Life and death: TGD point of view

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July 16, 2016

Abstract

Death and life belong to the greatest mysteries of science. The development of quantum theories of consciousness has made possible to say something non-trivial also about life and death. In this article I describe TGD inspired theory of consciousness and the view that it provides about life and death. There are several notions which are new from the point of view of standard physics. From the point of view of TGD inspired theory of consciousness the most important ones are Zero Energy Ontology (ZEO), Causal Diamond (CD), Negentropy Maximization Principle (NMP). One can say that self as conscious entity is a sequence of repeated state function reductions at the same boundary of CD and not affecting or states at it - Zeno effect- and that self dies as the first reduction to the opposite boundary of CD is forced by NMP and means reincarnation of self as time-reversed self.

From the point of view of TGD inspired quantum biology the identification of dark matter has $h_{eff}/h = n$ phases of ordinary matter having non-standard value of Planck constant is central: these phases allow to understand living matter as macroscopically quantum coherent phases. Second key notion is that of field body, in particular magnetic body. This is implied by TGD view about space-time as 4-D surface of certain 8-D space-time and means that physical systems have besides ordinary identify also field identity so that one can talk about magnetic body (MB). MB takes the role of intentional agent using biological body as motor instrument and sensory receptor: this for instance explains EEG as a communications and control tool.

Contents

1   Introduction

Life and death have remained the deepest mysteries of science. The development of quantum theories of consciousness has however encouraged scientist to make also questions about the essence of life and death. In this article TGD based view about consciousness, about about life and death is discussed.

Living system bring in mind elementary particle like coherent unit. This suggests that macroscopic quantum coherence is an essential aspect of life and consciousness. Non-predictability is second essential aspect of living systems and we experience it as free will. The description of this aspect however leads to problems in the materialistic approach originally inspired by physicalism and the idea that physicist can predict everything given the initial values.

State function reduction seems to be however a genuine non-deterministic physical phenomenon and leads to severe problems in quantum measurement theory: it is very difficult to combine the non-determinism of state function reduction with determinism of unitary time evolution (causality problem): this has led to a multitude of interpretations trying to avoid the paradox. The obvious first guess is that it might hold key to the understanding of consciousness.

TGD inspired quantum theory of consciousness can be seen as a generalization of quantum measurement theory replacing the notion of observer as kind of black box with the notion of self as conscious entity. In TGD framework causality problem is solved by assuming that there are two times: subjective time defined by sequence of state function reductions following the analog of unitary time evolution lasting for finite time and geometric time of physicist. Corresponding causalities are independent and quantum jump replaces entire time evolution with a new one so that the conflict between the causalities is resolved.

This picture leads to what I call Zero Energy Ontology (ZEO). In ZEO physical states are zero energy states, which are superpositions of pairs of positive and negative energy states serving as analogs of what might called classical event. They respect basic conservation laws and solution of field equations connects the members of state pair: this realizes holography. The members of pair are localized at boundaries of causal diamond (CD) obtained by taking the intersection of future and past directed light-cones of Minkowski space and replacing its points by CP_2.

State function reduction occurs in cascade like matter proceeding to shorter scales and from system to the sub-system if system decomposes to a product of unentangled sub-systems in the reduction. The outcome at passive boundary of CD is a set of inherently negentropically entangled subsystems having no entanglement between themselves. These systems can be seen as sub-selves of self experiencing these subsystems as mental images.

For given CD state function reduction occurs repeatedly to what I call passive (light-like) boundary of CD and leaves members of state pairs at it invariant. Also the passive boundary itself

remains unchanged. The members of state pairs at opposite, *active* boundary of CD experiences the analog of unitary time evolution followed by a reduction passive boundary: this occurs repeatedly as in Zeno effect. Active boundary also drifts further away from the passive boundary whereas nothing happens at the passive boundary.

The basic variational principle is Negentropy Maximization Principle (NMP), which demands that entanglement negentropy associated with entanglement is not reduced. In real number based theory entanglement negentropy would be non-positive and genuine information would not be possible. The requirement that the theory describes also cognition, however leads to the generalization of real number based physics to what I call adelic physics. p-Adic number fields allow only algebraic number valued entanglement and assign to it negentropy, which can be positive. One has negentropic entanglement (NE) NMP allows several variants but the mildest form requiring that NE is not reduced seems to be the realistic one.

Self can be regarded as generalized Zeno effect identified as a sequence of state function reductions to the same (passive) boundary of CD not changing the part of state at it. Eventually the first reduction to opposite boundary takes place and self dies and re-incarnates as time reversed self at the opposite boundary of CD - obviously a highly non-trivial prediction of ZEO. The flow of subjective time can be interpreted as the increase of temporal distance between the tips of CD.

One can compress the general vision to following mnenomics: ZEO, CD, NMP, NE, and Zeno effect. In the sequel I describe TGD more precisely. The implications of the general picture are discussed and this requires some ideas of TGD inspired quantum biology. In the Appendix a more detailed summary of NMP as it is now is given. The article [L3] gives a more detailed view about TGD and TGD inspired theory of consciousness as it is now.

2 TGD and TGD inspired theory of consciousness

General theory of relativity (GRT) plagued by the problem that the notions of energy and momentum are not well-defined for curved space-time time. The proposal for overcoming the energy problem (made 1977, thesis came 1982) was that space-times are not abstract 4-D manifolds but representable as 4-D surfaces in certain 8-dimensional space-time $H = M^4 \times CP_2$, which is empty Minkowski space M^4 with points replaced with certain very small 4-D space CP_2 fixed uniquely from the condition that standard model symmetries and standard model fields can be geometrized. This choice of H is uniquely fixed both by twistorial considerations [K18, K30] or by the condition that theory is consistent with standard model symmetries.

It soon turned out that the modification can be seen also as a generalization of string model with strings in 10-D space-time replaced with 3-D surfaces in 8-D H, whose "orbits" are identifiable as space-time surfaces. Recently the connection with string model picture has become much deeper. By strong form of holography (SH) 2-D string world sheets and partonic 2-surfaces carry the data needed to construct quantum states and construct solutions of field equations (preferred extremals). 4-D space-time is however necessary for quantum-classical correspond necessary to describe measurements.

TGD Universe is predicted to be fractal: this replaces the naive Planck length scale reductionism with fractality for which the simplest realization would be p-adic length scale hypothesis emerging from p-adic thermodynamics and dark matter hierarchy. Non-trivial predictions emerge in all scales from Planck length to cosmology and this makes it very difficult to communicate TGD for colleagues believing firmly on naive length scales reductionism.

In what follows I will proceed from quantum TGD to classical TGD without starting from particle physics observations - it would be extremely boring to repeat same old arguments again and again and reader can find these arguments from [K25].

2.1 Quantum TGD

The basic idea is to generalize Einstein's program as geometrization of classical physics to geometrization of the entire quantum theory so all notions of quantum theory except state function reduction which is identified as basic building brick of conscious experience would reduce to geometry.

2.1.1 Reduction of quantum theory to Kähler geometry and spinor structure of WCW

The condition that the entire quantum theory is geometrized requires infinite-dimensional geometric structure instead of space-time and the "world of classical worlds" (WCW) identified roughly as the space of space-time surfaces is the natural identification [K3, K7].

1. The construction of quantum TGD leads to a generalization of the notion of super-space of Wheeler and to construction of infinite-dimensional geometry that I call "World of Classical Worlds" (WCW) having rough mathematical identification as space of 3-surfaces in H (ZEO dictates the identification in more detail). The mere mathematical existence of WCW geometry fixes it essentially uniquely - this is true already for the loop spaces of string model [A1] - and therefore physics. A huge generalization of the symmetries of super-string models emerges giving hopes of understanding the theory.

   The geometrization of hermitian conjugation of quantum theory requires that WCW allows complex structure its metric is Kähler metric [K7] and coded by Kähler function identified in terms of Kähler action for a preferred extremal: this gives direct connection with classical physics since induced Kähler form define classical U(1) field, for the U(1) factor of electroweak gauge group assignable with weak hyper-charge. Twistorial lift implies the presence of a volume term identifiable in terms of cosmological constant. It would bring also Planck length into the theory as the radius of twistor sphere [K18].

2. Quantum states are identified as classical WCW spinor fields so that there is no need to perform quantization and state function reduction is the only genuinely quantal aspect of TGD [K20, K28]. Spinor structure requires identification of gamma matrices anticommuting to WCW metric and if the metric is Kähler metric, the anti-commutation relations are completely analogous to those of fermionic oscillator operators and one can indeed express the gamma matrices as linear superpositions of fermionic oscillator operators at space-time surface. Second quantization at space-time level is a purely classical notion at WCW level and becomes geometrized in WCW context.

3. Zero Energy Ontology (ZEO) is an essential element of theory. Usually one assumes that in classical physics generalized positions and their time derivatives (generalized velocities) giving at given moment of time in 3-D snapshot of space-time dictated the time evolution. This has generalization to Schrödinger equation. One has initial value problem.

   This Newtonian view does not work in TGD: boundary value problem provides a more natural formulation. The generalized positions at two moments of time are more natural data and the dynamical evolution connecting the two 3-D snapshots defines by holography more or less equivalent view about the situation. These pairs are analogous to classical events and one can construct as their quantum superpositions what I call zero energy states and quantum jumps are quantum events occurring between these classical events.

   ZEO is much more flexible than ordinary ontology since any zero energy state can be created from vacuum whereas in standard classical ontology only one solution of field equations is realized and in principle it is not possible to test the theory without additional assumptions. ZEO is especially natural in biology and neuroscience: the notions like function, behavioral pattern, and habit are not easy to describe in terms of the state of organism as 3-D snapshot of time evolution.

   The two time=constant snapshots are actually replaced with past and future boundaries of causal diamond (CD), which is the intersection of future and past directed light-cones of Minkowski space with each point replaced with CP_2. The ends of space-time surfaces are at the these boundaries. Zero energy states have opposite conserved quantum numbers at the opposite boundaries of CD: this guarantees that conservation laws are satisfied and the system is consistent with standard laws of physics. CDs form a fractal hierarchy. There are CDs within CDs and CDs can also overlap.

   In order to avoid confusion it must be made clear that since WCW spinor fields and zero energy states are formally purely classical entities. Only the state function reduction replacing

zero energy state (classical event) would be genuinely quantal element of the theory. The Wheelerism for this would be "Quantization without quantization".

4. The recent formulation for the notion of preferred extremal relies on strong form of General Coordinate Invariance (SGCI). SGCI states that two very different kinds of 3-surfaces can identified as fundamental objects. Either the light-light 3-D orbits of partonic 2-surfaces defining boundaries between Minkowskian and Euclidian space-time regions or the space-like 3-D ends of space-time surfaces at boundaries of CD (both ends!). If both choices are equally good, partonic 2-surfaces and their tangent space-data at the ends of space-time should be the most economic choice.

   This eventually led to the realization that partonic 2-surfaces and string world sheets should be enough for the formulation of WCW geometry and quantum TGD [K2]. Classical fields in the interior of space-time surface would be needed only in quantum measurement theory, which demands classical physics in order to interpret the experiments. The outcome is SH stating that quantum physics should be coded by string world sheets and partonic 2-surfaces inside given causal diamond (CD). SH is very much analogous to the AdS/CFT correspondence but is much simpler: the simplicity is made possible by much larger group of conformal symmetries. 2-dimensionality of space-time regions carrying fermion field can be deduce also from the condition that electromagnetic charge is well-defined for spinor modes: this requires that W boson fields vanish and this implies in the generic case 2-D string world sheets. Number theoretic vision suggests the interpretation of string world sheets and partonic 2-surfaces as commutative or co-commutative sub-manifolds of the space-time having quaternionic (associative) tangent space as a 4-surface in the imbedding space with octonionic (non-associative) tangent space [K17, K29].

   If these 2-surfaces satisfy some consistency conditions one can continue them to 4-D space-time surface inside CD such that string world sheets are surfaces inside them satisfying the condition that charged (possibly all) weak gauge potentials identified as components of the induced spinor connection vanish at the string world sheets and also that energy momentum currents flow along these surfaces. String world sheets carry second quantized free induced spinor fields and fermionic oscillator operator basis is used to construct WCW gamma matrices.

5. The existence of WCW geometry requires maximal possible group of symmetries for the geometry of WCW. Essentially a union of infinite-dimensional symmetric spaces labelled by so called zero modes not contribution to the line element of WCW would be in question. The natural candidate for this infinite-dimensional isometry group is symplectric group acting in CP_2 and at 3-D light-cone. This group maps vacuum extremals to vacuum extremals but is not a symmetry of more general extremals: if this were the case WCW metric would be trivial.

2.1.2   Quantum Criticality and hierarchy of Planck constants as dark matter hierarchy

The Kähler coupling strength α_K appearing in Kähler action is analogous to temperature. In its original form [K7] QC stated that this coupling strength is analogous to critical temperature and therefore has discrete spectrum. This idea makes sense even if Kähler action is generalized to contain additional terms: all coupling constants would be analogous to critical thermodynamical parameters.

   Indeed, the twistorial lift of TGD [K18, K30] replacing space-time surfaces with their twistor spaces in 12-dimensional product of twistor spaces of M^4 and CP_2 indeed brings in cosmological constant Λ and Planck length as radius of the sphere S^2 serving as the fiber of twistor space. This lift makes sense only for $M^4 \times CP_2$ making this choice unique. If Planck length and cosmological constant emerge in this manner their spectrum would be fixed by QC condition. The negative pressure implying accelerated cosmic expansion can be also assigned to magnetic flux tubes with monopole flux so that the situation remains open.

   The meaning of QC at the level of dynamics has become only gradually clearer. The development of several apparently independent ideas generated for about decade ago have led to the

realization that QC [K26] is behind all of them. Behind QC are in turn number theoretic vision and strong forms of general coordinate invariance (GCI) and holography (SGCI and SH).

1. The hierarchy of Planck constants labelling a hierarchy of dark phases of ordinary matter corresponds to a hierarchy of quantum criticalities assignable to a fractal hierarchy of sub-algebras of the super-symplectic algebra assignable to the boundary of causal diamond (CD) with points replaced with CP_2. The conformal weights are n-ples of those for the entire algebra, n corresponds to the value of effective Planck constant $h_{eff}/h = n$. These algebras are isomorphic to the full algebra and act as gauge conformal algebras so that a broken super-conformal invariance is in question. For $n > 1$ the hierarchy levels are interpreted in terms of dark matter. What is highly non-trivial that the conformal weights itself need not be integers or half integers as usually. The generators of algebra could have conformal weights which are proportional to zeros of zeta and poles of zeta so that the number of generating elements (finite for ordinary super-conformal algebras) would be infinite [K5]. Physical states would however have real conformal weights which would be half integers (conformal confinement).

2. QC in turn reduces to the number theoretic vision about SH. String world sheets carrying fermions and partonic 2-surfaces are the basic objects as far as pure quantum description is considered. Also space-time picture is needed in order to test the theory since quantum measurements always involve also the classical physics, which in TGD is an exact part of quantum theory.

   SH says that space-time surfaces are continuations of collections of string world sheets and partonic 2-surfaces to preferred extremals of Kähler action for which Noether charges in the sub-algebra of super-symplectic algebra vanish. This condition is the counterpart for the reduction of the 2-D criticality to conformal invariance. This eliminates huge number of degrees of freedom and makes SH possible. TGD does not reduce physics to that of strings since the fact that strings are surfaces inside 4-D space-time surfaces is an essential part of physics and also the experimental testing requires 4-D space-time as also the notion of 8-D imbedding space.

3. The hierarchy of algebraic extensions of rationals defines the values of the parameters characterizing the 2-surfaces, and one obtains a number theoretical realization of an evolutionary hierarchy. One can also algebraically continue the space-time surfaces to various number fields - reals and the algebraic extensions of p-adic number fields. Physics becomes adelic [K29].

   p-Adic sectors serve as correlates for cognition and imagination. One can indeed have string world sheets and partonic 2-surfaces, which can be algebraically continued to preferred extremals in p-adic sectors by utilizing p-adic pseudo constants providing huge flexibility. If this is not possible in the real sector, a fragment of imagination is in question! It can also happen that only part of real space-time surface can be generated: this might relate to the fact that imaginations can be seen as partially realized motor actions and sensory perceptions.

4. The assignment of the hierarchy of Planck constant to a hierarchies of inclusions of hyper-finite factors of type II_1 is natural. Also the interpretation in terms of finite measurement resolution makes sense. As n increases the sub-algebra acting as conformal gauge symmetries is reduced so that some gauge degrees of freedom are transformed to physical ones. The transitions increasing n occur spontaneously since criticality is reduced. A good metaphor for TGD Universe is as a hill at the top of a hill at the top.... In biology this interpretation is especially interesting since living systems can be seen as systems doing their best to stay at criticality using metabolic energy feed as a tool to achieve this. Ironically, the increase of $\hbar$ would mean increase of measurement resolution and evolution!

5. If twistorial lift is not performed, the only coupling constant of the theory is Kähler coupling constant $\alpha_K = g_K^2/4\pi\hbar$, which appears in the definition of the Kähler function K characterizing the geometry of WCW. In the most general case α_K has a spectrum of critical values and this conjecture seems at this moment the most reasonable one. It has indeed turned out that the discrete spectrum could have interpretation in terms of discretized coupling constant evolution for U(1) coupling constant of standard model. The identification of the spectrum in terms of zeros of so called fermionic zeta function expressible in terms of Riemann zeta

is attractive [K5]. The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed values of $\alpha_K = g_K^2/4\pi\hbar_{eff}$ should be analogous to critical temperatures and determined by QC requirement.

2.2   Classical TGD

In TGD framework classical physics is an exact part of quantum physics rather than being only an approximate limit of quantum theory emerging from the stationary phase approximation to path integral, which would in TGD allow all space-time surfaces. Now one does not have path integral but functional integral over the pairs of 3-surfaces at bounaries of CD. Only preferred extremals of Kähler are allowed in the functional integral so they satisfy classical field equations and even more: effective 2-dimensionality holds by SH. Stationary phase approximation can be made also now but selects "preferred preferred extremals". The reason is that for real value of α_K the Minkowskian space-time regions give imaginary exponent to the action exponential whereas Euclidian space-time regions give real exponent identifiable as exponent of Kähler function. In fact, the value of α_K can be also complex but this does not affect this picture.

2.2.1   Space-time surfaces as preferred extremals of Kähler action

Preferred extremal of Kähler action have remained for a long time one of the basic poorly defined notions of TGD. There are pressing motivations for understanding what "preferred" really means. For instance, the conformal invariance of string models naturally generalizes to 4-D invariance defined by quantum Yangian of quantum affine algebra (Kac-Moody type algebra) characterized by two complex coordinates and therefore explaining naturally the effective 2-dimensionality [K18].

In ZEO preferred extremals are space-time surfaces connecting two space-like 3-surfaces at the ends of space-time surfaces at boundaries of causal diamond (CD). A natural looking condition is that the symplectic Noether charges associated with a sub-algebra of symplectic algebra with conformal weights n-multiples of the weights of the entire algebra vanish for preferred extremals. These conditions would be classical counterparts the condition that super-symplectic sub-algebra annihilates the physical states.

What is needed is the association of a unique space-time surface to a given 3-surface defined as union of 3-surfaces at opposite boundaries of CD. One can imagine many manners to achieve this. "Unique" is probably too much to demand: for the proposal unique space-time surface is replaced with finite number of conformal gauge equivalence classes of space-time surfaces. This would bring in finite number of discrete degrees of freedom. In any case, it is better to talk just about preferred extremals of Kähler action and accept as the fact that there are several proposals for what the precise meaning of this notion.

2.2.2   Many-sheeted space-time and topological field quantization

At classical level the basic is the notion of many-sheeted space-time which can be visualized in 2-D situation as a structure consisting of space-time sheets extremely near to each other and connected by wormhole contacts. General Relativity becomes approximate description obtained by replacing the sheets with single slightly curved region of Minkowski space. The sheets correspond to material objects that one can say that we directly see them. The experimental tests distinguishing TGD from GRT relate to many-sheetedness.

The quantum field theory limit of TGD - GRT plus standard model - is obtained when the sheets are compressed to single region of slightly curved piece of M^4 by identifying gauge potentials as sums of induced gauge potentials for the spinor connection of CP_2 and gravitational field as sum for the deviations of the induced metrics from Minkowski metric. This corresponds to the vision that the force experienced by a test particle - small 4-surface - is sum of those induced as it touches various space-time sheets. One gets rid of topological complexity but the extreme simplicity of space-time dynamics is lost in this replacement.

One example is quite recently discovered fractionization of photon spin to spin 1/2 for helical photon beams, which vould be due the fact that helical photon beam corresponds to a 2-sheeted covering of M^4 locally. Therefore 2π rotation in M^4 does not bring the point of space-time surface to the original one. Also $1/n$ fractionization is predicted to be possible.

The compactness (finite size) CP_2 implies topological field quantization: the classical electric fields, magnetic fields, and radiation fields decompose to topological field quanta, space-time sheets, and one can say that physical systems have field identity, field body. This is not true in Maxwell's theory. I have called radiation quanta "massless extremals" (MEs) or topological light rays. For MEs the signals propagate at maximal signal velocity (for general space-time sheet light velocity is reduced since the paths along curved space-time sheet is general longer) and thanks to the tubular structure of ME they represent precisely target communications. A further property is that the shape of signal is preserved since positive frequency can propagate in one direction only.

Preferred extremal property implies further quantization conditions as is clear from the fact that the 2-D data should fix the preferred extremal by SH.

2.2.3 New ontology

TGD leads to a new ontology at both space-time level and quantum level.

1. At space-time level many-sheeted space-time represents new piece of ontology. Single space-time sheet is extremely simple objects and the information needed to construct it is by SH 2-dimensional. Complexity emerges at quantum field theory limit when the sheets o f the many-sheeted space-time are replaced with single slightly curved region of M^4.

2. The hierarchy of Planck constants identified in terms of dark matter as phases of ordinary matter represents second new ontological element.

3. A further modification of ontology is the replacement of the usual positive energy ontology (PEO) with what I call zero energy ontology (ZEO) already described. In ZEO quantum states are superpositions of quantum evolutions connecting the positive and negative energy parts of the states. Zero energy states are essentially 4-D and only the positive and negative energy parts are 3-D. Quantum jumps/state function reductions re-create the zero energy states with new ones and this allows to solve the basic paradox of ordinary quantum measurement theory due to the fact that non-determinism of state function reduction is in conflict with the determinism of unitary time evolution. One also ends up with identification of "self" as conscious entity: self corresponds to generalized Zeno effect: to a sequence of state function reduction to say positive (positive) energy part of zero energy state [K1] [L5]. Self dies when the first reduction to negative (positive) part occurs. Also the origin for the flow of experienced time can be understood.

2.2.4 Hierarchies

TGD Universe is characterized by various hierarchies. At space-time level there is a hierarchy of space-time sheets labelled by a hierarchy of p-adic length scales coming as primes near powers of two and probably generalizing to primes near powers of prime [K23, K29]. In zero energy ontology (ZEO) and at imbedding space level there is a hierarchy of causal diamonds (CDs) labelled by their size scales coming as integer multiples of CP_2 scales. The fractal hierarchy of symplectic sub-algebras leads to a generalization of quantum theory based on a hierarchy of Planck constants characterizing hierarchy of dark matters [K6, K26], hierarchies of inclusions of hyper-finite factors [K19], hierarchies of breakings of super-symplectic gauge symmetry [K20, K28] associated with a hierarchy of quantum criticalities [K26]. There is also a number theoretic hierarchy of algebraic extensions of rationals accompanied by those of p-adic number fields [K29] allowing to see evolution as a gradual increase of the complexity for extensions of rationals assignable to the parameters characterizing string world sheets and partonic 2-surfaces. In TGD inspired theory of consciousness [K9] self hierarchy emerges.

At the basic level the fundamental hierarchy seems to be the heirarchy of breakings of super-symplectic symmetry as gauge symmetry. Super-symplectic algebra and its Yangian generalization have the structure of conformal algebra and is naturally associated with critical systems which are now 4-dimensional. There are also other conformal algebras involved.

By SH implied by the SGCI the core of the mathematical description of quantum TGD reduces to that for 2-D systems associated with partonic 2-surfaces and string world sheets. Although space-time is 4-D, all that can be said mathematically about quantum physics can be reduced

to these 2-D "space-time genes". 4-D space-time surfaces are however necessary for the classical description of TGD necessary to interpret quantum measurements in terms of frequencies and wavelengths classical space-time picture about particles. This reduction implies that the representations of charges of super-symplectic Yangian [K18, K30] are in terms of fermionic strings connecting partonic 2-surfaces, which means enormous simplification of the theory. This representation also involves a generalization of AdS/CFT duality to TGD framework as manifestation of SGCI basically [K2].

2.3 Number theoretical physics

Number theoretical physics involves several threads [K29].

1. p-Adic physics as correlate for cognition, imagination, and intentionality [K16] p-Adic physics was originally inspired by the challenge of understanding the mass scales of elementary particles but it soon turned that the interpretation in terms of mathematical correlates of cognition and imagination is very natural. This in turn forced the conclusion that cognition is probably present in all length scales, rather than only at the level of brain. The eventual outcome was a fusion of real and p-adic physics in terms of adelic physics.

2. Classical number fields emerge very naturally in TGD framework [K17]. For instance, the conjecture is that space-time surfaces as preferred extremals of Kähler action are quaternionic sub-manifolds of imbedding space endowed with octonionic structure. Also quaternion analyticity [A3, A2] as a generalization of complex analyticity central in string models is very attractive conjecture [K18] in accordance with the original vision that 2-D analyticity in some sense generalizes to its 4-D variant.

3. Infinite primes [K15] are constructed by a repeated second quantization of arithmetic quantum field theory and could be essential for understand of quantum TGD.

In the sequel I discuss only the p-adic physics and the fusion of real physics and various p-adic physics to adelic physics as proposal for the physics of matter and mind or correlates of sensory and cognitive consciousness.

2.3.1 p-Adic physics as physics of cognition, imagination and intentionality

1. The attempt to understand elementary particle mass spectrum led to the hypothesis that p-adic number fields - one for each prime $p = 2, 3, 5, ...$, which are completions of rationals like real numbers, allow to construct what I called p-adic thermodynamics allowing to understand particle masses as kind of thermal masses resulting when massless particles suffer slight thermal mixing with particles with mass scale given by CP_2 mass of order 10^{-4} Planck masses.

2. The failure of well-orderedness property for p-adic numbers brings in the corresponding failure due to a finite measurement resolution and leads to the vision that p-adic numbers are ideal for describing the effects of finite measurement resolution and cognitive resolution.

3. The failure of strict determinism for the partial differential equations suggest strongly that it serves as a correlate for cognition, imagination, and maybe also intention is closely related.

4. The fusion of real physics and various p-adic physics (identified as correlates for cognition, imagination, and intentionality) to single coherent whole leads to adelic physics [K29]. Adeles associated with given extension of rationals are Cartesian product of real number field with all p-adic number fields extended by the extension of rationals. Besides algebraic extensions also the extension by any root of e is possible since it induces finite-dimensional p-adic extension. One obtains hierarchy of adeles and of corresponding adelic physics interpreted as an evolutionary hierarchy.

   An important restriction is that p-adic Hilbert spaces exist only if one restricts the p-adic numbers to an algebraic extension of rationals having interpretation as numbers in any number field. This is due to the fact that sum of the p-adic valued probabilities can vanish

for general p-adic numbers so that the norm of state can vanish. One can say that the Hilbert space of states is universal and is in the algebraic intersection of reality and various p-adicities.

5. One can define the p-adic counterparts of Shannon entropy for all finite-dimensional extensions of p-adic numbers, and the amazing fact is that these entropies can be negative and thus serve as measures for information rather than for lack of it. The formula is simple:

$$S = -\sum_k P_k log(P_k) \rightarrow \sum_k P_k log(N_p(P_k)) \ . \tag{2.1}$$

Here $N_p(x)$ is the p-adic norm, which for n-D extension is defined as n:th root of the determinant of the matrix of the linear map defined by multiplication with x. The change of sign is dictated by the fact that converging Boltzmann weights $e^{-E/kT}$ must in be TGD proportional to positive powers p^k with increasing k by the properties of p-Adic norm.

p-Adic entropy can have both signs bit NMP suggests that the sign tends to become negative so that interpretation as a measure for conscious information is possible. Furthermore, all non-vanishing p-adic negentropies are positive and the number of primes contributing to negentropy is finite since any algebraic number can be expressed using a generalization of prime number decomposition of rational number. These p-adic primes characterize given systen, say elementary particle.

The possibility of NE together with NMP [K10] implies that the reduction does not always lead to an unentangled state but can generate NE. Living systems would be systems generating NE and biological evolution could be seen as a gradual generation of negentropic resources - I have called them Akashic Records. For rational probabilities entanglement negentropy equals to real entropy [L2]. This might relate to the Jeremy Englands vision that high entropy is relevant for living matter.

What is important that entanglement negentropy and thermodynamical entropy are *not* negatives of each other. Hence NMP is not in conflict with the second law but predicts it for the ordinary matter as a consequence of non-determinism of state function reduction. It is however true that large entropic recources realized as a large number of states with the same energy makes possible both large thermodynamical entropy and NE with large negentropy.

2.3.2   The extension of real physics to adelic physics

In TGD framework cognition is described in terms of p-adic number fields and has led to a fusion of real and various p-adic physics to what I call adelic physics [K29]. Real physics corresponds to sensory experience and p-adic physics to cognition and imagination. Originally I talked about p-adic physics as physics of cognition and intentionality but I have have become ambivalent about intentionality: this issue remains unsettled.

Real-p-adic correspondence has been a longstanding problem. Continuous correspondence at space-time level does not respect symmetries. Algebraic correspondence respects symmetries but not continuity. Also GCI has been a problem. In the proposed framework real-p-adic correspondence can be realized in elegant manner without conflict with fundamental symmetries and achieving continuity only for discretization.

1. The naive idea is that rationals belong to the intersection of reals and p-adics. More generally, points in algebraic extension of rationals would be common to realities and p-adicities which correspond to "thought bubbles" or imaginations. This hierarchy defines a hierarchy of adeles having interpretation in terms of evolution leading to increasingly complex algebraic extensions of rationals.

2. The first guess was that this means at space-time level that imbedding space points with rational valued coordinates (or values in the extension of rationals) correspond to common points of real and p-adic space-time surfaces. This picture however leads to problems with both GCI and key symmetries of TGD. What are the preferred coordinates of space-time

surface which would be in algebraic extension of rationals in the intersection? Should one restrict symmetry groups to their discrete subgroups?

3. A partial resolution of the problem came from the realization that the intersection of realities and p-adicities corresponds to space-time surfaces, whose representation is such that they make sense both in real and p-adic sense [K29]. This requires that the WCW coordinates of these surfaces are invariant under various symmetries and general coordinate transformations of space-time belong to the extension of rationals in question. At the level of WCW the coordinates are highly unique on basis of symmetries and by GCI at space-time level. This also means discretization of the infinite-dimensional WCW and together with huge isometry group of WCW gives hopes about computatibility of TGD.

4. As often happens, also the original idea about points of given algebraic extension of rationals as common to real and p-adic space-time surfaces makes sense: one can say that these discrete points define cognitive representations in the real world. The point is that space-time surfaces can be identified as 4-surfaces in H and discretization is induced by that of H. At the first step, the pieces of hyperboloids inside CD and CP_2 can be replaced with their discrete variants making sense both in real and p-adic sense [L4].

   The discretization of space-time surface is *induced* by the discretization at the level of $CD \times CP_2$ in terms of algebraic points of space-time surface and one avoids problem with p-adic version of general coordinate invariance and various space-time symmetries because for coset spaces the coordinate choice is unique apart from isometries: angles or hyperbolic angles serve as coordinates. Angles do not exist in p-adic context. The phases $exp(i\phi)$ - and therefore the values of trigonometric functions - exist in algebraic extensions of p-adic numbers as roots of unity associated with angles $\phi_{m,n} = m2\pi/n$. Also the roots $e^{m/n}$ define finite-D extension of p-adic numbers since e^p is ordinary p-adic number.

   The outcome is a precise mathematical formulation for the p-adic counterparts of space-time surfaces as preferred extremals of Kähler action. The p-adic variants of coset spaces can be seen as discretizations of real coset spaces with discrete points replaced by p-adic continua analogous to the monads of Leibniz [L4]. This would make possible discretization without loosing differentiability central for field equations. One can define p-adic field equations inside these monads and strong SH makes sense in both real and p-adic sector.

   The same algebraic expressions would describe real and p-adic solutions of field equations locally when restricted to string world sheets and partonic 2-surfaces (maybe also their light-like orbits). Inside monads real-p-adic correspondence would respect algebraic structures and symmetries. In the intersections symmetry groups would be replaced with discrete subgroups and continuity would be respected in the approximation provided by discretization and would confirm with the idea about finite measurement resolution.

5. This procedure is unique for given choice of discrete subgroups G and H. One can however take any discrete subgroup with matrix elements in algebraic extension of rationals and its subgroup and form a discrete analog of coset space: there is infinite hierarchy of measurement/cognitive resolutions. For instance, in the case of $SU(2)$ these discrete approximations of $SU(2)$ containing finite set of points correspond to the discrete subgroups labelling inclusions of hyperfinite factors of type II_1 and include only Platonic solids as genuinely 3-D approximations of sphere. This is discrete structure in real world.

2.3.3   p-Adic physics as physics of imagination

A further step in the progress came from the discovery of SH [K2]. 2-dimensional surfaces (string world sheets and partonic 2-surfaces) are fundamental objects and 4-D physics is a kind of algebraic continuation from this intersection of reality and various p-adicities in both real and p-adic sectors of the adelic Universe. 4-D space-time surfaces are preferred extremals of Kähler action making them effectively 2-D in the sense that the 2-D surfaces serve as "space-time genes" . Also the quantum states assignable to the 2-D surfaces can be algebraically continued to the entire 4-D space-time.

It is however quite possible that the continuation in the real sector to a preferred extremal of Kähler action fails. In p-adic sectors the possibility of p-adic pseudo constants, which are piecewise constant functions with vanishing derivative, makes the continuation much easier. This inspires the idea that imagination corresponds to these p-adic continuations. p-Adic continuation might be possible whereas real continuation could fail: one would have imagined world, which cannot be realized as often happens!

2.3.4   Negentropic entanglement (NE)

In a given p-adic sector the entanglement entropy is defined by replacing the logarithms of probabilities in Shannon formula by the logarithms of their p-adic norms as already described. The resulting entropy satisfies the same axioms as ordinary entropy but makes sense only for probabilities, which are rational valued or in an algebraic extension of rationals. The algebraic extensions corresponds to the evolutionary level of system and the algebraic complexity of the extension serves as a measure for the evolutionary level. p-Adically also extensions determined by roots of e can be considered. What is so remarkable is that the number theoretic entropy can be negative.

A simple example allows to get an idea about what is involved. If the entanglement probabilities are rational numbers $P_i = M_i/N$, $\sum_i M_i = N$, then the primes appearing as factors of N correspond to a negative contribution to the number theoretic entanglement entropy and thus to information. The factors of M_i correspond to negative contributions. For maximal entanglement with $P_i = 1/N$ in this case the entanglement entropy is negative. The interpretation is that the entangled state represents quantally concept or a rule as superposition of its instances defined by the state pairs in the superposition. Identity matrix means that one can choose the state basis in arbitrary manner and the interpretation could be in terms of "enlightened" state of consciousness characterized by "absence of distinctions". In general case the basis is unique.

Metabolism is a central concept in biology and neuroscience. Usually metabolism is understood as transfer of ordered energy and various chemical metabolites to the system. In TGD metabolism could be basically just a transfer of NE from nutrients to the organism. Living systems would be fighting for NE to stay alive (NMP is merciless!) and stealing of NE would be the fundamental crime.

TGD has been plagued by a longstanding interpretational problem: can one apply the notion of number theoretic entropy in the real context or not. If this is possible at all, under what conditions this is the case? How does one know that the entanglement probabilities are not transcendental as they would be in generic case? There is also a second problem: p-adic Hilbert space is not a well-defined notion since the sum of p-adic probabilities defined as moduli squared for the coefficients of the superposition of orthonormal states can vanish and one obtains zero norm states.

These problems disappear if the reduction occurs in the intersection of reality and p-adicities since here Hilbert spaces have some algebraic number field as coefficient field. By SH the 2-D states states provide all information needed to construct quantum physics. In particular, quantum measurement theory.

1. The Hilbert spaces defining state spaces has as their coefficient field always some algebraic extension of rationals so that number theoretic entropies make sense for all primes. p-Adic numbers as coefficients cannot be used and reals are not allowed. Since the same Hilbert space is shared by real and p-adic sectors, a given state function reduction in the intersection has real and p-adic space-time shadows.

2. State function reductions at these 2- surfaces at the ends of CD take place in the intersection of realities and p-adicities if the parameters characterizing these surfaces are in the algebraic extension considered. It is however not absolutely necessary to assume that the coordinates of WCW belong to the algebraic extension although this looks very natural.

3. Does NMP apply to the sum of real and p-adic entropies (Option 1) or only to the sum of p-adic entanglement entropies (which can be negative) (Option 2). The situation is not settled yet.

   (a) For Option 1 the total entropy vanishes identically for *rational* probabilities and NMP would say nothing about the situation [L2]. NMP would not prevent or favor state function reduction. It is not clear whether this situation corresponds to that in the physics

of ordinary matter as opposite to that of living matter. For algebraic probabilities there would be a competition between real and p-adic sectors and p-adic sectors would win for algebraic extensions in the sense that p-adic entropy would be larger than real entropy.

(b) For Option 2 NMP would stabilize NE also for rational probabilities. One can wonder whether one obtains the ordinary state function reduction at all for this option. In ZEO state function reductions to the opposite boundary of CD would be however forced to occur and second law would be the outcome also in this case.

For both options it could quite well happen that NMP for the sum of real and p-adic entanglement entropies does not allow the ordinary state function reduction to take place since p-adic negative entropies for some primes would become zero and net negentropy would be lost.

In both cases mind would have causal power: it can stabilize quantum states against state function reduction and tame the randomness of quantum physics in absence of cognition! Can one interpret this causal power of cognition in terms of intentionality? If so, p-adic physics would be also physics of intentionality as originally assumed.

A fascinating question is whether the p-adic view about cognition could allow to understand the mysterious looking ability of idiot savants (not only of them but also of some greatest mathematicians) to decompose large integers to prime factors. One possible mechanism is that the integer N represented concretely is mapped to a maximally entangled state with entanglement probabilities $P_i = 1/N$, which means NE for the prime factors of P_i or N. The factorization would be experienced directly.

One can also ask, whether the other mathematical feats performed by idiot savants could be understood in terms of their ability to directly experience - "see" - the prime composition (adelic decomposition) of integer or even rational. This could for instance allow to "see" if integer is - say 3rd - power of some smaller integer: all prime exponents in it would be multiples of 3. If the person is able to generate an NE for which probabilities $P_i = M_i/N$ are apart from normalization equal to given integers M_i, $\sum M_i = N$, then they could be able to "see" the prime compositions for M_i and N. For instance, they could "see" whether both M_i and N are 3rd powers of some integer and just by going through trials find the integers satisfying this condition.

2.4   The notion of magnetic body (MB)

MB is assumed to be carrier of dark matter.

1. The flux tubes of MB can suffer h_{eff} changing phase transitions inducing the change of the length of flux tube. This leads to a view about living matter as a network of bio-molecules connected by magnetic flux tubes. The ability of biomolecules to find each other in the dense molecular soup would rely on the reduction of h_{eff} bringing molecules near each other. The reconnections of flux tubes possible if the field strengths are same and therefore also cyclotron frequencies are identical are also expected to central element in bio-communications since they change the topology of the network and make possible analogs of relays.

   The receptors to which information molecules attach could be seen as plugs to which magnetic flux tubes having information molecule at its end attach and give rise to a fusion of two flux tubes to a longer flux tube connection. For instance, nerve pulse transmission would be more like building quantum connections than communication.

2. Flux tubes with large h_{eff} make possible high T_c superconductivity [K12, K13]. Superconducting structures would be pairs of flux tubes carrying magnetic fluxes which have same or opposite directions. Cooper pairs would have members at separate flux tubes.

2.4.1   MB as intentional agent

Magnetic field associated with a given system decomposes to flux tubes and sheets to that system has MB (MB). The physics of MBs could be a new chapter in physics and MB could define the basic space-time correlate for non-locality.

1. Flux tubes of MB would serve as correlates for quantum entanglement, which in TGD framework can be negentropic and for this reason rather stable under state function reductions. In GRT context the idea about wormholes as correlates of entanglement between blackholes is highly analogous. The problem with wormholes is that they are highly unstable. Magnetic flux tubes carrying monopole flux are stable since flux conservation prevents their pinching. The pairs of flux tubes wit opposite fluxes can however split to two U-shaped flux tubes by reconnection. It is important to notice that magnetic flux tubes are necessarily closed and can be regarded as flux running along different space-time sheets in opposite direction and from sheet to another through the wormhole contacts at ends.

   One can of course ask whether the braiding of flux tubes could be the correlate for entanglement. To my opinion entanglement without braiding is possible.

2. MB and dark matter at it would serve as intentional agent in biological systems [K26]. The organism-environment duality would be replaced by the trinity MB-organism-environment. For instance, EEG and its strong correlation with brain state and consciousness could be understood in terms of communication of sensory data from cell membranes to MB and control and coordination signals from MB to biological body [K4]. Signals would consist of dark photons with with energies $E = h_{eff}f = n \times hf$ in bio-photon energy range and thus above thermal energies. For instance, the recently observed synchrony between hemispheres in absence of corpus callosum [J2] could be understood in terms of MB serving as "boss".

3. The formation of flux tube reconnections would serve as a correlate for directed attention - attention could be directed to objects of external world or to their representations in brain. The reconnection would take place for U-shaped flux tubes serving as kind of magnetic tentacles and lead to a formation of pairs of flux tubes connecting the two systems. If flux tubes carry monopole flux as one has reasons to expect, the flux tubes would be actually closed two-sheeted structures (also elementary particles would be this kind of structures) and flux tube pair would be pair of these. The flux tubes of MBs would serve as analogs of wave guides along with precisely targeted communications of dark photon signals ("massless extremals" (MEs)) would be possible. Also supra currents would be possible and the TGD based model of high T_c superconductivity relies on the same mechanism [K12]. These communications would be essential in living matter.

4. The formation of reconnections and phases transitions $n \to m$ changing $h_{eff} = n \times h$ would be a basic mechanism behind biocohemistry. U-shaped flux tubes would act like tentacles emerging from the system and reconnection of the tentacles would build a connection between two systems. The reduction of Planck constant would shorten the connecting flux tubes and could force the systems in the vicinity of each other after which bio-catalysis could take place. Braiding and its 2-braid variant for string world sheets and partonic 2-surfaces in 4-D space-time instead of strings in 3-D space would make possible realization of quantum computer program like structures.

2.4.2 MB is 4-dimensional

MB as preferred extremal represents in terms of space-time topology and geometry 4-D self-organization patterns, behaviors, functions, and skills. What is new that self-organization occurs for 4-D patterns rather than 3-D ones. The entire process is replaced with a new one. Sequence of state function reductions leads from a 4-D self-organization pattern to an asymptotic 4-D self-organization pattern [K22].

Morphogenesis provides examples of this kind of phenomena [I1, I2, I4]. The first key idea is that DNA and cell replication is induced by the replication of MBs serving as information carriers (see `http://tgdtheory.fi/public_html/tgdlian/tgdlian.html#lianPB`) [K22]. The second key idea is that in zero energy ontology (ZEO) MB is 4-dimensional and represents behavioral patterns rather than only 3-dimensional patterns.

According to Michael Levin, concerning morphogenesis and morphostasis the basic challenge is to understand how the shape of the organism is generated and how it is preserved. The standard local approach based on belief on genetic determinism does not allow one to answer these questions satisfactorily.

1. The first approach to this problem relies on a self-organization paradigm in which the local dynamics of cells leads to large scale structures as self-organization patterns. In TGD framework 3-D self-organization is replaced with 4-D self-organization (the failure of strict determinism of the classical dynamics is essential motivating zero energy ontology (ZEO)). One can speak about 4-D healing: expressing it in somewhat sloppy manner, the space-time surface serving as a classical correlate for the patient is as a whole replaced with the healed one: after the 4-D healing process the organism was never ill in geometrical sense! Note that in quantal formulation one must speak of quantum superposition of space-time surfaces.

2. Second approach could be seen as computational. The basic idea is that the process is guided by a template of the target state and morphogenesis and healing are computational processes. What Levin calls morphogenetic fields would define this template. It is known that organisms display a kind of coordinate grid providing positional information that allows cells to "decide" about the profile of genetic expression (for references see [I2]). In TGD framework MB forming coordinate grid formed from flux tubes is a natural candidate for this structure. They would also realize topological quantum computation (TQC) with basic computational operations realized at the nodes of flux tubes to which it is natural to associate some biological sub-structures.

The assumption about final goal defining a template can be argued to be too strong: much weaker principle defining a local direction of dynamics and leading automatically to the final state as something analogous to free energy minimum in thermodynamics might be enough. Unfortunately, second law is the only principle that standard physics can offer. Negentropy Maximization Principle (NMP) provides the desired principle in TGD framework. Also the approach of WCW spinor field to the maximum of vacuum functional (or equivalently that of Kähler function) gives a goal for the dynamics after the perturbation of the organism causing "trauma". If Kähler function is classical space-time correlate for entanglement negentropy, these two views are equivalent.

TGD thus suggests an approach, which could be seen as a hybrid of approaches based on self-organization and computationalism. The MB becomes the key notion and codes also for learned behaviors as TQC programs coded by the braiding of flux tubes. The replication of the MB means also the replication of the programs behind behavioral patterns (often somewhat misleadingly regarded as synonymous with long term memories): both structure and function are replicated. This hypothesis survives the killer tests provided by the strange findings about planaria cut into two and developing new head or tail while retaining its learned behaviors: the findings indicate that behavioral programs are preserved although planaria develops a new brain.

2.4.3 $h_{gr} = h_{eff}$ hypothesis

Nottale [E1] introduced originally the notion of gravitational Planck constant $h_{gr} = GMm/v_0$, where M is large mass such as that of Earth or Sun and m the mass of quantum coherent object and v_0 is a parameter with dimensions of velocity [E1]. Nottale did not propose macroscopic quantum coherence in astrophysical scales but in TGD framework this is a natural option [K14, K11].

The obvious question is whether the gravitational Planck constant deduced from the Nottale's considerations and the effective Planck constant $h_{eff} = n \times h$ deduced from ELF effects on vertebrate brain and explained in terms of non-determinism of Kähler action could be identical. At first this seems to be non-sensical idea since $h_{gr} = GMm/v_0$ has a gigantic value. The hypothesis $h_{eff} = h_{gr}$ leads to much stronger predictions [K27, K26] than either hypothesis alone. One can also introduce analogs of h_{gr} for other interactions: the idea is that when the coupling strength between two charges becomes so large that perturbation theory does not exist, a phase transition increasing the Planck constant happens and guarantees the convergence.

The essential point is that h_{eff} and h_{gr} would characterized body parts of MB: this allows to understand the dependent on masses of two particles. The flux tubes with a given value of h_{eff} would carry only particles of particular mass m so that the random soup of biomolecules would become a highly ordered structure analogous to library in which each book type is its own shelf. Furthermore, the cyclotron energies $E_c \propto h_{eff}/m$ would be same irrespective of particle mass m although cyclotron frequencies are different.

The proposed identification of the energy range of dark photon cyclotron energies in living matter is as visible and UV range assigned to bio-photons which would therefore result in the

transformation of dark photons to ordinary photons. Further important point, is that the energy spectrum would be in the range of molecular excitation energies (visible and UV range) so that dark photons transformed to ordinary ones would allow MBs to control biochemistry.

By Equivalence Principle one can describe gravitational interaction by reducing it to elementary particle level. For instance, gravitational Compton lengths do not depend at all on the masses of particles. Also the radii of the planetary orbits are independent of the mass of particle mass in accordance with Equivalence Principle. For elementary particles the values of h_{gr} are in the same range as in quantum biological applications. Typically 10 Hz ELF radiation should correspond to energy $E = h_{eff}f$ of UV photon if one assumes that dark ELF photons have energies of biophotons and transform to them. The order of magnitude for n would be therefore $n \simeq 10^{14}$.

The experiments of M. Tajmar et al [E2, E3] discussed in [K24] provide a support for this picture. The value of gravimagnetic field needed to explain the findings is 28 orders of magnitude higher than theoretical value if one extrapolates the model of Meissner effect to gravimagnetic context. The amazing finding is that if one replaces Planck constant in the formula of gravimagnetic field with h_{gr} associated with Earth-Cooper pair system and assumes that the velocity parameter v_0 appearing in it corresponds to the Earth's rotation velocity around its axis, one obtains correct order of magnitude for the effect requiring $r \simeq 3.6 \times 10^{14}$.

The most important implications are in quantum biology and Penrose's vision about importance of quantum gravitation in biology might be correct.

1. This result allows by Equivalence Principle the identification $h_{gr} = h_{eff}$ at elementary particle level at least so that the two views about hierarchy of Planck constants would be equivalent. If the identification holds true for larger units it requires that space-time sheet identifiable as quantum correlates for physical systems are macroscopically quantum coherent and gravitation causes this. If the values of Planck constant are really additive, the number of parallel space-time sheets corresponding to non-determinism evolution for the flux tube connecting systems with masses M and m is proportional to the masses M and m using Planck mass as unit. Information theoretic interpretation is suggestive since hierarchy of Planck constants is assumed to relate to negentropic entanglement very closely in turn providing physical correlate for the notions of rule and concept.

2. That gravity would be fundamental for macroscopic quantum coherence would not be surprising since by EP all particles experience same acceleration in constant gravitational field, which therefore has tendency to create coherence unlike other basic interactions. This in principle allows to consider hierarchy in which the integers $h_{gr,i}$ are additive but give rise to the same universal dark Compton length.

3. An interesting question is how large systems can behave as coherent units with $h_{gr} = GMm/v_0$. In living matter one might consider the possibility that entire organism might be this kind of system. Interestingly, for larger masses the gravitational quantum coherence would be easier. For particle with mass m $h_{gr}/h > 1$ requires larger mass to satisfy $M > M_P^2/m_e$. The first guess that life has evolved from long to shorter scales and reached elementary particle last. Planck mass is the critical mass corresponds to the mass of water blog with volume of size scale of 10^{-4} m (big neuron) is the limit.

The general proposal discussed above is testable. In particular, a detailed study of molecular energies with those associated with resonances of EEG could be highly rewarding and reveal the speculated spectroscopy of consciousness.

2.4.4 EEG as communications between MB and BB

Models of EEG and nerve pulse are basic applications of the notion of MB in neuroscience. The basis idea is that EEG and its fractal counterparts are communications to the various layers of MB having onion-like structure with cyclotron frequency correlating with the size of the layer. Josephson junctions about which basic example is cell membrane would communicate sensory information to MB as dark photons.

The general model for EEG follows neatly from this picture combined with the general model of high T_c superconductivity [K12, K13]. A fractal hierarchy of EEGs and its generalizations

identified in terms of generalized Josephson radiation is predicted with levels labeled by p-adic length scales and the value of $\hbar$ at various levels of dark matter hierarchy [K4]. At macrolevel one can approximate neuronal and axonal (and also cell-) membrane as Josephson junction formed by the two lipid layers of the membrane. At microscopic level ionic pumps and channels defined by Josephson junctions involving magnetic flux tubes connecting interior and exterior of the cell.

"Generalized" means that Josephson frequency as energy difference $E = ZeV/h_{eff}$ of Cooper pair for membrane potential is replaced with the sum of difference of cyclotron energies and E. This implies that the variations of membrane potential by oscillations and nerve pulses induced frequency modulation of the frequency of dark photons sent to the MB. This defines a coding of the information carried by nerve pulses do dark photons. Whale's song represents a good analogy for the coding. Besides EEG one would have its counterparts for various organs, organelles and even cell.

2.4.5 Experimental evidence for MB

The team led by Michael Tyszka, associate director of Caltech Brain Imaging Center, has however discovered that the resting state network seems to work normally in people born without corpus callosum [J2] (see `http://tinyurl.com/3gjhtgb`)! As if brain hemispheres were communicating by some other means than neural signalling! This finding challenges not only the views about the origin of brain synchrony as being created by neural circuits but also the models of autism and schizophrenia explaining them in terms of impaired communications between hemispheres.

The MB of entire brain controls it and could naturally do this via the intermediate control of brain hemispheres forcing them to operate in the same rhythm. Brain synchrony and resting network would not be produced by resonant neuro-circuits as usually believed but by the spatiotemporal coherence of the EEG radiation from the MB of entire brain forcing brain hemisphere MBs to oscillate in the same rhythm and in turning synchronizing the brain hemispheres [K21]. This would be like forcing soldiers to march in the same pace and brain hemispheres could cooperate without any neural communication between hemispheres. The communication between hemispheres would be needed for more refined collaboration involving "discussion" between hemispheres: hemispheres of a person without corpus callosum would be like soldiers obeying blindly the orders. This might be also an essential element of autism and schizophrenia.

2.5 ZEO and generalization of quantum measurement theory to a theory of consciousness

TGD inspired theory of consciousness can be seen as a generalization of the quantum measurement theory by bringing observer as self. The basic vision is that quantum measurement theory must be generalized so that observer ceases to be an outsider and is described by the quantum physics. ZEO plays a key role in this generalization and makes highly non-trivial predictions. Raising quantum measurement to a universal physical phenomenon requires the identification of the density matrix of subsystem as a universal observable and introduction of Negentropy Maximization Principle (NMP) [K10] as the fundamental variational principle of consciousness.

2.5.1 ZEO

One must generalize ontology in order to solve the contradiction between deterministic time evolution and the evolution by state function reductions. This requires understanding the notion of subjective time and its relationship to the geometric time. The new ontology must allow to see selves as something unchanged in some aspects and continually changing in some other aspects. Also the experience about the flow of subjective time must be explained.

1. In TGD framework the answer is Zero Energy Ontology (ZEO) [K10]. The concept of quantum state is generalized. States are now analogs for physical events characterized by initial and final quantum state that is pairs of positive and negative energy states. The conserved quantum numbers of the members are opposite so that zero energy states can be created from vacuum. This is a radical generalization of the physicalist world of view but entirely consistent with conservation laws: there is no need to give laws of physics in order to have free will. Positive and negative energy parts of the zero energy states can be assigned to

opposite light-like boundaries of causal diamonds (CDs), which are intersections of future and past directed light-cones multiplied by CP_2. CDs form a fractal scale hierarchy. They can be seen as imbedding space correlates for the 4-D perceptive fields of selves.

2. Causal diamond (CD) is a central notion in ZEO and serves as imbedding space correlate for self. State function reduction can occur to either boundary of CD ("upper" or "lower"). Self can be seen as a generalized Zeno effect - a sequence of state function reductions to either boundary of CD. These two kinds of selves can be said to be time reversals of each other. The period of non-boiling pot corresponds to the passive boundary of CD not changing in the reductions: also the parts of zero energy states at this boundary remain unaffected. The opposite - active - boundary is shifted towards future reduction by reduction and states at it are changed. The shifting the geometric future gives rise to the experienced time flow. This is the analog of unitary time evolution.

2.5.2 NMP as variational principle of consciousness

One must generalize standard quantum measurement theory to a theory of consciousness. The notions of NMP, entanglement negentropy and negentropic entanglement are the key notions.

1. Negentropy Maximization Principle (NMP) [K10] is the variational principle of consciousness in TGD framework reducing to quantum measurement theory in Zero Energy Ontology assuming adelic physics. Negentropy Maximization Principle or something akin to it should be consistent with the standard rules of quantum measurement theory and possibly generalize them. In particular, NMP should tell which observables are measured in given entangled situation. The density matrix defined by the entanglement is the unique candidate for the universal observable. All systems could be said to give rise to quantum measurements. NMP must decide how long the self "lives": self lives as long as repeated state function reductions at the same boundary give the maximal negentropy gain.

2. One must have a mathematical definition of negentropy [K10]. When negentropic entanglement (NE) is possible and what is the measure for the negentropy? Shannon entropy is the natural starting point and p-adic generalization of Shannon entropy by replacing the logarithms of probabilities with the logarithms of their p-adic norms might fit the bill. It is well defined for algebraic entanglement probabilities belonging to the algebraic extension of rationals defining also the extensions of varius various p-adic number fields) [L2].

   Adelicity holds true in the sense that the sum of real and p-adic information measures (finite number of primes contribute) over all primes vanishes for rational entanglement probabilities. This is not the case for the algebraic extensions of adeles induced by those of rationals [L2].

   It is not quite clear whether NMP applies to the sum of p-adic entropies or to the sum of real and p-adic entropies providing alternative definitions of information. Both options conform with the fact that large entropy seems to be prerequisite for life as proposed Jeremy England [I3] [K27] [L1].

3. Negentropic entanglement (NE) is a further key notion and entanglement negentropy identified as number theoretic entanglement entropy, which can be negative. NE can only increase in state function reductions and this brings in evolution forced by NMP.

In the formulation of NMP in terms of maximal negentropy gain one considers divisions of the system into subsystem and complement and finds the pair for which the reduction of entanglement would give maximum reduction of entropy. If the system is irreducible this kind of pair characterized by entropic entanglement cannot be found. The eigenstates of density matrix for negentropically entangled subsystems are in 1-1 correspondence. An interesting question is whether associations in the sense of neuro science corresponds to NE between the states of associated systems.

State function reduction cascade is a key notion. State function reduction sequences is a top down cascade propagating downwards to smaller system sized. First the reduction in CD scale occurs. The resulting two subsystems decompose to to two parts and so on untile decomposition is not possible anymore because it would not generate negentropy.

There is an obvious analogy with the Integrate Information Theory (IIT) of Tononi and Koch. The quantity Φ postulated by Tononi and Koch [J4] resembles negentropy in TGD [L6]. The basic objection against IIT is that the notion of conscious information is circular being based on entropy as fundamental notion. Information is defined as reduction of entropy when conscious entity learns what the state of system is. The notion of conscious information cannot involve this kind of dependence. In TGD framework negentropy for entanglement does not involve this kind of assumption since conscious information represents abstraction or rule with the superposed state pairs (a_i, b_i) representing the instances of a rule (A, B) and A and B representing concepts.

2.5.3 The notion of self

Self is identified as a generalized Zeno effect and corresponds to a sequence of state function reductions to a fixed (passive) boundary of CD remaining unaffected in the sequence of reductions: also the members of state pairs defining zero energy states at it are unaffected. Active boundary drifts farther away state function reduction by state function reduction and the state at it also changes. The analogy of unitary time evolution is in question and the experienced time corresponds to the increase of the temporal distance between the tips of CD.

1. One possibility is that sensory input and mental images ("Maya") generated by it can be assigned with the active boundary of CD. A more elegant assumption suggested by quantum measurement theory is that the passive boundaries for sub-CDs give rise to mental images as outcomes of repeated quantum measurements. The unchanging part of self ("Self") is associated with the passive boundary. It corresponds to negentropically entangled subsystem having no entanglement with environment. In ordinary ontology it would not be possible keep self un-entangled from the environment.

2. State function reductions occur at either boundary of CD as long as they produce maximal negentropy gain. If the reduction at opposite boundary produces larger negentropy gain, it occurs. Self dies and re-incarnates as time reversed self. During repeated state function reductions at same boundary the part of state at that boundary and boundary itself remains unaffected (this corresponds to unchanging part of self) whereas the state at opposite boundary changes and the bounary also shifts outwards. The increase of the distance between the tips of CD corresponds to the flow of geometric time and gives precise meaning for the ageing of self. For instance, sensory-motor rhythm could correspond to the sequence of repeated state function reductions to opposite boundaries of CD. Motor action would correspond to reversed arrow of time: this conforms with the finding of Libet that conscious decision is preceded by neural activity used to argue that there is no free will.

   Time reversed self evolves as reductions shifting the opposite boundary of CD to opposite time direction so that the size of CD continues to increase and defines a measure for the duration of the entire sequence of re-incarnations. This implies quantum physical realization for the idea about transmigration of souls!

3. The totally unexpected prediction is therefore that life is not just a brief spark in cosmic darkness. This particular life is only one in a sequence of lives: the next life will be lived at the opposite boundary of personal CD to opposite direction of geometric time. The negentropy gained during his life will be usable as possibly unconscious knowledge during the next life. What our next life will be depends how much we gather negentropic resources for the next life.

4. Self can also make moral choices since NMP in its weak form leaves us freedom to make also bad choices or especially negentropic choices (for details see [K10]). Possible are also choices, which do not yield optimal negentropy gain. By allowing sin NMP also makes possible really big negentropy gains: NMP would be like venture capitalist in this sense. In statistical sense there is however an evolution as increase of the negentropic sources of the Universe. Crime is part of being alive: living creatures are fighting desperately for NE and a clever but inmoral manner to gain it is to eat other living beings.

5. One big news is that selves form a hierarchy (CDs within CDs) and sub-selves are identified as mental images. In TGD framework it is also possible for sub-selves of two unentangled

selves to entangle negentropically. This corresponds to sharing of mental images and means that our conscious experience is not completely private. The pool of shared mental images might in fact make possible communication and social structures. Sharing of mental images is possible only in many-sheeted space-time forcing to generalize the standard view about subsystem.

2.5.4   Is metabolic energy needed to transfer negentropic entanglement?

If NMP is the variational principle conscousness negentropic entanglement (NE) is necessary for survival and living systems are fighting for NE. At deep level metabolic energy should closely relate to negentropic entanglement (NE) and thus information. Identification of these two is however not possible. Conscious information would be the basic currency and the transfer of metabolic energy and metabolites would make possible transfer of NE. It could be transfer of systems consisting of negentropically entangled parts or it could be transfer of NE with larger system, even Earth. NMP would force the systems to fight for NE and this would lead to the fight for metabolic resources. The transfer of entanglement (NE) is basic mechanism in quantum computation and would mean in biology stealing of NE, the fundamental crime! Metabolism in TGD framework is discussed in detail in [K8, L3].

I have considered three possible three possible identifications of NE.

1. NE could be small scale entanglement - say between parts of molecules. This option is not favored by the needed large values of h_{gr} and thus of mass M.

2. NE could be between nutrient and larger structure - say Earth, Sun, or some other large enough structure to give a value of $h_{gr} = GMm/v_0$ guaranteeing that dark cyclotron energies (no dependence on mass m) in the range of bio-photon energies (visible and UV) and guarantee that EEG frequencies correspond to these energies. This option discussed in [K27]. Nutrients would be carriers of both metabolic energy and NE. This option does not conform with the fact that even electrons can provide metabolic energy and in TGD framework therefore also NE for some bacteria (see http://tinyurl.com/o8xqh6g). This suggests that nutrients carry only the energy needed to transfer NE.

3. NE could be also between a larger structure and phosphate molecule added to ADP using metabolic energy. This option is the simplest one and would predict that phosphates are in unique role as standard entanglers to mass M. Any source of metabolic energy is in principle possible since metabolic energy is only needed to transfer the flux tube connecting phosphate to mass M to ADP so that ATP is obtained. The flux tube would represent the "high energy phosphate bond". ATP in turn attaches the flux tube to biomolecule, which becomes negentropically entangled. Metabolism would be make the transfer of NE possible. Metabolites would not contain information but it would be assignable to the flux tube between phosphate and mass M. Magnetic Mother Gaia would have very concrete meaning.

A good candidate for the larger structure could be a spherical layer at the distance of Moon from Earth would give correct value for $h_{eff} = h_{gr}$ [K27, L3].

3   Questions related to the notion of self and time

The notion of self and the relation between subjective and geometric time involves unclear aspects. In the following I try to articulate the problematic issues as clearly as possible. The precise nature of the hierarchy of causal diamonds (CDs) as correlate of self hierarchy should be characterized. The basic prediction that sub-selves have also time reversed varians should be interpreted and one can ask whether sensory-motor dichotomy is a sensible interpretation. One can of course wonder whether sub-selves are always experienced as mental images and whether after images really represent re-incarnations of sub-selves. One can ask whether the rather dramatic prediction of re-incarnations can be transformed to an experimentally testable prediction. If one takes seriously the notion of self hierarchy and identifies the EEG correlates of self in a manner proposed by Fingelkurts brothers [J1], this kind of prediction is possible.

3.1 Hierarchies of causal diamonds and space-time surfaces as geometric correlates for self hierarchy

Causal diamonds (CDs) identifiable as Cartesian products of intersections of future and past directed light-ones with CP_2, which plays no active role in the definition. I have not been able to nail down the precise definition for the hierarchy of causal diamonds. Self hierarchy demands that CDs serving as imbedding space correlates for selves have sub-CDs identifiable as mental images of self. The basic question is whether CDs can also overlap. If so then finite unions of CDs could be allowed.

Selves as conscious entities are assumed to have space-time surfaces within CDs as space-time correlates. These CDs are dynamical: the other boundary remains unaffected during sequence of repeated state function reductions as also the states at it. Second boundary shifts so that that the distance between the tips of CD increases and defines the experienced flow of time. These space-time surfaces form also a hierarchy.

Given space-time sheet has both Minkowskian and Euclidian regions - wormhole contacts - separated by wormhole throats at which the signature of the induced metric changes. Minkowskian space-time sheets are connected by Euclidian wormhole contacts. If the magnetic flux through wormhole contact is monopole flux, wormhole contact connecting two Minkowskian space-time sheets has interpretation as a building brick of elementary particles. Minkowskian space-time sheets at different levels of hierarchy are disjoint and separated by Euclidian wormhole contacts. This forces to modify the notion of quantum mechanical subsystem as a tensor factor of the state space.

What is new that two Minkowskian space-time sheets glued to larger disjoint Minkowskian space-time sheets can be connected by magnetic flux tube serving as a correlate for (negentropic) entanglement just as wormholes in GRT picture serve as correlates for entanglement. Two unentangled systems can therefore have subsystems, which are entangled and correspond to two space-time sheets connected by magnetic flux tubes! This is possible only in many-sheeted space-time and the hypothesis has been that two selves, which have no entanglement at their own level of self-hierarchy, can have entangled subselves and that this negentropic entanglement means sharing of mental images giving rise to a kind of stereo consciousness. The fusion of right and left visual fields would be example of stereo consciousness.

What does this situation mean at the level of CDs? It would seem that the CDs associated with selves sharing mental images overlap and that the space-time surfaces assignable to fused mental images/subselves belong to the intersection of CDs. Thus it seems that one must allow unions of also overlapping CDs.

3.2 Are time reversed sub-selves always experienced as mental images?

In the proposed vision about self as generalized Zeno effect self dies as the first state function reduction to the opposite boundary of CD takes place. This implies the re-incarnation of self with the property that the geometric time flows in opposite direction since the opposite boundary of CD shifts such that the temporal distance between it and the opposite static boundary increases in repeated state function reductions leaving the states at static boundary un-affected.

Subselves correspond to mental images. The question is whether self really experiences the time reversed sub-selves as a mental image and if this is the case, what can one conclude about this. For sub-sub...-selves this problem is not acute if sub-sub-selves are experienced as kind of statistical averages. One possible interpretation for self and its time reversal is in terms of sensory input and motor action. I have indeed proposed that motor action is essentially sensory experience in reversed time direction and Libet's discovery that conscious decision is preceded by neural activity (with respect to geometric time) provides a support for this interpretation. The time reversal of sensory mental image would represent motor action and at the level next below our level of hierarchy would be directly experienced as volitional act.

I have considered also other interpretations. One is suggested by visual illusion in which the picture of dancer is experienced to make either right or left pirouette. The direction of rotation would distinguish between mental images and its time reversal. It however seems that the sensory-motor dichotomy provides the most plausible and economical interpretation.

One can also wonder what happens, when mental the image is associated with a boundary of

CD_1, which overlaps with CD in such a manner that the opposite boundary is outside of CD. Does self experience the mental image associated with CD but not its time reversal?

3.3   Are after images reincarnations of mental images?

After images appear periodically as one can easily find by looking and lamp and closing eyes. They also change colors. Could these after images be interpreted as re-incarnations? This sounds attractive but one must be very careful. A sub-self, which dies and transforms to its time reversal reincarnates eventually as sub-self with original arrow of time. It should re-incarnate at time which is very near to the time when it died since the boundary of the static CD has not shifted and only single shift occurs at the re-incarnation. With respect to geometric time the new mental image should thus begin at the moment when previous subself died. After images are not experience to begin immediately which suggests that they are not re-incarnations but belong to a 4-D population of sub-selves. Our geometric past is alive and changes all the subjective time. This is not so confusing when one realize that ZEO means that conscious existence is essentially 4-dimensional. Also our memories are dynamical and change all the subjective time. Negative energy signals to geometric past which correspond to time reversed sub-selves indeed affect the geometric past and memory representations. In principle this kind of signalling could be carried out artificially to manipulate geometric past.

What does this picture mean for an observer measuring EEG of subject person? The operational architecture model of brain developed by Fingelkurts brothers (see `http://tinyurl.com/jpszfpy`) [J1] has strong resemblances with self hierarchy of TGD. The model suggests that sub-selves/mental images should have as correlates quasi-stationary segments of EEG having average duration of about .3 seconds in alpha band. The subjective time of the observer should correspond to the geometric time appearing as parameter in EEG and increases as the boundary of CD assignable to observer shifts in repeated reductions. During the time interval that time-reversed mental image lives, this geometric time increases. Does this mean that the re-incarnated sub-self is born in geometric past of observed and the re-incarnation should not be visible in the EEG recording? Or is the entire 3-D EEG recording updated in each repeated reduction so that it is consistent with the geometric past? This would be somewhat analogous for cosmic censorship postulated in General Theory of Relativity? If so, then the finite interval of subjective time for time reversed self would correspond to very short time interval between subsequent quasi-stationary EEG segments! Very strange indeed but possible if one accepts that subjective time and experienced time are not one and same thing and that there is self hierarchy each with its own subjective time and natural geometric time as temporal distance between the tips of corresponding CD.

3.4   Re-incarnation and EEG

It is amusing how fast the attitudes change as ideas evolve and experimental data emerge. Only few years ago I could not say anything definite about reincarnation in the framework of TGD inspired theory of consciousness. Now it has become an unavoidable prediction of zero energy ontology (ZEO), which itself is a "must" in TGD framework.

The prediction related to re-incarnation is however not quite what one might have expected. In death of self a reincarnation as time reversed conscious entity takes place. For time reversed self subjective time evolution corresponds to evolution in a reverse direction of geometric time. The next death/reincarnation after this re-incarnation gives rise to a self for which the arrow of geometric time is the original one.

Can one test this prediction? If one accepts the predicted fractal self hierarchy in which subselves correspond to mental images of self, this is possible. I am too lazy to retype basics about ZEO, CDs, and about how self as generalized Zeno effect emerges and just assume that reader knows the basic concepts or sees to trouble to refresh her knowledge about them.

1. Self hierarchy predicts that also our mental images are conscious entities. Motor-sensory dichotomy naturally corresponds to sub-self and time reversed sub-self. That is sensory mental image and that associated with motor action induced by sensory input. Motor action initiated in the geometric past at the opposite boundary of causal diamond (CD) (this explains Libet's finding that conscious decision is preceded by neural activity in geometric time). Note

that motor action does not proceed from brain to muscles but in reversed time direction from muscles to brain! This conforms with the vision in which magnetic body is intentional agent.

2. To proceed one must identify EEG correlates for the sub-selves (mental images) and their time reversed re-incarnates. Here the work of Fingelkurts brothers (see `http://tinyurl.com/jpszfpy`) working in Finland helps [J1]. They postulate what they call operational architecture of brain (OA) having operations (O) and operational modules (OM) as building bricks. Quasi-stationary EEG segments are assumed to serve as correlates for operations and synchrony of these segments associated with various locations in brain tells that they belong to the same OM.

   Synchrony means spatio-temporal coherence - not only spatial - and is very natural concept in ZEO, where 4-D CDs and space-time surfaces inside them serve as geometric correlates of selves. Synchrony implies that these EEG segments at different spatial locations begin and end at the same time. Between EEG segments there is rapid transition period (RTP) allowing to distinguish segments from each other. Quasi-stationary segments of EEG have average duration is about .3 seconds.

   The translation of this picture to TGD framework is rather straighforward. Operations correspond to sub-selves and OMs to collections of them forming sub-selves of self. CDs (sub-CDs) in turn serve as geometric correlates for selves (sub-selves). The quasi-stationary segments of EEG become correlates for sub-selves/mental images. Operational module corresponds to a self/CD having sub-selves/sub-CDs with synchronous EEG segments. The average duration of mental image would be about .3 seconds.

   Two sub-sequent quasi-stationary segments separated by RTP would correspond to sub-self and its re-incarnation in the original time direction. Note that a very brief period of geometric time defined by the duration of RTP identifiable as the duration of a unitary time evolution between two sub-sequent state function reductions at the same boundary of CD corresponds to a finite duration of experienced time - the lifetime of the time reversed mental image!

   The testable prediction is that the segment corresponding to time-reversed sub-self is located in geometric past and runs in opposite direction of geometric time. This EEG segment should be assignable to motor response accompanying sensory mental image. This is a highly non-trivial prediction testing the new view about time.

3. One can check whether these EEG segments appear as pairs with first member assignable to sensory mental image and second one to motor mental image. Time reversal implies that second law is obeyed in "wrong" time direction for EEG segment assignable to the motor output and this can be tested. Already Fantappie [J3] discovered that both directions of (geometric) time appear in living matter and introduced the notion of syntropy as time reversal of entropy. Spontaneous molecular self-assembly is a basic example of a syntropic process and identifiable as a decay process in reverse direction of geometric time. Phase conjugation is known to occur for phase conjugate laser light and sound. Does a process analogous to self-assembly occur for segments of EEG associated with motor actions: is the motor part of EEG time reversed? To answer this question one needs phase information about EEG besides power spectrum. In principle this information is contained in EEG.

4 Appendix: Details related to NMP

What happens in state function reduction and what NMP really says is still far from being completely clear. The basic condition is that standard measurement theory emerges as a special case and is forced by NMP [K10]. This does not however fix the NMP completely.

4.1 Adelic NMP as the only reasonable option

I have considered two options for NMP.

1. In the original approach to NMP it was assumed that both generic entanglement with real entanglement probabilities and entanglement with algebraic entanglement probabilities are

possible. Real entanglement is entropic and demands standard measurement theory leading to a 1-D eigen-space of the density matrix. Algebraic entanglement can be negentropic in number theoretic sense for some p-adic primes, and in this case state function reduction occurs only if it increases negentropy. It takes place to N-dimensional eigen-space of the density matrix. The basic objection is that real entanglement is transcendental in the generic case reducing to algebraic entanglement only as a special case. Algebraic entanglement is also extremely rare without additional physical assumptions.

2. In the adelic approach entanglement coefficients and therefore also entanglement probabilities are always algebraic numbers from the condition that the notion of p-adic Hilbert space makes sense. Also extensions of rationals defining finite-dimensional extension of p-adic numbers (roots of e can appear in extension) must be allowed. Same entanglement can be seen from both real (sensory) and p-adic perspectives (cognitive). The entanglement is always entropic in the real sector but can be negentropic in some p-adic sectors. It is now clear that the adelic option is the only sensible one.

4.2 Variants of the adelic NMP

The adelic option allows to consider several variants.

1. Negentropy could correspond **a)** to the sum $N = N_R + \sum_p N_p$ of real and various p-adic negentropies or **b)** to the sum $N = \sum N_p$ of only p-adic negentropies. N_p is non-vanishing for a finite number of p-adic primes only as is easy to find. Im both cases $\sum_p N_p$ could be interpreted as negentropy assignable to cognition. N_R might have interpretation as a measure of ignorance of one of the entangled systems about the state of other.

2. NMP implies that state function reduction (measurement of density matrix leading to its eigen-space) occurs if negentropy **1)** is not reduced or **2)** increases. This means that negentropic entanglement is stable against NMP.

Can one select between these options?

1. For option **a)** NMP becomes trivial for rational entanglement probabilities as is easy to find: one has $N = N_R + \sum_p N_p = 0$. NMP does not force state function reduction to occur but it could occur and imply ordinary state function reduction as a special case for option **1)** (when eigen-spaces are 1-dimensional). Therefore one would have option **1a)**.

2. If option **1a)** is unrealistic, only the options **1b)** and **2b)** with $N = \sum_p N_p$ are left. For option **2b)** state function necessarily occurs for $N = \sum_p N_p < 0$ but not for $N = 0$ - not even in rational case. For option **2b)** the state function reduction could occur also for $N = 0$. However, since N_p is proportional to $log(p)$ and the numbers $log(p)$ are algebraically independent, $N = 0$ is not actually possible so that **1b)** and **2b)** are equivalent. Therefore NMP states that $N = \sum_p N_p$ must increase for $N < 0$: this forces state function reduction to an eigen-space of density matrix.

   But is it really possible to have $\sum N_p < 0$ making possible ordinary state function reduction? For rational entanglement probabilities this is not possible by $S_R = \sum_p N_p$ and one might even speculate that for algebraic extensions one as $\sum_p N_p \geq S_R$. Mathematician could probably check the situation. $\sum_p N_p \geq S_R$ holds true, entanglement is stable against NMP and ordinary state function reduction is not possible. This would leave only the option **1a)** and negentropic entanglement with $N > 0$ would be stable also now. $N = 0$ entanglement (possibly rational always) would allow ordinary state function reduction.

This leaves still two options. Negentropy gain is **A)** maximal or **B)** non-negative but not necessarily maximal: I have considered the latter option earlier. For option **1a)** reduction is possible only for $N = 0$ and in this case negentropy gain is zero for all possible eigen-spaces of density matrix and maximality condition does not say anything.

1. For option **1a)** reduction is possible only for $N = 0$ and in this case negentropy gain is zero for all possible eigen-spaces of density matrix and **A)** and **B)** are equivalent. One obtains ordinary state function reductions.

2. Consider next the equivalent options **1b)** and **2b)** making sense if $\sum_p N_p < 0$ is possible. For option **A)** negentropy gain is maximal and the reduction occurs to an eigen-space with maximum dimension $N = N_{max}$. There can be several eigen-spaces with the same maximal dimension. As a special case one obtains ordinary state function reduction. The reduction probability is same as in standard quantum measurement theory.

   For option **B)** the reduction could occur also to any N-dimensional eigen-space or its subspace. The idea would be that NMP allows something analogous to a choice between good and evil: the negentropy gain could in this case be also smaller than the maximal one corresponding to $log(N_{max})$. This would conform with the intuition that we do not seem to live in best possible world. On the other hand, negentropy transfer between systems could be also seen as stealing in some situations and metabolism identified as negentropy transfer could be seen as the fundamental "crime" to which all other forms of reduce.

To sum up, the only option which guarantees without additional assumptions (possibility of $\sum N_p < 0$) ordinary state function reduction and stability of negentropic entanglement is option **1a)**.

4.3   Could quantum measurement involve also adelic localization?

For option **B)** there is still one possible refinement involved. p-Adic mass calculations lead to the conclusion that elementary particles are characterized by p-adic primes and that p-adic length scale hypothesis $p \simeq 2^k$ holds true: a more general form of hypothesis allows also to consider primes near powers q^n of some small prime such as $q = 3$.

Could state function reduction imply also adelic/cognitive localization in the sense that the negentropy is nonzero and positive for only single p-adic prime in the final state? The reduction would occur to p^k-dimensional eigen-space with p^k dividing N: any divisor would be allowed. Note that Hilbert spaces with prime dimension are prime with respect to the decomposition to tensor product so that reduction would select prime power factor of the eigen-space. This would in general reduce negentropy gain.

The information theoretic meaning would be that prime-dimensional Hilbert spaces are stable against decomposition to tensor products so that the notion of entanglement would not make sense and therefore also the change of the state by the reduction of entanglement would be impossible. I have considered the possibility that prime-dimensional state spaces could make possible stable storage of quantum information [L7]. The prime-dimensional state when imbedded to higher-dimensional space - say space representing N qubits - could be interpreted as an entangled state and would be unstable with respect to state function reduction.

This hypothesis would provide considerable insights to the origin of p-adic length scale hypothesis. To get a contact with physics consider electron as an example.

1. In the case of electron one would have $p = M_{127} = 2^{127} - 1 \sim 10^{38}$. Could electron decompose to two entangled subsystems with density matrix equal to $p \times p$ identity matrix? The dimension of eigen-space would be huge and electron would carry negentropy of 127 bits: also p-adic mass calculations combined with a generalization of Hawking-Bekenstein formula suggest that electron carries entropy of 127 bits: in adelic picture these views are mutually consistent.

   The recent view indeed is that all elementary particles correspond to closed monopole magnetic flux tubes with a shape of highly flattened rectangles with short sides identifiable as extremely short wormhole contacts (CP_2 size) and long sides with length of order Compton length. Magnetic monopole flux traverses along first space-time sheet between wormhole throats, goes through wormhole contact, and returns back along second space-time sheet. Many-fermion states are assigned with the throats and are located at the ends of strings traversing along the flux tubes.

   Could this structure be in the case of electron a 127-sheeted structure such that the two wormhole contacts carry a superposition of pairs formed by states containing $n \in \{1, ..., 127\}$ fermions at second contact and n antifermions with opposite charges at second contact so that $2^{127} - 1$ dimensional eigen-space would be obtained for a fermion with given spin and isospin. For instance, $n = 0$ state with no fermion-pairs could be excluded.

2. Right-handed neutrinos and antineutrinos are candidates for the generators of $N = 2$ supersymmetry in TGD framework. It however seems that SUSY is not manifested at LHC energies, and one can wonder whether right-handed neutrinos might be realized in some other manner. Also the mathematics involved remains still somewhat unclear. For right-handed neutrinos, which are not covariantly constant transformation to left-handed neutrinos is possible and leads to the mixing and massivation of neutrinos. For covariantly constant right handed neutrino spinors this does not happen but they can included into the spectrum only if they have non-vanishing norm.

   This might be the case with a proper definition of norm with $\overline{\Psi} p^k \gamma_k \Psi$ replaced by $\overline{\Psi} n^k \gamma_k \Psi$: here n^k defines normal of the light-like boundary of CD. Covariantly constant right-handed neutrinos have neither electro-weak, color, nor gravitational interactions so that their negentropic entanglement would be highly stable. Unfortunately, the situation is still unclear and this leaves open the idea that right-handed neutrinos might play fundamental role in cognition and negentropy storage. Amusingly, I proposed the notion of cognitive neutrino long time ago but based on arguments which turned out to be wrong.

   One could indeed consider the possibility that each sheet of the 127-sheeted structure contains at most one ν_R at the neutrino end of the flux tube accompanied by $\overline{\nu}_R$ at anti-neutrino end. One would have a superposition $p = 2^{127} - 1$ states formed by many-neutrino states and their CP conjugates at opposite "ends" of the flux tube. It is also possible that $\overline{\nu}_R - \nu_R$ pairs are spin singlets so that one has superposition over many-particle states formed from these analogous to coherent state.

   This is not the only possibility. The proposal for how the finite range of weak interactions emerges suggests a possible realization for how the number of states in superposition reduces from 2^{127} to $2^{127} - 1$. The left weak isospin of fermion at wormhole throat is compensated by the opposite weak isospin of neutrino/antineutrino plus $\overline{\nu}_R/\nu_R$ or cancelling its fermion number: therefore weak charges vanish in scales longer than the flux tube length of order of the Compton length. The physical picture is that massless weak boson exchanges occur inside the flux tube which therefore defines the range of weak interactions. Same mechanism could be at work for both wormhole throat pairs and therefore also for fermion and anti-fermion at opposite wormhole throats defining building bricks of bosons. The state $\overline{\nu}_R - \nu_R$ would be excluded from the superposition of pairs of many-particle states and superposition would contain $p = 2^{127} - 1$ states.

3. Could this relate to $h_{eff} = n \times h$ hypothesis? It has been assumed that $h_{eff}/h = n$ corresponds to space-time surfaces representable as n-fold singular coverings, whose sheets co-incide at the 3-D ends of the space-time surface at opposite boundaries of CD. There is of course no need to assume that the covering considered above corresponds to singular covering and the vision that only particles with same value of n appear in same vertices suggests that $n = 1$ holds true for visible matter.

   One can still ask whether the elementary particle characterized by $p \simeq 2^k$ could corresponds to k-fold singular covering and to $h_{eff}/h = k$? This would require that phase transitions changing the value of k take place at the lines of scattering diagrams to guarantee that all particles have the same value of k in given vertex. These phase transitions are a key element of TGD inspired quantum biology.

   In the first order of perturbation theory this would not mean any deviations from standard quantum theory for given k and the general vision that loop corrections from the functional integration over WCW vanish suggests that there are no effects in perturbation theory for given k. p-Adic coupling constant evolution would be discrete and make itself visible by the phase transitions at the lines of scattering diagrams (not identifiable as Feynman diagrams). The different values of $h_{eff}/h = n$ be also seen through non-perturbative effects assignable to the bound states and also via the proportionality of p-adic mass scales to $p^{-1/2} \simeq 2^{-k/2}$ predicted by p-adic mass calculations.

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