objects. Quantum Platonia having spinor fields of WCW as basic objects is a proper name for this view.

No physical reality behind these mathematical entities is needed since state functions (SFRs) as quantum jumps between them explain the conscious experience. Therefore the ontology is minimal. Number theoretic vision predicts evolution as an increase of the conscious information content. ZEO provides a mechanism of conscious memory so that quantum Platonia learns of itself.

2 Brief summary of TGD

Topological Geometrodynamics is a proposal for a unification of fundamental interactions on which I have worked for the past 43 years. The books "Topological Geometrodynamics"(2006) [K15] and "Topological Geometrodynamics: Revised Edition" [K2] provide summaries of the theory of TGD. The book "Life and Consciousness: TGD based vision" (2014) [K1] describes a TGD inspired theory of consciousness. The article "Philosophy of adelic physics" (2017) [L14, L16] describes a number theory based vision of TGD and extends real number based physics to p-adic number fields to describe physical correlates of cognition. The most recent mathematical progress concerning the construction of scattering amplitudes in TGD is discussed in the articles [L48, L49, L50].

The article "Summary of Topological Geometrodynamics" (2020) [L52] provides the most recent summary of TGD with illustrations. My CV (`https://cutt.ly/3bJ2aSm`) contains a list of published articles, books, and online books about TGD. A list of online articles can be found at `https://cutt.ly/ZbJ2s75`.

2.1 The basic problem and idea behind TGD

TGD relies on a new view of space-time inspired by the problem of GRT due to the loss classical conservation laws (the "energy problem"). Matter makes the flat Minkowski space M^4 of Special Relativity (SRT) curved so that it loses Poincare transformations as its symmetries. Poincare invariance implies the conservation laws of energy, momentum, and angular momentum via Noether's theorem so that they are lost in GRT.

The following is a short summary of the solution of this problem provided by TGD (see the illustration).

1. If space-times are 4-surfaces in a space of form $H = M^4 \times S$, S some compact space with a very small size, space-time isometries (Poincare transformations) are lifted to those of H. If these isometries act as symmetries of a general coordinate invariant action determining the space-time surface as an orbit of a 3-surface, Poincare symmetries are not lost and Noether's theorem guarantees the existence of conserved charges and gives explicit expressions for them [L79].

   The geometry of $S = S = CP_2$ codes for the symmetries of SM: color symmetries correspond to the isometry group $SU(3)$ and electroweak symmetries to the holonomies of CP_2 being broken by CP_2 geometry. CP_2 does not allow spinor structure in the standard sense [L79] but - as already observed by Hawking and others [A4, A1] - it allows a modified spinor structure obtained by coupling spinors to an odd multiple of the Kähler gauge potential: this coupling is essential to obtain correct electromagnetic charges for fermions. For quarks and leptons the couplings would correspond to $n = 1$ and $n = 3$.

2. Dirac equations appear at several levels: at the level of H; at the level of causal diamond (CD); at the level of space-time surfaces; and at the level of WCW. The most recent steps of progress relate to the detailed mathematical understanding of the solutions at the level of

H, CD and space-time surface. One can understand color confinement already at the level of H and a rather dramatic prediction of an entire fractal hierarchy of standard model physics emerges [L97, L96, L98].

3. Besides sub-manifold geometry, topology also becomes important (hence the term "**TGD**") since the many-sheeted space-time of TGD is topologically non-trivial at all scales and the physical objects that we see around us correspond directly to space-time sheets, topologically condensed at ever larger space-time sheets. Fracal length scale hierarchies are formed.

It must be emphasized that TGD not yet a theory able to provide precise rules for calculating scattering amplitudes although also in this respect dramatic progress has taken place during the last years. A collective theoretical and experimental effort would be needed to achieve the analogs of Feynman rules.

Applications have played a key role in the development of TGD. TGD replaces the length scale reductionism of the standard model and string theories with fractality so that the applications range over all scales from QCD type physics, via nuclear and hadron physics, to atomic and molecular physics and biology and eventually to astrophysics and cosmology. In all scales the basic concepts which are new from the perspective of the standard model physics play a key role and lead to non-trivial predictions.

Furthermore, the new view of quantum measurement theory together with number theoretic vision leads to a TGD inspired theory of consciousness as a generalization of quantum measurement theory solving the basic problem of the standard quantum measurement theory and also predicts the possibility of quantum coherence in arbitrarily long scales. Applications are not discussed in this article but there are numerous articles and quite a number of books at my homepage as also articles published in the journals founded by Huping Hu, which are devoted to various applications.

It is perhaps good to explain what TGD is not and what it is or hoped to be. The article [L44] gives a slighly out-of-date overview of various aspects of TGD and is warmly recommended.

2.2 Geometric vision

"Geometro-" 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 the illustration). Also the interpretation as a generalization of string models by replacing string with a 3-D surface is natural.

Standard model symmetries uniquely fix the choice of 8-D space in which space-time surfaces live to $H = M^4 \times CP_2$ [L79]. Also the notion of twistor is geometrized in terms of surface geometry and the existence of twistor lift fixes the choice of H completely [A5] so that TGD is unique [L15, L22, L63, L64] (see the illustration).

Practically any GCI action 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 correlates for massless particles. World as a set or particles is replaced with a network having 3-D particles as nodes and flux tubes as bonds between them serving as correlates of quantum entanglement.

2.2.1 Holography = holomorphy principle

During last years it has become clear that holography reduces to the notion of generalized complex structure for both imbedding space and the space-time surface [L73] and space-time surfaces correspond to roots of two functions f_1 and f_2 analytic with respect to the 4 generalized complex coordinates, one of which is real number valued hypercomplex coordinate varying along light-like curves.

This means a general solution of field equations which is universal in the sense that it the same for any general coordinate invariant action constructible in terms of the induced geometry. The dependence on action comes only from, presumably 2-D, singularities at which the generalized

holomorphy and the associated minimal surface property fail. There are good reasons to believe that the singularities contain the information needed to construct the scattering amplitudes.

1. The space-time surfaces in the imbedding space $H = M^4 \times CP_2$ are identified common roots for the pair (f_1, f_2) of generalized holomorphic functions defined in H. If the Taylor coefficients of f_i are in an extension of rationals, the conditions defining the space-time surfaces make sense also in an extension of p-adic number fields induced by this extension. As a special case this applies to the case when the functions f_i are polynomials. For the completely Taylor coefficients of generalized holomorphic functions f_i, the p-adicization is not possible. The Taylor series for f_i must also converge in the p-adic sense. For instance, this is the case for $exp(x)$ only if the p-adic norm of x is not smaller than 1.

2. The 6-D surfaces satisfying only the condition $f_i = 0$,$i = 1$ or $i = 2$, have interpretation as analogs of twistor spaces of M^4 and CP_2 and the proposal is that this description is equivalent with the twistor lift of TGD introducing the twistor space of H as a product of twistor spaces of M^4 and CP_2 and defining twistor space of the space-time surface as a 6-D surface.

3. Also the maps defined by analytic functions g in the space of function pairs (f_1, f_2) generate new space-time surfaces. One can assign Galois group and ramified primes to h if it is a polynomial P in an extension of rationals. The composition of polynomials P_i defines inclusion hierarchies with increasing algebraic complexity and as a special case one obtains iterations, an approach to chaos, and 4-D analogs of Mandelbrot fractals.

Holography=holomorphy hypothesis allows to reduce the classical field equations to purely algebraic conditions $(f_1, f_2) = (0, 0)$, where f_i are analytic functions of one hypercomplex and 3 complex coordinates of $H = M^4 \times CP_2$. The solutions are minimal surfaces irrespective of the classical action as long as it is general coordinate invariant and expressible in terms of induced geometry. This means universality of the dynamics and is quantum criticality expressed by the holomorphy. This implies saddle surface property for the spacetime surface meaning that the real parts of f_i do not have minima or maxima in general.

The iterates of a polynomial $(g, 1)$ (say) with prime degree p, define analogs of primes. This leads also to a generalization of the p-adic number fields to function fields with elements expressed as functional power series as powers of g in which the powers g^k are multiplied by polynomials with degree lower than p. This leads to a definition of functional primes providing an explanation for the origin of p-adic length scale hypothesis. One can say that p-adic function fields and the adele form by them emerges from the real dynamics. The p-adic variants of the embedding space and space-time are convenient auxiliary structures but need not be fundamental.

2.2.2 The world of classical worlds

Quantum TGD leads to a generalization of the geometrization of the physics program of Einstein. The geometrization applies even to the quantum theory itself and the space of space-time surfaces - "the world of classical worlds" (WCW) - becomes the basic object endowed with a Kähler geometry (see the illustration). General Coordinate Invariance (GCI) for space-time surfaces has dramatic implications. A Given 3-surface fixes the space-time surface almost completely as an analog of Bohr orbit (preferred extremal [K3]). This implies holography and leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces. Quantum TGD reduces to wave mechanics in the space of these Bohr orbits, the WCW.

Quantum theory is geometrized in terms of the notion of a "world of classical worlds" (WCW) consisting of space-time surfaces identifiable as preferred extremals (PEs) analogous to Bohr orbits. General Coordinate Invariance (GCI) implies 3-D holography and probably also effectively 2-D holography (strong holography (SH)).

The mere existence of WCW Kähler geometry requires a maximal isometry group. This was shown by Freed [A2] to be the case for loop spaces. This leads to the vision that physics is unique from its existence. Indeed, the twistor lift of TGD [L39, L40] works only for $H = M^4 \times CP_2$ [A5] since only M^4, E^4, and CP_2 have twistor spaces with the Kähler structure required by the existence of the twistor lift based on 6-D Kähler action. On the number theory side, the octonionic M^8 is the unique choice.

Later it turned out that it might be possible to realize the counterparts of the twistor spaces of M^4 and CP_2 without the introduction of the twistor spaces of H or M^8 as 6-D surfaces in H such that their 4-D intersection defines the space-time surface [L84, L93, L101].

2.2.3 Zero Energy Ontology

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 this and this).

Quantum jumps occur between superpositions of 4-D time evolutions and the basic problem of the standard quantum measurement theory disappears. Ordinary state function reductions (SFRs) correspond to "big" SFRs (BSFRs) in which the arrow of time changes (see the illustration). 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 [L30].

In "small" SFRs (SSFRs) as counterparts of "weak measurements" the arrow of time does not change and the passive boundary and the states at it remain unchanged (Zeno effect). The sequence of "small" state function reductions (SSFRs) defined the TGD counterpart of the generalized Zeno effect, would correspond to an analysis having as a correlate the decay of 3-surface to smaller 3-surfaces and would also give rise to a conscious entity, self.

This means considerable progress in the understanding of the quantum measurement theory based on ZEO [L33, L65, L76] [K16].

1. Negentropy Maximization Principle [L74] implying evolution follows as an analog of the second law. In the sequence of quantum jumps the algebraic complexity, which is measured as the dimension of extension of rationals associated with the polynomials associated with the singularities, is bound to increase in a statistical sense.

2. The second new result [L76] is a quantum formulation of the ZEO. Zero energy states within a single CD as an analog of a perceptive field and containing space-time surfaces is generalized so that quantum states also involve a wave function in the space of CDs. The moduli space of CDs is finite-dimensional and maximally symmetric and forms the backbone of WCW in the sense that each space-time surface satisfying holography is within a particular CD. This leads also to a new view of Poincare symmetry allowing to overcome the problems due to the fact that CD itself is not Poincare invariant.

3. Zero energy ontology [K16] is realized in terms of the holography = holomorphy principle (H-H) [L84, L93, L86, L103]. The reduction of extremely non-linear partial differential equations to local algebraic equations is a huge simplification as such and one can say that TGD is exactly solvable.

   The slight failure of the classical non-determinism associated with H-H has a natural identification as a counterpart of the p-adic non-determinism and has deep implications for TGD inspired view of consciousness and TGD itself since it plays a key role in the construction of scattering amplitudes.

   This leads also to a generalization of the p-adic number fields to function fields and explains the origin of p-adic length scale hypothesis. One can say that p-adic function fields and the adele form by them emerges from the real dynamics. The p-adic variants of the embedding space and space-time are convenient auxiliary structures but need not be fundamental.

TGD develops by explaining what TGD is and also this work led to considerable progress in several aspects of TGD.

1. The understanding of the details of the $M^8 - H$ duality have developed through many twists and turns [L41, L42, L75, L83, L86] to its most recent form [L104]. M^8 as the analog of momentum space is identified as octonions and the dynamics of 4-surfaces in M^8 is coded by associativity. The number theoretic local G_2 symmetry provides the long sought concrete realization of the $M^8 - H$ duality mapping the associativity based dynamics in M^8 to the dynamics on H relying on generalized holomorphy.

2. The notion of causal diamond (CD) [L76] is central to zero energy ontology (ZEO) [K16] and emerges as a prediction at the level of H. The pre-image of CD under $M^8 - H$ duality in M^8 is a region bounded by two mass shells in the normal space of $y \in Y^4 \subset M^8$, which itself is an Euclidean region.

   $M^8 - H$ duality maps the points of cognitive representations defined by the points of Y^4 with coordinates as algebraic integers in the algebraic extension of rationals and identified as momenta of fermions with a fixed mass squared in M^8 to either boundary of CD in H.

3. The emergence of holography = holomorphy principle (H-H) [L84, L93, L86, L103] forces a profound modification of the ideas about $M^8 - H$ duality and number theoretical vision.

4. Galois confinement for physical states at the level of M^8 is understood at the level of momentum space and is found to be necessary. Galois confinement implies that fermion momenta using a suitable unit determined by CD are algebraic integers but integers for Galois singlets just as in ordinary quantization for a particle in a box replaced by CD. Galois confinement could provide a universal mechanism for the formation of all bound states.

2.2.4 What does the attribute "Topological" mean?

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 $H = M^4 \times CP_2$.

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 the illustration). The real space-time surface is extremely complex. In the recent formulation the interactions for particles interpreted as analogs of Bohr orbits are contact interactions associated with their intersections consisting of string world sheets.

The topological description applies to particles, which at fundamental level correspond to closed monopole flux tubes with size of their Compton length. Family replication phenomenon of fermions finds an explanation in terms of the genus of 2-D parton surface and an explanation for why there are 3 fermion families, emerges [K6, K11].

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

2.3 Number theoretic vision

Number theoretical vision adds to "geometric" and "topological" a third aspect to what it is to be TGD. There is however no natural way to add this aspect to "TGD".

2.3.1 p-Adic and adelic physics

The notion of p-adic physics generalized to adelic physics in which physics in various p-adic number fields and real physics fuse to a larger whole. Adelic physics fusing real and various p-adic physics are 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 worlds".

The hierarchy of algebraic extensions of rationals gives rise to a hierarchy of Planck constants $h_{eff} = nh_0$ and defines extensions of p-adic number fields and adeles allowing an interpretation as an evolutionary hierarchy (see the illustration). Physically this defines a hierarchy of phases of ordinary matter behaving like dark matter. The interpretation is not in terms of galactic dark matter but in terms of missing baryonic matter identified.

The polynomials with rational coefficients are characterized by ramified primes. A possible interpretation for ramified primes is as p-adic primes characterizing elementary particles [L68, L95] [K11, K6]. An alternative, and in fact more plausible, interpretation for the p-adic primes characterizing space-time sheets is provided by p-adic function fields: this option explains the p-adic length scale hypothesis [L84, L93]. The notion of multi-p-adicity is also possible for numbers expressing as power series of n. In this case p-adic topology is possible for any prime factor of n.

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 assumed to correspond to the dimension of extension of rationals. The interpretation of the latter hierarchy is as phases of ordinary matter behaving like dark matter. Quantum coherence is possible in all scales.

2.3.2 $M^8 - H$ duality

The idea of $M^8 - H$ duality has progressed through frustratingly many several twists and turns. I have discussed several variants of $M^8 - H$.

1. The basic technical problem relates to the lack of the concrete realization of the $M^8 - H$ duality since explicit realization of the parametrization of the quaternionic normal space has been missing.

2. The second open question is whether $M^8 - H$ duality is between 4-D surfaces in M^8 and space-time surfaces in H or is it enough that only the 3-D holographic data in H are fixed by $M^8 - H$ duality. There are indeed some intuitive arguments supporting the latter view. Could it be that M^-H duality is not an alternative view to see the dynamics but a way to determine holographic data in H so that a consistency with holography = holomorphy hypothesis is obtained?

Quite recently it turned out [L104, L86] that a modification of the original form of the $M^8 - H$ duality formulated in terms of a real analytic function $f(o)$ of octonions leads to a possible solution of these problems. The crucial element is local G_2 invariance of the conditions involved.

1. The conditions $f(o) = 0$ and $f(o) = 1$ are invariant under local G_2 and give as a solution a discrete set of 6-spheres. Also the conditions $Re(f) = 0$ and $Im(f) = 0$ are invariant under local G_2. These conditions give rise to dual time evolutions of a six-sphere S^6. The intersection with the complement of quaternionic M^4 gives rise to 4-D surfaces Y^4 as dual time evolutions of a 3-sphere with respect to the time defined by the real part of the octonion.

   The condition $RE(f) = 0$, where RE (IM) refers to quaternionic real (imaginary) part, is equivalent with the condition $f(o) = 0$ whereas the condition $IM(f) = 0$ is equivalent with the condition $Im(f) = 0$. The local G_2 acts as a dynamical spectrum generating symmetry group since $f \circ g_2 = g_2 \circ f$ holds true. The roots of $f(o) = 0/1$ for the simplest situation in which the quaternionic normal space is fixed M^4, are 6-spheres S^6.

2. The 4-surfaces $Y^4 \subset M^8$ for the simplest solutions $Im(f) = 0$ and $Re(f) = 0$ is identifiable as the intersection $Y^4 = E^4 \cap S^6$, where E^4 is the normal space of a fixed quaternionic $M^4 \subset M^8$. This guarantees that the normal space of Y^4 at each point is quaternionic M^4. The assumption that M^4 contains a commutative subspace M^2 guarantees that the normal space correspond to a point of CP_2 so that the Y^4 can be mapped to $X^4 \subset H = M^4 \times CP_2$.

3. Local G_2 transformations give more general surfaces Y^4. One can choose the function $f(o)$ to be a real part of an analytic function of a hypercomplex coordinate of M^4 and 3 complex coordinates of M^8. This gives good hope that the image X^4 of Y^4 satisfies the holography = holomorphy hypothesis. Local G_2 also defines the moduli space of Hamilton-Jacobi structures [L73] of M^8 and M^4 and X^4.

4. The real analytic functions $f(o)$ and $g(o)$ can be multiplied, divided and summed so that the analog of a function field is in question. Also iterations of $f(o)$ are possible. The roots $Im(g) = 0$ of $g = f \circ f ... \circ f$ contain the roots of f plus roots of higher iterates. A complexity hierarchy analogous to that appearing for function pairs (f_1, f_2) at H sides emerges and the interpretation in terms of cognitive hierarchies is suggestive. An interesting question is whether there is a simple relationship between functions $f(o)$ and function pairs (f_1, f_2).

5. An interesting question is whether the 3-spheres associated with the roots $f(o) = 0$ correspond to "very special moments of time", which emerged in the original form of $M^8 - H$ duality. Could these spheres correspond at the level of H singularities at which the local G_2 element becomes multiple-valued so that the quaternionic normal space is not unique. The

situation is analogous to a singularity of a vector field. This would give rise to cosmic strings and CP_2 type extremals. These singularities could be also associated with the classical non-determinism of H-H principle. Also the vertices of particle reactions could be assigned with them.

6. The ramified primes of a polynomial of a single variable are expected to play an important role in the number theoretic view of TGD. If f assigned to $M^8 - H$ duality [L104] is a polynomial P with rational coefficient, the ramified primes would be assigned with the discriminant of P. The conjecture is that the classical action defining the space-time surface is expressible as a power of discriminant of P defined by the differences of these ramified primes [L79]. This would be one aspect of the 4-D version of Langlands duality [L84, L93]. This would imply a huge degeneracy since alll space-time surfaces related by local G_2 transformations as analogs of conformal transformations would have the same classical action defining the Kähler metric of WCW. Local G_2 would define zero modes for the WCW metric and symplectic degrees of freedom would correspond to non-zero modes as also conjectured [L81].

2.4 The description of particles and particle interactions in the TGD framework

The TGD based description of particles [L71] and particle interactions [L92, L72] has developed considerably during the last yeaars and the new view deserves a separate section.

Several key ideas of quantum TGD distinguish between TGD and QFTs.

1. The basic problem of QFT is that it involves only an algebraic description of particles. An explicit geometric and topological description is missing but is implicitly present since the algebraic structure of QFTs expresses the point-like character of the particles via commutation and anticommutation relations for the quantum fields assigned to the particles.

   In the string models, the point-like particle is replaced by a string, and in the string field theory, the quantum field Ψ(x) is replaced by the stringy quantum field Ψ(string), where "string" corresponds a point in the infinite-D space of string configurations (say loop space). The interpretation is as a second quantization of string theory. This approach is rather baroque since one must introduce a non-linear action principle in the string space. This however allows to understand M^4 as the configuration space for the positions of a point-like particle.

   In TGD, the quantum field Ψ(x) is replaced by a formally *classical* spinor field Ψ (Bohr orbit). The 4-D Bohr orbits are preferred extremals of classical action satisfying holography forced by general coordinate invariance without path integral and represent points of the "world of classical worlds" (WCW). The components of Ψ correspond to multi-fermion states, which are pairs of ordinary 3-D many-fermion states at the boundaries of causal diamond (CD).

   The gamma matrices of the WCW spinor structure are linear combinations of the fermionic oscillator operators for the second quantized free spinor field of H. They anticommute to the WCW metric, which is uniquely determined by the maximal isometries for WCW guaranteeing the existence of the spinor connection. Physics is unique from its existence, as implied also by the twistor lift and number theoretic vision and of course, by the standard model symmetries and fields.

   Also the notion of induced spinor fields as a restriction of spinor fields to space-time surface is involved and the induced spinor fields satisfy the modified Dirac equation as the analog of massless Dirac equation [L88, L97, L96].

2. In TGD, the notion of a classical particle as a 3-surface moving along 4-D "Bohr orbit" as the counterpart of world-line and string world sheet is an exact aspect of quantum theory at the fundamental level. The notions of classical 3-space and particle are unified. This is not the case in QFT and the notion of a Bohr orbit does not exist in QFTs. TGD view of course conforms with the empirical reality: particle physics is much more than measuring of the correlation functions for quantum fields.

   Quantum TGD is a generalization of wave mechanics defined in the space of Bohr orbits. The Bohr orbit corresponds to holography realized as a generalized holomorphy generalizing

2-D complex structure to its 4-D counterpart, which I call Hamilton-Jacobi structures [L73]. Classical physics becomes an exact part of quantum physics in the sense that Bohr orbits are solutions of classical field equations as analogs of complex 4-surfaces efined as roots of two generalized analytic functions in $H = M^4 \times CP_2$ endowed with generalized complex coordinates. The space of these 4-D Bohr orbits gives the WCW [L81], which corresponds to the configuration space of an electron in ordinary wave mechanics.

There is no need for the second quantization to describe many particle systems as in the case of wave mechanics since the many-particle states are described topologically as unions of disjoint 3-surfaces and unions of partonic orbits inside them.

3. The second quantized spinor fields of H are needed to define the spinor structure in WCW. The spinor fields of H are the free spinor fields in H coupling to its spinor connection of H. The Dirac equation can be solved exactly and second quantization is trivial and one avoids the usual problems caused encountered for curved space-times, such as the non-existence of spinor structure and existence of several spinor structures encountered already in QCD lattice calculations where the periodic boundary conditions effectively replace the topology of the Minkowski space with that of 4-torus.

   This determines the fermionic propagators in H and induces them at the space-time surfaces. The propagation of fermions is thus trivialized. All that remains is to identify the vertices.

4. At the fermion level, all elementary particles, including bosons, can be said to be made up of fermions and antifermions, which at the basic level correspond to light-like world lines on 3-D parton trajectories, which are the light-like 3-D interfaces of Minkowski spacetime sheets and the wormhole contacts connecting them.

   The light-like world lines of fermions are boundaries of 2-D string world sheets and they connect the 3-D light-like partonic orbits bounding different 4-D wormhole contacts to each other. The 2-D surfaces are analogues of the strings of the string models.

5. In TGD, classical boson fields are induced fields and no attempt is made to quantize them. Bosons as elementary particles are bound states of fermions and antifermions. This is extraordinarily elegant since the expressions of the induced gauge fields in terms of embedding space coordinates and their gradients are extremely non-linear as also the action principle. This makes standard quantization of classical boson fields using path integral or operator formalism a hopeless task.

6. There is however a problem: how to describe the creation of a pair of fermions and, in a special case, the corresponding bosons, when there are no primary boson fields? Can one avoid the separate conservation of the fermion and the antifermion numbers?

   Here the notion of exotic smooth structure could come in rescue. 4-D space-times are unique in that they allow exotic smooth structures [A6, A7, A3], which can be regarded as the standard smooth structure with defects. At the level of M^8 space-time surface Y^4 consist of topological cylinders $S^3 \times R$ and the cylinder allows exotic smooth structures: the same could be true for their images under $M^8 - H$ duality.

   The creation of a fermion pair corresponds intuitively to the turning of the fermion line backwards in time: this would be the defect. The proposal [L91, L67, L98] is that fermion pair creation is associated with the exotic smooth structure identifiable as a 3-D edges of the space-time surface at which space-time sheets which are hypercomplex conjugates of each other meet.

For more detailed representations, one can consult the books [K15, K1, K2], the article [L14] about adelic physics, and the articles [L17, L27]. The latest mathematical progress is described in the articles [L48, L49, L50, L58]. The homepage dedicated to TGD (`http://tgdtheory.fi`) contains online books and articles - also updated versions of published articles.

3 TGD inspired theory of consciousness

TGD inspired theory of consciousness can be regarded as an extension of quantum measurement theory to a theory of consciousness that relies on Zero Energy Ontology (ZEO) [L54]. When I wrote the first version of this chapter, the view about ZEO, in particular about what happens to the causal diamonds (CDs) in state function reductions, involved many uncertainties. In [L76] the recent, much more precise view is represented.

3.1 Conditions satisfied by the theory of consciousness

Any quantum theory of consciousness must be consistent with existing physics. Since existing physics cannot explain biological phenomena and consciousness, a theory explaining them is bound to predict some new physics.

The new theory must solve the basic problems intractable to current theoretical physics. Many of these problems are philosophical. This theory should also be applicable to quantum biology and neuroscience and answer at least the following questions.

1. In everyday life everyone, even a strict physicalist, will in their subjective experience, regard free will as real, but in the role of natural scientist, deny it since it is inconsistent with the determinism of classical physics. Could the underlying view of time be wrong? Could free will be consistent with deterministic field equations after all?

   It seems that behavior is built from deterministic time evolutions connecting initial and final states. Biological functions, behaviors, and computer programs represent good examples of this. Could free will be in the selection between deterministic time evolutions. These questions suggest a new ontology in which a deterministic classical time evolution becomes the basic entity instead of the time=constant snapshot of time evolution central to the standard ontology.

2. A similar problem plagues quantum measurement theory. The state function reduction (SFR) is non-deterministic whereas the Schrödinger equation is deterministic. This has led to myriads of "interpretations". This problem is analogous to the conflict between free will and classical deterministic physics.

   It is easy to trace the origin of the problem. In standard quantum theory the observer can affect the measured system but still remains an outsider. A quantum theory of consciousness would generalize quantum measurement theory. The notion of "self" as part of a system would replace that of "observer".

   Quantum coherence is assumed to be possible only at very short scales. Coherence of biological systems, however, suggests this assumption is wrong. There is also the question whether there is some scale at which quantum behavior transforms to classical behavior. This question has not been answered. Could the quantum world actually prevail at all scales and only appear as classical? Could discontinuous quantum jumps somehow look like deterministic and smooth classical time evolutions?

3. Experienced time and the geometric time of the physicist are very different. Subjective time however correlates with geometric time: contents of sensory experience correspond to a moment of geometric time within an accuracy of .1 second: one can speak of a sensory chronon. How should one distinguish between these two times?

4. Are there physical correlates for cognition and imagination? Could they be realized at the level of space-time?

5. What do life, death, and aging mean? Could they be universal notions applicable at all scales? Does consciousness survive after the cessation of bodily function in some sense? If this were the case, universality might make it possible to provide indirect, and yet convincing, evidence for life after death.

3.2 ZEO based quantum measurement theory extends to a theory of consciousness

ZEO based quantum measurement theory [L54] leads to a quantum theory of consciousness (see the illustration). In particular, the theory predicts that the arrow of time (AT) changes in "Big" (ordinary) SFRs (BSFRs) (see the illustration) 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 [L49, L50]. 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 [L106]. 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 [K13] and h_{eff} hierarchy [L32]. 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}.

3.2.1 ZEO

The TGD based view of consciousness relies on ZEO solving the basic paradox of quantum measurement theory. First, a brief summary of ZEO [L54] is required.

1. The notion of a causal diamond (CD) (see the illustration) 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 [L13])via the $M^8 - H$ duality [L38, L49, L50].

2. The quantum formulation based on the notion of fini-dimensional moduli space of CDs forming that backbone of WCW [L76]. This formulation makes it possible to get rid of various uncertainties of the earlier formulations. The sequences of "small" state function reductions (SSFRs), or rather a sequence unitary transformations, which in the moduli space of CDs correspond to dispersion analogous to that associated with Schrödinger equation followed

by localizations in the moduli space (SSFR) as position measurements. These are the TGD counterparts of sequences of measurements of the same observables. Present are also "big" SFRs (BSFRs) changing the arrow of time and serving as the TGD counterparts of the ordinary SFRs.

3. In the ZEO, quantum states are not 3-dimensional, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. By holography time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving AT that give rise to an analog of the Zeno effect [K16] [L54].

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 [L58] 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.

3.2.2 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* [L30] for atomic systems can be explained by the same mechanism [L30]. 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 [J2] 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 [J1] 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 [L34, L28].

   In biology, the reversals of AT may occur routinely [J5] 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 [L37, L106]. Homeostasis would occur spontaneously rather than being a result of programming.

3.2.3 Sequence of SSFRs as life cycle

The original proposal was that SSFRs are TGD counterparts of "weak" measurements, which are much like classical measurements and do not involve any dramatic changes. One can ask what weak measurements actually are and holography = holomorphy vision suggests that they correspond to the classical non-determinism of field equations present already for 2-D minimal surfaces.

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 [L51] 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 [L51]. Cognitive measurement would be a measurement involving entanglement with the degrees of freedom related to the classical non-determinism of space-time surfaces predicted by holomorphy = holography principle [L86]. The time T identified as the temporal distance between the tips increases in a statistical sense and correlates with the subjective time identified as a sequence of SSFRs.

2. The identification of a "geometric now" as a correlate of "subjective now" is not unique. The most natural identification of the geometric time is as the linear M^4 time coordinate assignable with the line connecting the tips of CD (see the illustration). 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 suggests that the 3-D roots r_n of the real analytic function $f(o)$, in a special case polynomial $P(o)$ (or even analytic function) define special moments $t = r_n$ of M^4 linear time: I have called them "very special moments in the life of self" [L10, L11, L12, L31, L49, L50]. The surfaces $Y^4 \subset M^8$ would in turn correspond to the roots of $Im(f) = 0$ or of $Re(f) = 0$ as duals of each other. If these moments correspond to the values of T_{now} for SSFRs, the size of CD increases in a step-wise manner.

   The two views are consistent if the roots r_n correspond to the loci of classical non-determinism. This could be the case that the g_2 element as holomorphic function of generalized complex coordinates of M^8 has singularity at r_n. This would mean that the quaternionic plane M^4 is not unique at it. The singularity would be analogous to a singularity of a vector field and would naturally be associated with $f(o) = 0$ just like the singularity of a vector field is naturally associated with its zero.

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 [L49, L50] 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 $g(g_2(o)) = g_2(f(o))$. As a special case, $f(o)$ is a polynomial $P(o)$ with algebraic or even rational coefficients 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 real and imaginary (in octonionic sense) parts and $Y^4 \subset M^8$ corresponds to a root for the $Im(P)$ or $Re(P)$ [L104].

   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.

3.2.4 Internal degrees of freedom related to the non-determinism of the space-time surfaces and consciousness

In TGD, consciousness and cognition are assigned with the SSFRs assigned with the, presumably discrete, internal degrees of freedom (IDF) assignable with the classical non-determinism. Ordinary SFRs (BSFRs) are assigned with the ordinary degrees of freedom (ODF) assignable to the entire Bohr orbits and measured in the ordinary quantum measurements. Several questions related to the relationship of IDF and ODF, highly relevant to the view of consciousness, come to mind.

Consider two systems A and B. For instance, A could represent a conscious observer and B a part of the environment or second conscious observer. Many kinds of entanglements and entanglement reductions are possible. Besides the ordinary entanglement ODF(A)-ODF(B) also entanglements of type IDF(A)-ODF(B), IDF(A)-IDF(B), and IDF(A)-ODF(A) are possible.

1. There can be ordinary entanglement of type ODF(A)-ODF(B) but no entanglement of other types . Could the reduction of this entanglement relate to sensory perception?

   One can also consider the entanglement of type IDF(A)-ODF(A)-ODF(B). Could this entanglement be relevant for the formation of the cognitive representation as thought about the sensory mental image?

2. The reduction of IDF(A)-ODF(B) entanglement would induce an effect on B. IF B is a conscious entity it could be hypnosis. If B is an ordinary physical system it could be psychokinesis.

3. Could IDF(A)-IDF(B) entanglement for conscious entities make possible telepathy?

4. Could the reduction of IDF(A)-ODF(A) type entanglement relate to the realization of motor action, and more generally, to the realization of intentional actions?

The precise role of quantum criticality in the realization of intentional actions should be understood. In TGD quantum criticality is completely universal as also consciousness so that even elementary particles can cognize and the p-adic length scale hypothesis gives a measure for the degree of cognition. Conservation laws pose strong restrictions in this case: a stable particle like proton or electron serves as an example. The intuitive idea is that a perturbation is needed to trigger a BSFR, which transforms intention realized as entanglement to a motor action or to an action affecting the external world. Is the quantum entanglement of IDF with its ODF enough to trigger a BSFR of the system: a spontaneous decay of an unstable particle would be an example now. Something similar should be true also in the macroscopic situation.

3.3 Negentropy Maximization Principle (NMP) as variational principle of consciousness

Negentropy Maximization Principle (NMP) defines the variational principle of consciousness in TGD [K12] [L60] but as an analog of second law rather than as a usual variational principle.

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 [L14, L16] the entropy $N = -S_1 - S_2$ is the sum of real and various p-adic negentropies. They are real numbers but defined for entangelment probabilities belonging to some extension of p-adic numbers using the generalization of Shannon formula: ordinary e-based logarithms are replaced by p-based logaritms.

   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 or generation of NE. One can also say that NE distinguishes between living and inanimate matter and between dark and ordinary matter.

3.3.1 NMP as a generalization of the second law of thermo-dynamics

On the basis of empirical facts, Jeremy England [I5] has proposed that SL implies evolution. This statement seems to be in conflict with the standard thermodynamic view of biology [L6].

England's view that SL implies evolution, is clearly in error. NMP [L60] 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 [K12] [L60].

   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 [L6].

   p-Adic number fields, combining with real numbers to form an adele, are needed [L14, L16]. 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 [L49, L50]. 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.

3.3.2 Is it possible to measure cognitive entanglement negentropy?

Entanglement negentropy as a measure of conscious information is not the negative of the ordinary entanglement entropy but sum over p-adic contributions obeying however the same kind of formula as the Shannon entropy. For a given p-adic prime p, the logarithms of probabilities are replaced by integer value p-based logarithms of their p-adic norms. This requires that the entanglement probabilities are rationals or belong to the extension of rationals. Suppose that they can be measured somehow.

The problem is that the entanglement probabilities cannot be known with an infinite precision and the approximation as a rational number can lead to very different outcomes for the negentropy. For instance, multiplying the probabilities with a rational $r = m/n$ very near to unity such that m and n are very large integers, can change the sum of the p-based logarithms dramatically. The reason is that real and p-adic topologies are very different. The power p^n for large n approaches zero in p-adic sense but to infinity in real sense.

Measurement of the amount of conscious information is in question and it is not surprising if problems emerge if one starts from real numbers which are essentially measures for magnitude: consciousness cannot be weighed.

The first question is of course whether cognitive entanglement negentropy is useful in any way? This seems to be the case. If one takes the number theoretical physics predicted by TGD as a correlate for cognitive consciousness seriously, one can see the effects due to the reduction of negentropy at a qualitative level. In absence of metabolic energy feed needed to increase the values of h to h_{eff}, h_{eff} spontaneously decreases and the negentropic resources are reduced. The level of consciousness is reduced and the system gets tired or even loses consciousness. This can be seen as a direct qualitative support for the notion if subjective existence is accepted as something real.

What is clear is that if the cognitive measurement problem can be solved it must be carried out in the number theoretic framework. At least to me this means that notions like field body, zero energy ontology, and number theoretic physics are taken seriously. For the sake of simplicity, consider in the sequel rational probabilities. One can also consider the possibility that the probabilities are always rational: this would conform with the way how they are estimated experimentally, at least in real number based physics by repeated measurements.

1. As far as the approximation as rationals is considered, only the p-based logarithms appearing in the expression of negentropy are problematic. The integer of the lowest power of p is sensitive to the approximation as a rational. Could some additional physically motivated assumptions allow to eliminate this sensitivity? And could one restrict the number of primes involved?

2. Suppose approximate values for the probabilities have been somehow deduced as rational numbers by performing measurements for a cognitive ensemble. The estimates for the probabilities $P_k = m_k/n_k$ are rational. The integers in m_k and n_k can be developed to powers series in powers for a given prime p_i and the integer exponent of the lowest power of p_i determines the norm of m_k and n_k.

   If the actual probabilities P_k are rational numbers $P_k = m_k/N$, only a finite number of p-adic primes matter since the p-adic norms of numerator and denominator of $P_k = m_k/N$ are equal to 1 for large primes and p-based logarithm vanishes. One should be able to identify for a given probability reliably the prime, which appears as the lowest power in the expansion.

3. Canonical identification, crucial for the interpretation of p-adic mass calculations [L68, L95], provides an attractive way to fix the p-adic norm assigned to the real probability. Canonical identification $I : \sum x_k p^k \to \sum x_k p^{-k}$ maps p-adic numbers in a continuous way to real numbers. The inverse of I is for a finite number of the pinary digits two-valued. The reason is that the p-adic numbers $-1_p = (p-1)/(1-p)$ and $1/p$ are mapped to the same real number p. Assuming that the number of the pinary digits is finite, the image of a real number is unique. This could allow us to determine the p-adic norm of the p-adic probability assigned to a real probability reliably.

   This raises the possibility that one could, at least formally, assign cognitive negentropy also with ordinary probabilities, even with association probabilities associated with language models. If one can assign a useful information measure to these probabilities, one is forced to ask whether the system involved could have rudimentary consciousness?

Consider an actual cognitive measurement (whatever it could mean!).

1. The assumption that the experimenter can control the total number N of measurements looks unrealistic since cognitive entanglement is in question so that standard kind of measurement is simply impossible. It is not possible to put the mind on a scale.

2. The assumption that a measurement in the standard sense is possible indeed leads to problems. The actual measurement n_i would correspond to the total number N of measurements so that one has $P_k = m_k/N$. The problem is that the prime decomposition of N is highly sensitive to its value and changes dramatically in $N \to N+1$. A technical way to avoid these problems is to assign p-adic norms to the probabilities by canonical identification. This option looks rather convincing.

3. An alternative way to get rid of this sensitivity is to assume that N is not under the control of experiment and the probabilities are deduced in some other way than by performing a measurement for a cognitive ensemble.

4. Could time series of measurement, whose duration cannot be controlled by the observer be considered. Could the number of loci of non-determinism for the Bohr orbit somehow determine the number N of cognitive measurements? If so, the geometric duration of the Bohr orbit would determine the value of N and the probabilities P_k.

   p-Adic length scale hypothesis for which the holography = holomorphy vision leading to a generalization of p-adic number fields to their functional counters suggests that favored values for N are primes or powers of prime.

Assuming that one is not satisfied with the technical solution of the problem, could the assumptions about the measured cognitive system help?

1. The number of p-adic primes associated with m_k and n_k in $P_k = m_k/n_k$ are finite and they have a decomposition to a finite number of primes p_i. A reasonable assumption is that the integers m_k and n_k can be taken to be as small as possible. This conforms with the frequency interpretation of P_k. This would help to make the approximation as rationals more unique and for instance multiplication by a rational, which is a ratio of very large integers and near to unity is not allowed.

2. I have proposed the notion of multi-p p-adicity [L68, L95] motivated by the need to define interaction vertices for particles characterized by different p-adic primes. Multi-p p-adicity would be related to the world of the "classical worlds" (WCW) expected to have a spin glass type structure having a decomposition to regions with ultrametric topology characterized by a p-adic primes.

   In the interfaces of the regions of WCW with different values of p-adic prime p, multi-p p-adicity would prevail and mean that the integers involved have expansion in powers of integer n: the primes p_i dividing n would define p-adic primes p_i associated with the multi-p p-adicity. This assumption would give very strong constraints on the p-adic expansion of probabilities and the lowest power for each p_i could be highly unique for the integers m_k and n_p in $P_k = m_k/n_k$. The assumption that the integers m_k and n_k have expansion in powers of the same integer n would make the rational approximation highly unique.

3. Negentropy Maximization Principle [L74], which states that the number theoretic evolution tends to maximize algebraic complexity and therefore the maximal value of the negentropy, suggests a possible (admittedly ad hoc guess): determine the rational approximation from the condition that the negentropy is maximized!

4 TGD inspired quantum biology

Often, problems have served as starting points for developments in TGD. This also applies to biology. The following lists include some examples. A more detailed discussion is in [L27]. Consider first general questions.

1. How can one understand the coherence of living systems? If biochemistry alone explained life, we would be sacks of water with some chemicals added. Sacks of water do not climb in trees or write poems. Could quantum coherence induce ordinary coherence? What entities serve as intentional agents and how could they realize their intentions?

2. Why is metabolism needed? Particles with nonstandard h_{eff}/h_0 have a higher energy as a rule. Is metabolic energy needed to excite particles to dark states and thus to increase their "IQ"? Could evolution be seen as an increase of $h_{eff}/h_0 = n$ as the dimension of EQ forced by the fact that the number of extensions with a dimension higher than a given integer n is infinitely larger than the number of extensions with a dimension smaller than n.

3. What is morphogenesis? If biology is merely biochemistry, this question remains unresolved. However, if space-time topology is non-trivial at all scales, the situation changes dramatically. All structures - *including bio-molecules, membrane like structures, organelles, organs, etc. - are 4-D space-time surfaces representing dynamic patterns*, and morphogenesis emerges at a classical level in the 4-D sense [L26, L8]. Holography implies that 3-D surfaces are equivalent to corresponding 4-D surfaces as analogs of Bohr orbits. Thus ZEO replaces the ordinary quantum state as a structure with zero energy state as an analog of function, behavior, or program and notions such as 4-D brain emerge. One might even say that structure and function are equivalent.

4. The extreme effectiveness of bio-catalysis is not well-understood. In particular, there is a question how the reactants are able to find each other in the molecular crowd. Here the networks formed by monopole flux tubes connecting molecules with identical cyclotron frequencies would be in an key role.

5. Homeostasis in which a system is able to stay around a critical, and therefore unstable, equilibrium point is poorly understood. Here ZEO suggests a mechanism: when the system starts to fall from the top of the hill, a BSFR and a time reversal takes place and brings it back.

6. Biological evolution seems to be in conflict with the second law of thermodynamics. Number theoretical vision leads to a generalization of the second law to Negentropy Maximization Principle (NMP) forcing the increase of the number theoretical complexity.

There are also questions related to the basic biomolecules.

1. How the bio-molecules were selected? Could the ability to communicate select subset of biomolecules? Communication would rely on dark photons signals with Josephson frequencies and at resonance a signal as a modulation of a carrier frequency would induce a sequence of pulses analogous to nerve pulses.

2. Is the genetic code (GC) totally accidental? Could the biochemical realization of the GC mimic a deeper level of the GC? Could the genetic code relate also to the communications between the biomolecules? Hyperbolic 3-space H^3 realized either as a mass shell or as a light-cone proper time = constant surface has a unique tessellation, which involves the tetrahedron, octahedron, and icosahedron: usually only one of them is involved. This tessellation leads to a model of the genetic code. This also leads to a proposal that genetic code is universal and has also in ordinary biomatter also new realizations. For instance, a cell membrane could provide a 2-dimensional realization of the code.

3. Replication of DNA, transcription to RNA and translation of RNA to amino acids are poorly understood. The dynamics in question is essentially symbolic dynamics, analogous traffic rule based dynamics involving consciousness in an essential way. How could this symbolic dynamics emerge? Here the dark analogs of these molecules realized in terms of the monopole flux tubes at which the dark matter controlling biomatter reside, could play a fundamental role as intelligent controllers. The realization of cognition in terms of classical non-determinism would be also essential.

4. There are also several hen-egg questions. For instance: was DNA, RNA or amino-acids, or cell membrane first? If the dark variants of biomolecules were first, these hen-egg problems disappear.

The TGD based model for living matter relies heavily on the notions of MB carrying $h_{eff} > h$ phases behaving like dark matter and ZEO. MB would serve as a boss controlling ordinary biomatter and receiving information from biomatter by dark electromagnetic radiation. EEG would be one particular example of this kind of communication and control. ZEO would be in a key role making possible homeostasis and the weak non-determismism of classical dynamics of space-time surfaces analogous to biological functions would make possible conscious cognition at molecular level.

4.1 MB carrying dark matter as controller of ordinary biomatter

MB contains dark matter identified, as phases of ordinary matter characterized by EQ with a dimension $n = h_{eff}/h_0$ serving as a measure of the algebraic complexity of a given space-time region [L104], 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 [L32]. One can assign to classical gravitational *resp.* electric fields gravitational *resp.* electric Planck constant characterizing the flux tubers of gravitational *resp.* electric field body [L66, L70]. The gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ was introduced originally by Nottale [E1] The electric Planck constant $\hbar_{em} = Qq/v_0$ has similar form. Gravitational/electric Planck constant differs from the ordinary Planck constant in that it characterizes the flux tubes connecting large mass/charge with a particle rather than single particle.

4.1.1 Anatomy of magnetic body

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 [L35].

Also the Earth's magnetic field with nominal value of $B_E = .5$ Gauss has two parts.

1. The monopole flux part (see the illustration) 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 [J3].

   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 [L46]. 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 [L62]. 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?

4.1.2 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 [J3] 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 gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. 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 $E = h_{gr}f$ of dark photons should be in the biophoton energy range (visible and UV) characterizing molecular transitions [K4, K5].

3. For the value $v_0/c \simeq 2^{-11}$, suggested by the Nottale's model Sun-particle pairs [E1], the predicted cyclotron energy scale would be 3 orders of magnitude higher than the energy scale of visible photons. For Earth-particle pairs [L61, L56] $\beta_0 = v_0/c = 1/2$ implies that gravitational Compton length $\Lambda_{gr} = GM/\beta_0$ equals to Schwartschild radius of the Earth gives the correct cyclotron frequency scale.

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 [L2, L1] 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 3.2.3).

4.1.3 Evidence for dark charged particles

The notion of dark matter as a controller of biomatter preceded its justification based on number theory [L13, L14].

1. The values of $h_{eff} = nh_0$ must be so large that the energies $E = h_{eff}f$ of dark photons with EEG frequencies are in the biophoton energy range (visible and UV) assignable to molecular transitions [K4, K5].

2. What makes the large values of h_{eff} possible? Nottale's hypothesis [E1] introduces the notion of the gravitational Planck constant $\hbar_{gr} = GMm/v_0$, whose form is fixed by an Equivalence Principle (EP). In the TGD framework, $h_{eff} = h_{gr}$ is assigned to gravitational flux tubes [L29]. There are non-trivial implications that reflect EP.

   (a) The cyclotron energy spectrum $E_c = n\hbar_{gr}eB/m = nGMeB/v_0$ does not depend on the mass m of the charged particle and is thus universal. The energies involved are proposed to be in the range of biophoton energies (at least) suitable for control of the transitions of the bio-molecule. One cannot exclude lower energies above thermal energy for physiological temperature.

   (b) Note that The gravitational binding energies of a mass m for Bohr orbits around M do not depend on M at all [L62].

Also relatively small values of h_{eff} are possible.

1. Electrons can also have dark phases, but now the value of h_{eff} would be much smaller and satisfy the generalized Nottale hypothesis $h_{eff} = h_{em}$, where h_{em} is the electromagnetic analogue of h_{gr} assignable to flux tubes accompanying valence bonds. This inspires a model of valence bonds [L53] predicting that the value of $h_{eff}/h_0 = n = h_{em}$ increases along the rows of the Periodic Table.

   This picture can explain why molecules such as proteins containing atoms towards the right end of the rows of the Periodic Table are ideal carriers of metabolic energy. It also explains why ions, such as Ca^{++} involved with the control and communications of the cell membrane with the "large" part of MB and having very large $h_{eff} = h_{gr}$, are towards the left end of the rows.

2. The energy scale of dark variants of valence electrons is proportional to $1/h_{eff}^2$ so that the orbital radii are scaled up and the identification as a Rydberg atom provides the only possibility in the standard physics model. Could dark valence electrons be in question? There is empirical evidence, known for decades, for the mysterious disappearance of valence electrons of some rare earth metals in heating. An article by Chatterjee *et al* [D1] discusses this phenomenon for Yb.

   The finding [D2] about "misbehaving" Ruthenium atoms also supports the view that covalent bonds involve dark valence electrons. Pairs of Ru atoms were expected to transform to Ru dimers in thermo-dynamic equilibrium but this did not happen. This suggests that valence electrons associated with the valence bond of Ru dimers are dark in the TGD sense and the valence bonded Ru dimer has a higher energy than a pair of free Ru atoms.

   TGD based explanation [L19] could be justified by a resonant coupling of dark electron with an ordinary Rydberg state of the valence electron. In the lowest approximation, dark valence electrons have energies in the spectrum of ordinary valence electrons so that a resonant coupling with Rydberg states can be considered. The evidence found by Randell Mill [D3] for atoms with an abnormally large scale of binding energy suggests the formula $h = 6h_0$ [L18]. Atomic binding energies are proportional to $1/h_{eff}^2$ and Mills reports that the binding energy scale can be 4 times larger than for ordinary atoms. This would correspond to $h_{eff} = h/2$.

4.1.4 Pollack effect

In the Pollack effect (PE) [**?**]egatively charged exclusion zones (EZs) are induced at the boundary between the gel phase and water by an energy feed such as IR radiation.

1. In the TGD view of quantum biology, the dark matter at field/magnetic bodies with a large value of h_{eff} has higher "IQ" and controls the ordinary biomatter and receives information from it (say by EEG). A simple model for linear dark proton triplets predicts their states to be in a 1-1 correspondence with DNA, RNA, tRNA, and amino-acids and the numbers of codons coding for given amino-acid are predicted to be the same as for the vertebrate genetic code [**?**]

2. The Pollack effect would play a key role in the transfer of ordinary particles to dark phases at the field bodies [**?**] p-Adic length scale hypothesis [**?**, **?**] for which the number theoretic vision provides a justification, makes possible quantitative predictions.

3. The negative charge of EZ is explained as a formation of flux tubes carrying dark protons, which are interpreted as dark nuclei. Every 4^{th} proton should transform to a dark proton transferred to the flux tubes to explain the observations.

   EZs are able to remove impurities from their interior in conflict with the second law of thermodynamics (SL). The TGD based explanation is that the time reversal by BSFR at the level of MB [**?**]lso induces an effective time reversal in long time scales at the level of ordinary bio-matter.

4. PE explains the occurrence of a charge separation in living matter. DNA has one negative charge per nucleotide, microtubules are negatively charged, the cell is negatively charged, and ATP carries 3 units of negative charge. Therefore ZEO suggests that PE plays a key role in bio-control and macroscopic SFRs play a key role in living matter.

5. Pollack effect is expected to occur at quantum critical temperature $T_P \sim 300$ K for the Pollack effect involved with the transformation of nucleons to their dark counterparts at magnetic flux tubes. Dark nuclei would transformed to ordinary nuclei liberating almost all nuclear binding energy.

   T_P could be near the Hagedorn temperature for gravitational monopole flux tubes. The infinite number of degrees of freedom for the monopole flux tubes indeed implies that there is a limiting temperature T_H, known as Hagedorn temperature. At the level of chemistry, the Pollack effect would naturally correspond to the flip of a topological qubit having as its bit values OH and O^- + dark proton [**?**]nd this means that it has many generalizations.

It has become clear that of Pollack effect can be generalized considerably. A mechanism providing the energy needed to kick ordinary protons to dark protons at the monopole flux tubes. Photons are one such mechanism but one can imagine large number of mechanisms of this kind. This suggests that Pollack effect is plays a key role in quantum biology [L105, L7, L43, L78, L70, L100].

Also "cold fusion" identified in TGD as dark fusion at the monopole flux tubes of the magnetic body could involve Pollack effect [L94]. One can also speculate with the role of generalized Pollack effect in making possible conscious computers as hybrids of classical and quantum computers [L89, L99].

4.1.5 Basic differences between organic and in-organic matter

One of the basic differences between organic and in-organic matter would be the presence of dark protons and electrons.

1. The notions of acids and bases would reduce to the presence of dark protons: pH would characterize the fraction of dark protons. Reduction and oxidation (the REDOX reaction) could be understood in terms of a transfer of dark electrons associated with valence bonds [L107].

2. In biochemistry the density of dark protons would be much higher in PE [I2, I3, L3, I6, I8]. Dark ions could play a key role in TGD based view of biochemistry as the findings of Blackman and others suggest [J3].

4.1.6 Biocatalysis and water memory

Bio-catalysis and water memory [I7] remain mysteries in the bio-chemical approach. MB carrying dark matter could provide the needed mechanisms. Reconnection of flux tubes would be the basic mechanism of bio-catalysis and also explain water memory, which in the TGD framework forms the basis of the immune system [K9].

1. According to the TGD view of catalysis, tentacle-like U-shaped flux tubes associated with MBs of reactants reconnect to a pair of flux tubes connecting the molecules [L25]. This happens if there is a cyclotron resonance for dark cyclotron radiation assignable to massless extremals (MEs) associated with these "tentacles". This requires that the flux tubes have identical magnetic field strengths and - by flux quantization - the same thickness. The same value of h_{eff} guarantees resonance. The next step is the shortening of the "tentacles" by a reduction of h_{eff} and the liberation of energy which "kicks" the reactants over the potential wall making an otherwise extremely slow process possible.

2. The physics of water is plagued by anomalies [I7]. TGD suggests an explanation [L20] in terms of flux tubes assignable to hydrogen bonds [L20, L24]. These flux tubes could have $h_{eff} > h$ so that these flux tube could be long and give rise to long range quantal correlations. Water could be seen as a many-phase system. MBs assignable to water molecule clusters could mimic the cyclotron frequency spectrum of the invader molecule and make possible water memory and a primitive immune system based on reconnections of the "tentacles" of a water cluster and invader molecule [L47]. In this framework water would represent a primitive life form.

4.2 Adelic physics, cognition, and biology

$M^8 - H$ duality [L38, L49, L50] concretizes the number theoretic vision.

1. $M^8 - H$ duality states that space-time surfaces X^4 in $H = M^4 \times CP_2$ correspond to Euclidean 4-D surfaces Y^4 in M^8 (octonions O with the Minkowskian inner product defined by the real part of the octonion product).

   According to the holography = holomorphy vision, for $X^4 \subset H$ holomorphic polynomial maps $g : C_2 \to C_2$ define complexity hierarchies by the functional composition [L102]. In particular, iteration hierarchies and analogs of Mandelbrot fractals and Julia sets are obtained as a special case.

2. For octonion maps $f(o)$ for M^8 similar complexity hierarchies are obtained. The p-adic analogs of functional fields are obtained in both cases: now the prime p correspond to an order of a polynomial. For polynomials $P(0)$ with rational coefficients ramified primes are obtained and discriminant are obtained as number theoretic invariants.

Galois group chararacterizes the extension of rationals defined by the roots of a polynomial $P(o)$

1. The wave functions in the set of space-time surfaces obtained by the action of Galois group G of the extension of rationals defined by the roots of a polynomial $P(o)$ may be interpreted as functions in G defining the group algebra $L(G)$ of G. They define quantal cognitive representations.

   Also their fermionic counterparts of these representations 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 [L51, L60].

2. Galois confinement [L47] would force n-particle states to behave as coherent units like hadrons do as color-confined states.

3. 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 [L60, L58] 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)?

4.3 Genetic code (GC)

The model of bio-harmony [L4, L5, L36, L45, L57] 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 [L23], 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 [L36].

2. Dark proton triplet - dark codon - would be analogous to baryon and Galois confinement [L47] 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 the completely exceptional honeycomb of the hyperbolic 3-space H^3 (cosmic time = constant hyperboloid) which, instead only a single Platonic solid, involves tetrahedron, octahedron, and icosahedron. H^3 is also central to special relativity and cosmology [L57, L69].

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) [L59].

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