

# Life and Death and Consciousness

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### Abstract

Life and death 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.

## 1 Introduction

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

To begin with, it is good to represent the basic ideas of TGD inspired theory of consciousness.

1. Living system bring in mind elementary particle like coherent unit. This suggests that macroscopic quantum coherence is an essential aspect of life and consciousness. Non-predictability, which does not mean randomness, is second essential aspect of living systems and we experience it as free will. The description of this aspect however leads to problems in the materialistic approach originally inspired by physicalism and the idea that physicist can predict everything given the initial values.

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

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

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

State function reduction occurs in cascade like matter proceeding to shorter scales and from system to the sub-system if system decomposes to a product of unentangled sub-systems in

the reduction. The outcome at passive boundary of CD is a set of inherently negentropically entangled subsystems having no entanglement between themselves. These systems can be seen as sub-selves of self experiencing these subsystems as mental images.

For given CD state function reduction occurs repeatedly to what I call passive (light-like) boundary of CD and leaves members of state pairs at it invariant. Also the passive boundary itself remains unchanged. The members of state pairs at opposite, *active* boundary of CD experiences the analog of unitary time evolution followed by a reduction passive boundary: this occurs repeatedly as in Zeno effect. Active boundary also drifts further away from the passive boundary whereas nothing happens at the passive boundary.

3. The basic variational principle of consciousness theory identified as quantum measurement theory is Negentropy Maximization Principle (NMP), which demands that entanglement negentropy associated with entanglement is not reduced. In real number based theory entanglement negentropy would be non-positive and genuine information would not be possible. The requirement that the theory describes also cognition, however leads to the generalization of real number based physics to what I call adelic physics. p-Adic number fields allow only algebraic number valued entanglement and assign to it negentropy, which can be positive. One has negentropic entanglement (NE) NMP allows several variants but the mildest form requiring that NE is not reduced seems to be the realistic one.
4. Self as conscious entity can be regarded as generalized Zeno effect identified as a sequence of state function reductions to the same (passive) boundary of CD not changing the part of state at it. Eventually the first reduction to opposite boundary takes place and self dies and re-incarnates as time reversed self at the opposite boundary of CD - obviously a highly non-trivial prediction of ZEO. The flow of subjective time can be interpreted as the increase of temporal distance between the tips of CD.

To help the reader to build a context it helps to summarize what TGD inspired consciousness is and what it is not. In particular, I try to make explicit those key assumptions of TGD, which are in conflict with the existing belief system. The basic assumptions of TGD as a theory can be certainly be blamed of being speculative but the basic predictions of TGD follow from these assumes and are not speculations in the framework of TGD.

1. The approach is that of physicist but not of physicalist. TGD tries to extend physics as a theory of regularities of conscious experience to a theory of consciousness. TGD does not try to reduce consciousness to a property of some system as physicalist would do, and therefore also avoids the hard problem plaguing monistic and dualistic approaches. For physicist the idea that consciousness would be assignable only to brain, human brain, or even male brain is extremely non-feasible and bring in mind the view about Earth as the center of Universe. One could blame TGD for panpsychism. This kind of view is adopted also by Tononi and Koch in IIT approach [J7] (for TGD based criticism of IIT see [K39]). Self hierarchy is the key prediction challenging the standard neuroscience based view, and combined with the identification of sub-selves as mental images gives rise to a rather powerful and predictive approach. Hence in the following life and death are seen as universal notions expected to make sense in much wider framework than biological systems.
2. The experience from discussions is that the relationship between geometric and subjective times is difficult notion. In particular, understanding of how subjective time as a sequence of state function reductions (to the same boundary of causal diamond (CD)) corresponds to clock time has been one of the main challenges of TGD inspired theory of consciousness during the last two decades.

Existence is often thought to be just single type of existence but now conscious existence is assigned with state function reductions, something between two quantum worlds (objective existences in the sense of physics), which represent mathematical existence and are zombies. For a non-mathematician this notion is not easy to grasp. It is however extremely economical ontologically since it allows to get rid of the assumption that there is something “behind” the quantum worlds as mathematical realities. Conscious existence means continual re-creation of the quantum universe and together with NMP it implies evolution.

3. In ZEO physical states are replaced with something analogous to events, pairs of positive and negative energy states with opposite total quantum numbers. This is also new and difficult to comprehend. For people thinking in terms eastern philosophies ZEO might be easier notion but for a “westener” the idea that there are only observations of events and that physical world as something absolute and given is only a narrative, looks weird. ZEO is of course consistent with the laws of physics, in particular conservation laws, but implies their scale dependence accepted already in quantum field theories.

ZEO can be also defended by its extreme flexibility allowing to avoid the usual problems causing grey hairs for theoretician. In classical physics initial values fix the entire time evolution and only single solution of field equations is realized: in strict sense theories are untestable and obsolete. One can also wonder what metaphysical principle selects the initial values. Also in quantum physics conservation laws restrict strongly the set of allowed time evolutions and the idea about theory for entire Universe becomes somewhat obsolete.

4. The assumption about fixed arrow of time is not usually questioned. ZEO forces to give up this belief, and predicts the notions of time-reversed self and re-incarnation. These can be argued to be very weird predictions, and they might be of course wrong. This can be tested. TGD inspired theory of consciousness is indeed a theory and good theories usually predict something not consistent with naive everyday intuitions. Libet’s strange findings about active aspect of consciousness [J1] could be understood if the arrow of time changes in motor actions.
5. The notion of macroscopic quantum coherence is central and represents new physics relevant for quantum biology. The new quantum biology comes from several sources: the hierarchy of Planck constants  $h_{eff} = n \times h$  making possible macroscopic quantum coherence for large enough values of  $n$  assignable to dark matter as phases of ordinary matter so that dark matter would become key player in the drama of living matter.

Second new notion is what I call many-sheeted space-time. In field theory and general relativity limit of TGD the effects of many-sheeted space-time show as small anomalies [K31] but in biology this notion becomes central.

The third new notion is that of magnetic body (MB) deriving from the new view about classical fields implied by the postulate that space-times are 4-D surfaces in  $M^4 \times CP_2$ . Systems have field identity, field body, in particular magnetic body serving as intentional agent receiving sensory data from biological body and controlling it by using analog of EEG realized in terms of dark photons. Also this notion raises strong emotional reactions. I can only defend TGD by telling that this is what TGD naturally predicts, and I have done quite impressive work in finding anomalies where magnetic body raises its head.

One can compress the general vision to following mnemonics: ZEO, CD, NMP, NE, and Zeno effect. In the sequel I describe TGD more precisely. The article [L5] gives a more detailed view about TGD, TGD inspired theory of consciousness, and TGD inspired quantum biology. Appendix of this article contains a summary of TGD inspired quantum biology.

## 2 TGD

General theory of relativity (GRT) plagued by the problem that the notions of energy and momentum are not well-defined for curved space-time. 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 [K22, K38] 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 [K32].

## 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, K9].

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 [K9] and coded by Kähler function identified in terms of Kähler action for a preferred extremal: this gives direct connection with classical physics since induced Kähler form define classical U(1) field, for the U(1) factor of electroweak gauge group assignable with weak hyper-charge. twistor lift implies the presence of a volume term identifiable in terms of cosmological constant. It would bring also Planck length into the theory as the radius of twistor sphere [K22].

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 [K25, K35]. Spinor structure requires identification of gamma matrices anticommuting to WCW metric and if the metric is Kähler metric, the anti-commutation relations are completely analogous to those of fermionic oscillator operators and one can indeed express the gamma matrices as linear superpositions of fermionic oscillator operators at space-time surface. Second quantization at space-time level is a purely classical notion at WCW level and becomes geometrized in WCW context.
3. ZEO (Zero Energy Ontology) is an essential element of theory. Usually one assumes that in classical physics generalized positions and their time derivatives (generalized velocities) giving at given moment of time in 3-D snapshot of space-time dictated the time evolution. This has generalization to Schrödinger equation. One has initial value problem.

This Newtonian view does not work in TGD: boundary value problem provides a more natural formulation. The generalized positions at two moments of time are more natural data and

the dynamical evolution connecting the two 3-D snapshots defines by holography more or less equivalent view about the situation. These pairs are analogous to classical events and one can construct as their quantum superpositions what I call zero energy states and quantum jumps are quantum events occurring between these classical events.

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

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

In order to avoid confusion it must be made clear that since WCW spinor fields and zero energy states are formally purely classical entities. Only the state function reduction replacing zero energy state (classical event) would be genuinely quantal element of the theory. The Wheelerism for this would be “Quantization without quantization”.

4. The recent formulation for the notion of preferred extremal relies on strong form of General Coordinate Invariance (SGCI). SGCI states that two very different kinds of 3-surfaces can be identified as fundamental objects. Either the light-like 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 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 deduced 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 [K21, K36].

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 contributing to the line element of WCW would be in question. The natural candidate for this infinite-dimensional isometry group is symplectic 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  $\alpha_K$  appearing in Kähler action is analogous to temperature. In its original form [K9] QC stated that this coupling strength is analogous to critical temperature and therefore has discrete spectrum. This idea makes sense even if Kähler action is generalized to contain additional terms: all coupling constants would be analogous to critical thermodynamical parameters.

Indeed, the twistor lift of TGD [K22, K38] 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  $\Lambda$  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 [K33] is behind all of them. Behind QC are in turn number theoretic vision and strong forms of general coordinate invariance (GCI) and holography (SGCI and SH).

1. The hierarchy of Planck constants labelling a hierarchy of dark phases of ordinary matter corresponds to a hierarchy of quantum criticalities assignable to a fractal hierarchy of sub-algebras of the super-symplectic algebra assignable to the boundary of CD with points replaced with  $CP_2$ . The conformal weights are  $n$ -ples of those for the entire algebra. These algebras are isomorphic to the full algebra and act as gauge conformal algebras so that a broken super-conformal invariance is in question. For  $n > 1$  the hierarchy levels are interpreted in terms of dark matter. What is highly non-trivial that the conformal weights itself need not be integers or half integers as usually. The generators of algebra could have conformal weights which are proportional to zeros of zeta and poles of zeta so that the number of generating elements (finite for ordinary super-conformal algebras) would be infinite [K6]. Physical states would however have real conformal weights which would be half integers (conformal confinement).

Could  $n$  correspond to the value of effective Planck constant  $h_{eff}/h = n$ ? Why  $n$  should correspond to the number of sheet for the space-time surface as covering space? It has become clear that there is no obvious reason why for this. Number theoretic vision provides much more feasible answer. Adelic hierarchy corresponds to a hierarchy of extensions of rationals and the Galois groups of extensions act as symmetry groups permuting number theoretic discretizations of space-time surface and combining them to single  $n$ -fold covering space, where  $n$  divides the the order of Galois group of the extension. These groups also act as automorphism groups of the dynamical Kac-Moody groups assignable to the hierarchy of sub-algebras of the super-symplectic algebra.

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

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

physics and also the experimental testing requires 4-D space-time as also the notion of 8-D 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 [K36].  
p-Adic sectors serve as correlates for cognition and imagination. One can indeed have string world sheets and partonic 2-surfaces, which can be algebraically continued to preferred extremals in p-adic sectors by utilizing p-adic pseudo constants providing huge flexibility. If this is not possible in the real sector, a fragment of imagination is in question! It can also happen that only part of real space-time surface can be generated: this might relate to the fact that imaginations can be seen as partially realized motor actions and sensory perceptions.
4. The assignment of the hierarchy of Planck constant to a hierarchies of inclusions of hyperfinite factors of type  $II_1$  is natural. Also the interpretation in terms of finite measurement resolution makes sense. As  $n$  increases the sub-algebra acting as conformal gauge symmetries is reduced so that some gauge degrees of freedom are transformed to physical ones. The transitions increasing  $n$  occur spontaneously since criticality is reduced. A good metaphor for TGD Universe is as a hill at the top of a hill at the top.... In biology this interpretation is especially interesting since living systems can be seen as systems doing their best to stay at criticality using metabolic energy feed as a tool to achieve this. Ironically, the increase of  $\hbar$  would mean increase of measurement resolution and evolution!
5. If twistor lift is not performed, the only coupling constant of the theory is Kähler coupling constant  $\alpha_K = g_K^2/4\pi\hbar$ , which appears in the definition of the Kähler function  $K$  characterizing the geometry of WCW. In the most general case  $\alpha_K$  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 [K6]. 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 boundaries 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  $\alpha_K$  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  $\alpha_K$  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 [K22].

In ZEO preferred extremals are space-time surfaces connecting two space-like 3-surfaces at the ends of space-time surfaces at boundaries of CD. A natural looking condition is that the symplectic

Noether charges associated with a sub-algebra of symplectic algebra with conformal weights  $n$ -multiples of the weights of the entire algebra vanish for preferred extremals. These conditions would be classical counterparts the condition that super-symplectic sub-algebra annihilates the physical states.

What is needed is the association of a unique space-time surface to a given 3-surface defined as union of 3-surfaces at opposite boundaries of CD. One can imagine many 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.

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

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

The compactness (finite size)  $CP_2$  implies topological field quantization: the classical electric fields, magnetic fields, and radiation fields decompose to topological field quanta, space-time sheets, and one can say that physical systems have field identity, field body. This is not true in Maxwell’s theory.

The notion of magnetic body carrying dark matter identified as macroscopically quantum coherent  $h_{eff} = n \times h$  phases has become central in TGD inspired quantum biology [K27, K26]. Magnetic body becomes intentional agent using biological body as a sensory receptor and motor instrument. Communication and control would be based EEG and its fractally scaled variants consisting of dark photons. The size of magnetic body is rather large, at EEG frequency range the size scale is defined by the wave length of photons involved and is of the order of the size scale of Earth. The proposal is that bio-photons are created in a phase transition transforming dark photons to ordinary photons [K28]: since bio-photons have energies are in the range of visible and UV photons, this requires that the value of  $h_{eff}/h$  is roughly the ratio of the frequency of EEG photon with the frequency of visible photon and rather large.

I have called radiation quanta “massless extremals” (MEs) or topological light rays. For MEs the signals propagate at maximal signal velocity (for general space-time sheet light velocity is reduced since the paths along curved space-time sheet is general longer) and thanks to the tubular structure of ME they represent precisely target communications. A further property is that the shape of signal is preserved since positive frequency can propagate in one direction only.

### 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 of the many-sheeted space-time are replaced with single slightly curved region of  $M^4$ .

2. The hierarchy of Planck constants identified in terms of dark matter as phases of ordinary matter represents second new ontological element. Dark matter is assumed to reside at magnetic body which also represents a new ontological element.
3. A further modification of ontology is the replacement of the usual positive energy ontology (PEO) with what I call ZEO already described. In ZEO quantum states are superpositions of quantum evolutions connecting the positive and negative energy parts of the states. Zero energy states are essentially 4-D and only the positive and negative energy parts are 3-D. Quantum jumps/state function reductions re-create the zero energy states with new ones and this allows to solve the basic paradox of ordinary quantum measurement theory due to the fact that non-determinism of state function reduction is in conflict with the determinism of unitary time evolution. One also ends up with identification of "self" as conscious entity: self corresponds to generalized Zeno effect: to a sequence of state function reduction to say positive (positive) energy part of zero energy state [K1] [L7]. 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 [K30, K36]. In ZEO and at imbedding space level there is a hierarchy of CDs labelled by their size scales coming as integer multiples of  $CP_2$  scales. The fractal hierarchy of symplectic sub-algebras leads to a generalization of quantum theory based on a hierarchy of Planck constants characterizing hierarchy of dark matters [K7, K33], hierarchies of inclusions of hyper-finite factors [K24], hierarchies of breakings of super-symplectic gauge symmetry [K25, K35] associated with a hierarchy of quantum criticalities [K33]. There is also a number theoretic hierarchy of algebraic extensions of rationals accompanied by those of p-adic number fields [K36] 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 [K11] self hierarchy emerges.

At the basic level the fundamental hierarchy seems to be the hierarchy 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 [K22, K38] 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 [K36].

1. p-Adic physics as correlate for cognition, imagination, and intentionality [K20] 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 [K21]. 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 [K22] in accordance with the original vision that 2-D analyticity in some sense generalizes to its 4-D variant.

3. Infinite primes [K19] 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  $p = 2, 3, 5, \dots$ , 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 [K36]. 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:

$$S = - \sum_k P_k \log(P_k) \rightarrow \sum_k P_k \log(N_p(P_k)) . \quad (2.1)$$

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 system, say elementary particle.

The possibility of NE together with NMP [K12] 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 [L4]. This might relate to the Jeremy England's 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 resources 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 [K36]. 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 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 [K36]. 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 computability 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 [L6].

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 [L6]. This would make possible discretization without losing 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!

This argument becomes more precise as one realizes that SH is slightly broken: even information theoretically one has only effective 2-dimensionality [K36]. This means that 4-surfaces as preferred extremals are dictated by the data at string world sheets and possibly also partonic 2-surfaces and by data discrete set of points with preferred imbedding space coordinates in the extension of rationals defining the adelic structure by inducing the extensions of p-adic number fields. For p-adic number fields pseudo-constants make it easy to construct the algebraic continuation to a preferred extremal containing the discretization. For reals this is possible only in special cases. These discretizations correspond to realizable imaginations.

Note that Galois group acts as symmetries in the space of space-time discretizations and under certain conditions gives rise to a space-time surface, which is a covering space with  $n$  sheets,  $n$  a factor of the order of Galois group. The identification  $h_{eff}/h = n$  is natural and reduces the hierarchy of Planck constants and dark matter to adelic physics. Ramified primes for the extension of rationals involved are preferred for extension and if the extension allows especially many realizable imaginations, it is survivor in the number theoretic fight for survival. Ramified

primes for these extensions should be winners in the number theoretic evolution. Whether p-adic length scale hypothesis and its generalization follow from this conjecture, remains an open question.

#### 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 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 [L4]. 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.

### 3 ZEO and generalization of quantum measurement theory to a theory of consciousness

TGD inspired theory of consciousness is based on certain basic assumptions such as the identification of state function reduction as a measurement of universal observable identified density matrix characterizing entanglement and Negentropy Maximization Principle (NMP) as fundamental principle. Both the adelic approach and the notion of “World of Classical Worlds” (WCW) force to challenge these assumptions.

#### 3.1 Questions

##### 3.1.1 Do all state function reductions correspond to measurements of density matrix?

The earlier approach has assumed that state function reduction always corresponds to a measurement of density matrix serving as a universal observable. Measurement of density matrix allows to measure simultaneously arbitrary number of commuting observables by assuming to be a function of product of measured commuting observables represented as matrices. This makes sense at space-time level but at the level of WCW one encounters difficulties. For instance, the choice of quantization axis corresponds to a higher level choice localization to a sector of WCW with moduli characterizing this choice. Also the measurement of  $h_{eff}/h = n$  measuring the dimension of Galois group would make sense and force a localization to an extension with Galois group with this dimension. Single entanglement between different points of WCW is not possible (WCW spinor field is analogous to classical spinor describing single particle state and no second quantization is assumed at the level of WCW and one has complete locality), this selection cannot correspond to a measurement of density matrix.

But is the measurement of density matrix really the only possible quantum measurement and does it correspond to act of goal directed intentional free will? Density matrix characterizes

entanglement with environment. Is the measurement of density matrix only a reaction: a choice amongst given alternatives. Eastern philosophers make a sharp distinction between real intentional action and mere reaction. For instance, Krishnamurti talks a lot about this and sees that basically all problems of human kind is that we have not been able to transcend to the level at which our actions would be more than reactions.

Genuine intentional actions would very naturally correspond to self measurements realized as WCW localities such as fixing the quantization axis, or selecting the extension of rationals defining particular evolutionary level of adelic hierarchy, or choosing the boundary of CD at which state function reductions occur (arrow of geometric time) are possible.

### 3.1.2 Is NMP a fundamental principle or does it follow from adelic physics?

NMP has been regarded as a fundamental principle of TGD inspired theory of consciousness. Adelic approach however strongly suggests the reduction of NMP to number theoretic physics somewhat like second law reduces to probability theory: there would be no need to postulate NMP as a separate principle and NMP would hold true only in statistical sense so that we would not live in the best possible world as strongest form of NMP would imply. The dimension of the extension rationals characterizing the hierarchy level of physics and defined an observable measured in state function reductions is positive and can only increase in statistical sense. Therefore the maximal value of entanglement negentropy increases as new entangling number theoretic degrees of freedom emerge.  $h_{eff}/h = n$  identifiable as factor of Galois group of extension characterizes the number of these degrees of freedom for given space-time surfaces as number of its sheets.

This forces to re-think what happens in the state function reduction in which the passive boundary of state function reduction becomes opposite boundary meaning death of self and its re-incarnation as time-reversed self: this reduction has been seen as strongest support for NMP as fundamental principle rather than consequence of adelic physics. The new view relies of the observation that the states at passive boundary are eigenstates of some observables, call them passive observables. The reductions at active boundary must correspond to measurements of observables commuting with the passive observables. Self as a generalized Zeno effect can live only as long as it is able to measure observables commuting with the passive ones. The increase the dimension of extension of rationals in unitary time evolutions between reductions - number theoretic evolution - could generate new observables commuting with the passive observables. Self lives as long as it evolves.

In the sequel I describe briefly the basic of TGD inspired theory of consciousness as generalization of quantum measurement theory to ZEO (ZEO), describe the definition of self, consider the question whether NMP is needed as a separate principle or whether it is implied is in statistical sense by the unavoidable statistical increase of  $n = h_{eff}/h$  if identified as a factor of the dimension of Galois group extension of rationals defining the adèles, and finally summarize the vision about how p-adic physics serves as a correlate of cognition and imagination.

In the sequel I will use some shorthand notations for key principles and notions. General Coordinate Invariance (GCI); World of Classical Worlds (WCW); Strong Form of GCI (SGCI); Strong Form of Holography (SH); Preferred Extremal (PE); Zero Energy Ontology (ZEO); Negentropy Maximization Principle (NMP); Negentropic entanglement (NE) are the most often occurring acronyms.

## 3.2 ZEO

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

1. In TGD framework the answer is ZEO [K12]. The concept of quantum state is generalized. States are now analogs for physical events characterized by initial and final quantum state that is pairs of positive and negative energy states. The conserved quantum numbers of the members are opposite so that zero energy states can be created from vacuum. This is a radical

generalization of the physicalist world of view but entirely consistent with conservation laws: there is no need to give laws of physics in order to have free will. Positive and negative energy parts of the zero energy states can be assigned to opposite light-like boundaries of CDs, which are intersections of future and past directed light-cones multiplied by  $CP_2$ . CDs form a fractal scale hierarchy. They can be seen as imbedding space correlates for the 4-D perceptive fields of selves.

2. 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.

### 3.3 From quantum measurement theory to a theory of consciousness

The notion of self can be seen as a generalization of the poorly defined definition of the notion of observer in quantum physics. In the following I take the role of skeptic trying to be as critical as possible.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. The density matrix was assumed to define the universal observable. Note that a density matrix, which is power series of a product of matrices representing commuting observables has in the generic case eigenstates, which are simultaneous eigenstates of all observables. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

#### 3.3.1 Self as generalized Zeno effect

The precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO (ZEO) only rather recently (2014).

1. Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant - “small” state function reductions. The parts of zero energy states at second boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.
2. The first quantum jump to the opposite boundary corresponds to the act of “free will” or birth of re-incarnated self. Hence the act of “free will” changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means “death” of self and “re-incarnation” of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.
3. This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur

repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

### 3.3.2 State function reductions at the level of WCW

One can identify several rather abstract state function reductions selecting a sector of WCW.

1. There are quantum measurements inducing localization in the moduli space of CDs with passive boundary and states at it fixed. In particular, a localization in the moduli characterizing the Lorentz transform of the upper tip of CD would be measured. The measured moduli characterize also the analog of symplectic form in  $M^4$  strongly suggested by twistor lift of TGD - that is the rest system (time axis) and spin quantization axes. Of course, also other kinds of reductions are possible.
2. Also a localization to an extension of rationals defining the adeles should occur. Could the value of  $n = h_{eff}/h$  be observable? The value of  $n$  for given space-time surface at the active boundary of CD could be identified as the order of the smallest Galois group containing all Galois groups assignable to 3-surfaces at the boundary. The superposition of space-time surface would not be eigenstate of  $n$  at active boundary unless localization occurs. It is not obvious whether this is consistent with a fixed value of  $n$  at passive boundary.

The measured value of  $n$  could be larger or smaller than the value of  $n$  at the passive boundary of CD but in statistical sense  $n$  would increase by the analogy with diffusion on half line defined by non-negative integers. The distance from the origin unavoidably increases in statistical sense. This would imply evolution as increase of maximal value of negentropy and generation of quantum coherence in increasingly longer scales.

3. A further abstract choice corresponds to the replacement of the roles of active and passive boundary of CD changing the arrow of clock time and correspond to a death of self and re-incarnation as time-reversed self.

### 3.3.3 Can the reductions at the level of WCW reduce to measurements of density matrix?

Can one assume that these measurements reduce to measurements of a density matrix of either entangled system as assumed in the earlier formulation of NMP, or should one allow both options. This question actually applies to all quantum measurements and leads to a fundamental philosophical questions unavoidable in all consciousness theories.

1. Do all measurements involve entanglement between the moduli or extensions of two CDs reduced in the measurement of the density matrix? Non-diagonal entanglement would allow final states states, which are not eigenstates of moduli or of  $n$ : this looks strange. This could also lead to an infinite regress since it seems that one must assume endless hierarchy of entangled CDs so that the reduction sequence would proceed from top to bottom. It looks natural to regard single CD as a sub-Universe.

For instance, if a selection of quantization axis of color hypercharge and isospin (localization in the twistor space of  $CP_2$ ) is involved, one would have an outcome corresponding to a quantum superposition of measurements with different color quantization axis!

Going philosophical, one can also argue, that the measurement of density matrix is only a reaction to environment and does not allow intentional free will.

2. Can one assume that a mere localization in the moduli space or for the extension of rationals (producing an eigenstate of  $n$ ) takes place for a fixed CD - a kind of self measurement possible for even unentangled system? If there is entanglement in these degrees of freedom between two systems (say CDs), it would be reduced in these self measurements but the outcome

would not be an eigenstate of density matrix. An interpretation as a realization of intention would be appropriate.

3. If one allows both options, the interpretation would be that state function reduction as a measurement of density matrix is only a reaction to environment and self-measurement represents a realization of intention.
4. Self measurements would occur at higher level say as a selection of quantization axis, localization in the moduli space of CD, or selection of extension of rationals. A possible general rule is that measurements at space-time level are reactions as measurements of density matrix whereas a selection of a sector of WCW would be an intentional action. This because formally the quantum states at the level of WCW are as modes of classical WCW spinor field single particle states.
5. If the selections of sectors of WCW at active boundary of CD commute with observables, whose eigenstates appear at passive boundary (briefly *passive observables*) meaning that time reversal commutes with them - they can occur repeatedly during the reduction sequence and self as a generalized Zeno effect makes sense.

If the selections of WCW sectors at active boundary do not commute with passive observables then volition as a choice of sector of WCW must change the arrow of time. Libet's findings show that conscious choice induces neural activity for a fraction of second before the conscious choice. This would imply the correspondences "*big*" measurement changing the arrow of time - self-measurement at the level of WCW - intentional action and "*small*" measurement - measurement at space-time level - reaction.

Self as a generalized Zeno effect makes sense only if there are active commuting with passive observables. If the passive observables form a maximal set, the new active observables commuting with them must emerge. The increase of the size of extension of rationals might generate them by expanding the state space so that self would survive only as long as it evolves.

Otherwise there would be only single unitary time evolution followed by a reduction to opposite boundary. This makes sense only if the sequence of "big" reductions for sub-selves can give rise to the time flow experienced by self: the birth and death of mental images would give rise to flow of time of self.

A hierarchical process starting from given CD and proceeding downwards to shorter scales and stopping when the entanglement is stable is highly suggestive and favors self measurements. CDs would be a correlate for self hierarchy. One can say also something about the anatomy and correlates of self hierarchy.

1. Self experiences its sub-selves as mental images and even we would represent mental images of some higher level collective self. Everything is conscious but consciousness can be lost or at least it is not possible to have memory about it. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.
2. By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J8] could be understood as a sharing of mental images between brain hemispheres, which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.
3. At the level of 8-dimensional imbedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or

light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. For instance .1 second time scale defining sensory chronon corresponds to the secondary p-adic time scale characterizing the size of electron's CD (Mersenne prime  $M_{127}$ ), which suggests that Cooper pairs of electrons are essential for the sensory qualia.

The above argument states that the measurements at the level of WCW cannot be regarded as measurements of a density matrix since no second quantization at level of WCW is carried out. About a year after developing this argument I realized that the hierarchy of infinite primes suggests an infinite hierarchy of second quantizations. Could the counterpart for the hierarchy of infinite primes be realized at WCW level automatically? One can indeed interpret the measurements at WCW as either localizations or as reductions of entanglement between states associated with different points of WCW. The point is that the disjoint union of 3-surfaces  $X^3$  and  $Y^3$  can be regarded either as a pair  $(X^3, Y^3)$  of 3-surfaces in  $WCW \times WCW$  or as a 3-surface  $Z^3 = X^3 \cup Y^3 \subset WCW$ . The general identity behind this duality  $WCW = WCW \times WCW = \dots = WCW^n = \dots$

One could think the situation in terms of  $(X^3, Y^3) \in WCW \times WCW$  in which case one can speak of entanglement between WCW spinor modes associated with  $X^3$  and  $Y^3$  reduced by the measurement of density matrix. Second interpretation as a localization of wave function of  $Z^3 = X^3 \cup Y^3 \in WCW$ .

### 3.3.4 Experimental support for the relative arrow of time

It has been found that the arrow of time is relative [?] (see <http://tinyurl.com/yatp6dum>). Expressing this in more cautious terms, heat can flow from system with temperature  $T_1$  to a system with temperature  $T_2 > T_1$  if there is correlation between the two systems meaning that the density matrix for the two nuclear systems (samples consisting of hydrogen atoms and carbon atoms) is not mere tensor product of density matrices but contains an additional term describing correlation. It must be emphasized that this finding is not in conflict with the standard view about second law which only says that heat flows from system with higher temperature to that with lower temperature provided that there are no correlations between the systems.

The argument runs as follows. The mutual information for the uncorrelated systems vanishes, and since it can only increase this implies flow of heat in the standard direction. If the mutual information is non-vanishing in the initial situation (due to the correlation) it can also decrease and this can give a heat flow in non-standard direction. This has been observed.

Although one can model the finding using standard thermodynamics, one can ask whether something deeper might be involved. Should one be cautious and talk only about the changing direction of heat flow due to the breaking of the basic assumptions of thermodynamics, and avoid speaking about direction of thermodynamical time? Or could a genuine change of the arrow of time take place? Going even deeper, one must ask what thermodynamical time, the time of physicist (geometric time), and the arrow of time do really mean? What is the relationship between these two times? This leads to ponder questions about the basics of quantum measurement theory and here I can only consider TGD based vision [L9].

1. The basic prediction of zero energy ontology (ZEO) is that the arrow of geometric time can have both signs whereas the arrow of subjective time (relating closely to thermodynamic time) defined by experience created by sequence of state function reductions is always the same. The arrow of geometric time is indeed relative. The flow of geometric time corresponds to the increase of distance between tips of causal diamond (CD) and the increase in particular reduction is at either tip of CD and in this manner defines arrow of time. CD grows either "upwards" or "downwards". A geometric measure for experienced time is that distance between the tips of CD which always increases.

Time reflection symmetry (T) with respect to the center of CD is broken in TGD: the classical time evolutions of space-time surfaces are not T mirror images of each other. This is true also for the quantal evolutions defined by zero energy states essentially as quantum superpositions of classical evolutions. States and their time reversals obey the initial conditions at opposite

boundaries of CD. Arrow of time is forced by the place (either boundary of CD), where initial conditions are posed, not by the initial conditions themselves.

2. One must however remember that ZEO describes genuine quantum systems whereas thermodynamics describes ensemble, which is a highly idealized notion. In ZEO arrow of geometric time would change in each "big" quantum jump and would remain the same during the sequence of "small" state function reductions defining the counterpart of Zeno effect or weak measurement.
3. Initial conditions breaking the basic assumptions of thermodynamics induce correlations and the heat flow in "wrong" direction in the model for the finding. The arrow of time is claimed to be changed in time interval of length of order 2 millisecond. Interestingly, millisecond happens to characterize the time scale of nerve pulse and ZEO predicts that in living matter the change of the arrow of time takes place routinely. In ZEO based description the growth of the temporal distance between the tips of CD would be of order 2 milliseconds.

It would be however the opposite boundary of CD in geometric past that would recede farther away. One can argue that it is not possible to measure the position of the past boundary of CD directly. But is it possible to measure the distance between the tips of CD indirectly from the behavior of the ensemble? ZEO would suggest that the time appearing in the Hamiltonian modelling the system corresponds to the distance between tips of CD and never decreases. The change of the direction of heat flow would correspond to the reduction to the original boundary of CD in the experiment and the correlation would make ZEO visible.

If the two descriptions are equivalent, the initial correlations for the ensemble force should correspond to posing initial conditions at the non-standard boundary of CD leading to the reversal of the arrow of time. The very act of posing the correlations would correspond to a "big" state function reduction to opposite boundary of CD. In standard quantum measurement theory state preparation indeed corresponds to this state function reduction so that the two descriptions might be consistent.

## 4 Negentropy Maximization Principle

Negentropy Maximization Principle (NMP [K12] ) stating that the reduction of entanglement entropy is maximal at a given step of state function reduction process following  $U$ -process is the basic variational principle for TGD inspired theory of consciousness and says that the information contents of conscious experience is maximal. Although this principle is diametrically opposite to the second law of thermodynamics it is structurally similar to the second law. NMP does not dictate the dynamics completely since in state function reduction any eigen state of the density matrix is allowed as final state. NMP need not be in contradiction with second law of thermodynamics which might relate as much to the ageing of mental images as to physical reality.

### 4.1 Basic Form Of NMP

Negentropy Maximization Principle (NMP) in its original form codes for the basic rules of the standard state function reduction and implies that system ends up to an eigenstate of the density matrix identified as observable. In TGD framework must ask whether NMP should be restricted only to the entanglement between zero modes of WCW representing classical degrees of freedom and quantum fluctuating degrees of freedom or generalize it to apply to any pair of subsystems so that state function reduction sequence could be regarded as a sequence of self measurements. I have chosen the latter option as a working hypothesis.

NMP that the state function reduction process following  $U$ -process gives rise to a maximal reduction of entanglement entropy at each step of the process. State function process could proceed at the level of all CDs. It is not clear whether one can assign any geometric time duration to this process or whether there is any need for this. If the subsystem allows entangled pairs of free systems (no binding energy) there is more or less unique pair with the maximal entanglement entropy and NMP therefore implies a decomposition to a unique pair of unentangled systems. The process repeats itself for these systems and stops when the resulting subsystem cannot be

decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. Number theoretic entanglement entropies mean an important modification of this picture.

## 4.2 Weak Form Of NMP

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities  $p_n$  by the logarithms of their p-adic norms  $|p_n|_p$ . This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding or some positive emotion like love.

Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness.

NMP combined with number theoretic entropies leads to an important exception to the rule that the generation of bound state entanglement between system and its environment during  $U$  process leads to a loss of consciousness. When entanglement probabilities are rational (or even algebraic) numbers, the entanglement entropy defined as a number theoretic variant of Shannon entropy can be non-positive (actually is) so that entanglement carries information. NMP favors the generation of algebraic entanglement. The attractive interpretation is that the generation of algebraic entanglement leads to an expansion of consciousness (“fusion into the ocean of consciousness”) instead of its loss.

State function reduction period of the quantum jumps involves much more than in wave mechanics. For instance, the choice of quantization axes realized at the level of geometric delicacies related to CDs is involved.  $U$ -process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction involves also a choice between generic and negentropic entanglement (between real world, a particular p-adic world, or their intersection) it might be possible to identify a candidate for the physical correlate for the choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The hedonistic option is risky since it can lead to non-algebraic bound state entanglement implying a loss of consciousness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices. Note that if the total entanglement negentropy defined as sum of contributions from various levels of CD hierarchy up to the highest matters in NMP then also sub-selves should develop negentropic entanglement. For instance, the generation of entropic entanglement at cell level can lead to a loss of consciousness also at higher levels. Life would evolve from short to long scales.

The consistency with quantum measurement theory leads to an important constraint on the density matrix giving rise to negentropic entanglement. The density matrix of the final state must be a projector as in the ordinary quantum measurement theory. It's dimension can be however higher than one now. Therefore negentropic entanglement cannot be confused with real entanglement and there is no problem due to the fact that for real number based entanglement it is impossible to know in practice whether the entanglement coefficients are rational numbers. The entanglement giving rise to a density matrix, which is projector corresponds in the 2-particle case entanglement matrix proportional to unitary matrix typical for quantum computer type systems.

TGD inspired theory of consciousness forces to challenge the hypothesis that NMP always forces the state function reduction to the sub-space defined by the projector with maximal dimension appearing in the decomposition of the density matrix. NMP would not allow the self to make choices, which are bad deeds in the sense that they do not increase maximally the negentropic resources of the Universe. We would live in the best possible Universe becoming better all the time. This is obviously too good to be true.

A weaker form of NMP allows the choice leading to maximal negentropy gain but allows also

those choices for which the reduction occurs to a sub-space of the space defined by projector. When this sub-space is 1-dimensional standard quantum measurement results and the self is isolated from the target of observations. Negentropic entanglement has interpretation as attention with positively colored contents of consciousness. Experience of love would be one attribute of this kind of state. Weak form of NMP would be like God allowing the sinner to chose between Good and Evil.

#### 4.2.1 Do positively colored emotions allow a representation of Boolean logic?

Weak form of NMP allows the state function reduction to occur in  $2^n - 1$  manners corresponding to subspaces of the sub-space defined by n-dimensional projector if the density matrix is n-dimensional projector (the outcome corresponding to 0-dimensional subspace and is excluded). If the probability for the outcome of state function reduction is same for all values of the dimension  $1 \leq m \leq n$ , the probability distribution for outcome is given by binomial distribution  $B(n, p)$  for  $p = 1/2$  (head and tail are equally probable) and given by  $p(m) = b(n, m) \times 2^{-n} = (n!/m!(n-m)!) \times 2^{-n}$ . This gives for the average dimesion  $E(m) = n/2$  so that the negentropy would increase on the average. The world would become gradually better. Note that one assumes that there is some preferred basis for the states and these numbers apply when this basis is given.

One cannot avoid the idea that these different degrees of negentropic entanglement could actually give a realization of Boolean algebra in terms of conscious experiences.

1. There should be a mapping of k-dimensional subspaces of n-dimensional space to the fermionic representation of Boolean algebra
2. Could one speak about a hierarchies of codes of cognition based on the assignment of different degrees of "feeling good" to the Boolean statements? If one assumes that the  $n$ :th bit is always 1, all independent statements except one correspond at least two non-vanishing bits and corresponds to negentropic entanglement. Only of statement (only last bit equal to 1) would correspond 1 bit and to state function reduction reducing the entanglement completely (brings in mind the fruit in the tree of Good and Bad Knowledge!).
3. A given hierarchy of breakings of super-symplectic symmetry corresponds to a hierarchy of integers  $n_{i+1} = \prod_{k \leq i} m_k$ . The codons of the first code would consist of sequences of  $m_1$  bits. The codons of the second code consists of  $m_2$  codons of the first code and so on. One would have a hierarchy in which codons of previous level become the letters of the code words at the next level of the hierarchy.

In fact, I ended up with almost Boolean algebra for decades ago when considering the hierarchy of genetic codes suggested by the hierarchy of Mersenne primes  $M(n+1) = M_{M(n)}$ ,  $M_n = 2^n - 1$ .

1. The hierarchy starting from  $M_2 = 3$  contains the Mersenne primes 3, 7, 127,  $2^{127} - 1$  and Hilbert conjectured that all these integers are primes. These numbers are almost dimensions of Boolean algebras with  $n = 2, 3, 7, 127$  bits. The maximal Boolean sub-algebras have  $m = n - 1 = 1, 2, 6, 126$  bits.
2. The observation that  $m = 6$  gives 64 elements led to the proposal that it corresponds to a Boolean algebraic assignable to genetic code and that the sub-algebra represents maximal number of independent statements defining analogs of axioms. The remaining elements would correspond to negations of these statements. I also proposed that the Boolean algebra with  $m = 126 = 6 \times 21$  bits (21 pieces consisting of 6 bits) corresponds to what I called memetic code obviously realizable as sequences of 21 DNA codons with stop codons included. Emotions and information are closely related and peptides are regarded as both information molecules and molecules of emotion.
3. This hierarchy of codes would have the additional property that the Boolean algebra at  $n + 1$ :th level can be regarded as the set of statements about statements of the previous level. One would have a hierarchy representing thoughts about thoughts about.... It should be emphasized that there is no need to assume that the Hilbert's conjecture is true.

One can obtain this kind of hierarchies as hierarchies with dimensions  $m, 2^m, 2^{2^m}, \dots$  that is  $n(i+1) = 2^{n(i)}$ . The conditions that  $n(i)$  divides  $n(i+1)$  is non-trivial only for at the lowest

step and implies that  $m$  is power of 2 so that the hierarchies starting from  $m = 2^k$ . This is natural since Boolean algebras are involved. If  $n$  corresponds to the size scale of CD, it would come as a power of 2.

p-Adic length scale hypothesis has also led to this conjecture. A related conjecture is that the sizes of CDs correspond to secondary p-adic length scales which indeed come as powers of two. In case of electron this predicts that the minimal size of CD associated with electron corresponds to time scale  $T = .1$  seconds, the fundamental time scale in living matter (10 Hz is the fundamental biorhythm). It seems that the basic hypothesis of TGD inspired partly by the study of elementary particle mass spectrum and basic bio-scales (there are 4 p-adic length scales defined by Gaussian Mersenne primes in the range between cell membrane thickness 10 nm and size  $2.5 \mu\text{m}$  of cell nucleus!) follow from the proposed connection between emotions and Boolean cognition.

Hilbert's conjecture relates in interesting manner to space-time dimension. Suppose that Hilbert's conjecture fails and only the four lowest Mersenne integers in the hierarchy are Mersenne primes that is 3, 7, 127,  $2^{127} - 1$ . In TGD one has hierarchy of dimensions associated with space-time surface coming as 0, 1, 2, 4 plus imbedding space dimension 8. The abstraction hierarchy associated with space-time dimensions would correspond discretization of partonic 2-surfaces as point set, discretization of 3-surfaces as a set of strings connecting partonic 2-surfaces characterized by discrete parameters, discretization of space-time surfaces as a collection of string world sheet with discretized parameters, and maybe - discretization of imbedding space by a collection of space-time surfaces. Discretization means that the parameters in question are algebraic numbers in an extension of rationals associated with p-adic numbers.

In TGD framework it is clear why imbedding space cannot be higher-dimensional and why the hierarchy does not continue. Could there be a deeper connection between these two hierarchies. For instance, could it be that higher dimensional manifolds of dimension  $2 \times n$  can be represented physically only as unions of say  $n$  2-D partonic 2-surfaces (just like  $3 \times N$  dimensional space can be represented as configuration space of  $N$  point-like particles)? Also infinite primes define a hierarchy of abstractions. Could it be that one has also now similar restriction so that the hierarchy would have only finite number of levels, say four. Note that the notion of n-group and n-algebra involves an analogous abstraction hierarchy.

### 4.3 Can One Define Measures For The Information Contents Of Mental Image?

Despite the fact that one cannot write formula for the contents of conscious experience, one can define information measures for conscious experience as differences of the information measures for the initial and final quantum histories. Negentropy gain is the most natural information measure of this kind. For instance, the sum of the net entanglement negentropy gains over the steps of the self measurement cascade could define a quantity characterizing net information gain for a single moment of consciousness at each step.

One could also information measure to selves as the entanglement negentropy after the state function reduction process has ended. This would assign to each subsystem stable under NMP a negentropy. For bound state entanglement this information would be negative but for negentropic entanglement it would be positive. One can ask whether the hypothesis that this information increases during quantum jump sequence is equivalent with NMP. In the case of entire Universe the application of this principle becomes problematic.

Entropy gradients with respect to subjective time could be used to characterize how the information gain of conscious experience of self changes. These gradients approach zero when self approaches thermal equilibrium. In TGD framework entropy gradients correlate with emotions, which means a somewhat counter intuitive connection between emotions and information gain or loss (consistent however with the fact that peptides are both informational molecules and molecules of emotion [J2]). Note that the binding of information molecules to receptors means the formation larger bound states accompanied by the experience of oneness at molecular level (are sex and spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

### 4.3.1 Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic worlds, which suggests that life and conscious intelligence reside in the intersection of the real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes  $p$ . Same would apply to the expressions defining quantum states. In particular, entanglement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP.

1. For the minimal option life would be also effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world sheets partonic two-surfaces appears in  $U$ -matrix so that only the data from rational and some algebraic points of the partonic 2-surface dictate  $U$ -matrix. This means discretization at parton level and something which might be called number theoretic quantum field theory should emerge as a description of intentional action.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K5]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K17].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves  $\sqrt{5}$ , conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

## 4.4 Hyper-Finite Factors Of Type $II_1$ And NMP

Hyper-finite factors of type  $II_1$  bring in additional delicacies to NMP. The basic implication of finite measurement resolution characterized by Jones inclusion is that state function reduction can never reduce entanglement completely so that entire universe can be regarded as an infinite living organism. It would seem that entanglement coefficients become  $\mathcal{N}$  valued and the same is true for

eigen states of density matrix. For quantum spinors associated with  $\mathcal{M}/\mathcal{N}$  entanglement probabilities must be defined as traces of the operators  $\mathcal{N}$ . An open question is whether entanglement probabilities defined in this manner are algebraic numbers always (as required by the notion of number theoretic entanglement entropy) or only in special cases.

## 5 Questions related to the notion of self and time

The notion of self and the relation between subjective and geometric time involves unclear aspects. In the following I try to articulate the problematic issues as clearly as possible.

1. The precise nature of the hierarchy of causal diamonds (CDs) as correlate of self hierarchy should be characterized. The basic prediction that sub-selves have also time reversed variants should be interpreted and one can ask whether sensory-motor dichotomy is a sensible interpretation.
2. Are sub-selves always experienced as mental images and whether after images really represent re-incarnations of sub-selves.
3. Can the rather dramatic prediction of re-incarnations be transformed to an experimentally testable predictions. If one takes seriously the notion of self hierarchy and identifies the EEG correlates of self in a manner proposed by Fingelkurts brothers [J3], this kind of prediction is possible.

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

CDs are obtained from the intersections of future and past directed light-ones by replacing their points with  $CP_2$ : as a matter fact,  $CP_2$  plays no active role in the definition. I have not been able to nail down the precise definition for the hierarchy of causal diamonds. Self hierarchy demands that CDs serving as 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. One could consider also a more precise identification of self. By SH string world sheets and/or partonic 2-surfaces or their light-like orbits could serve as space-time correlates of selves. The orbit of partonic 2-surface is indeed analogous to nervous system residing at the boundary between internal (Euclidian) and external (Minkowskian) worlds.

Given space-time surface has both Minkowskian and Euclidian regions - wormhole contacts - separated by wormhole throats at which the signature of the induced metric changes. Minkowskian space-time sheets are connected by extremely short  $CP_2$  sized Euclidian wormhole contacts and in GRT-standard model approximation are approximated by single GRT space-time. If the magnetic flux through wormhole contact is monopole flux, the wormhole contact connecting two Minkowskian space-time sheets has interpretation as a building brick of elementary particles. Minkowskian space-time sheets at different levels of hierarchy are disjoint and separated by Euclidian wormhole contacts. This forces to modify the notion of quantum mechanical subsystem as a tensor factor of the state space.

What is new that two Minkowskian space-time sheets glued to larger disjoint Minkowskian space-time sheets can be connected by magnetic flux tube serving as a correlate for (negentropic) entanglement just as wormholes in ER-EPR proposal of Maldacena and Susskind [?, ?] (see <http://tinyurl.com/y7za98cn>) serve as correlates for maximal entanglement between blackholes. Two unentangled systems can therefore have subsystems, which are entangled and correspond to two space-time sheets connected by magnetic flux tubes! This is possible only in many-sheeted space-time and the hypothesis has been that two selves, which have no entanglement at their own level of self-hierarchy, can have entangled subselves and that this negentropic entanglement (NE) means

sharing of mental images giving rise to a kind of stereo consciousness. The fusion of right and left visual fields would be example of stereo consciousness. Stereo consciousness would make also possible to communicate besides bits also their meaning: during conscious communication the mental images of two selves would fuse temporarily to single mental image by the reconnection of magnetic flux tubes. This reconnection would make possible also directed attention.

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

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

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

Subselves correspond to mental images. The question is whether self really experiences the time reversed sub-selves as a mental image and if this is the case, what can one conclude about this. For sub-sub...-selves this problem is not acute if sub-sub-selves are experienced as kind of statistical averages.

A possible interpretation for self and its time reversal is in terms of sensory input and motor action. I have indeed proposed that motor action is essentially sensory experience in reversed time direction and Libet's discovery [J1] 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?

## 5.3 Re-incarnation and EEG

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

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

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

1. Self hierarchy predicts that also our mental images are conscious entities. Motor-sensory dichotomy naturally corresponds to sub-self and time reversed sub-self. That is sensory mental image and that associated with motor action induced by sensory input. Motor action initiated in the geometric past at the opposite boundary of CD (this explains Libet's finding that conscious decision is preceded by neural activity in geometric time). Note that motor action does not proceed from brain to muscles but in reversed time direction from muscles to brain! This conforms with the vision in which magnetic body is intentional agent.

2. To proceed one must identify EEG correlates for the sub-selves (mental images) and their time reversed re-incarnates. Here the work of Fingelkurts brothers (see <http://tinyurl.com/jpszfpy>) working in Finland helps [J3]. 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 straightforward. 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 [J6] 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.

## 5.4 After images as reincarnations of mental images?

After images (see <http://tinyurl.com/kevnzqg>) appear periodically as one can easily find by looking and lamp and closing eyes. They also change colors. Could these after images be interpreted as re-incarnations? This sounds attractive but one must be very careful. A sub-self  $S$ , which dies and transforms to its time reversal  $S_1$  reincarnates eventually as sub-self  $S_2$  with the original arrow of time. According to the assumption about first reduction to opposite boundary made  $S_2$  emerges at time later than  $S$  died and this conforms with what is known. The time interval between two subsequence after images would give information about the average value of  $\Delta t$ . The after images need not be identical copies of the original and their color indeed changes.

An alternative interpretation is that after images are not re-incarnations but belong to a 4-D population of sub-selves. Our geometric past is alive and changes all the subjective time. This is not so confusing when one realize that ZEO means that conscious existence is essentially 4-dimensional. Also our memories are dynamical and change all the subjective time. Negative energy signals to geometric past which correspond to time reversed sub-selves indeed affect the

geometric past and memory representations. In principle this kind of signalling could be carried out artificially to manipulate geometric past.

## 5.5 Re-incarnation and time reversed selves as basic predictions of TGD inspired theory of consciousness

Life has been hard for skeptics during last two decades. A typical skeptic has as building bricks of his ego the items in the list of notions that they regard as pseudoscientific. This allows to attack the people who have the gift of imagination and passion for genuine understanding, which skeptics unfortunately do not possess. What makes attacks easy that no arguments based on contents are needed and the skeptic need not waste his time by trying to understand the arguments of the person to be labelled as pseudoscientist or crackpot.

The typical rhetoric tricks used begin from replacement of Dr X with Mr X and end up with the “conclusion” that the work of Mr X is totally incomprehensible. I have learned that rather often skeptic of this kind is an academic dropout who never managed to do his MsC. Obviously, the role of skeptic became a manner to survive socially and retain the illusion “I am a scientist”. During last decades the list of pseudoscientific notions has shortened item by item as quantum biology and quantum consciousness have emerged as respected branches of science. The notion of re-incarnation (see <http://tinyurl.com/jfpowqg>) has been certainly regarded as one of safest pillars supporting the ego of skeptic but even this pillar is in danger to fall down. Poor skeptics.

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

### 5.5.1 Reincarnation: a testable prediction?

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

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

1. Self hierarchy predicts that also our mental images are conscious entities. Motor-sensory dichotomy naturally corresponds to sub-self and time reversed sub-self. That is sensory mental image and that associated with motor action induced by sensory input. Motor action initiated in the geometric past at the opposite boundary of causal diamond (CD) (this explains Libet’s finding that conscious decision is preceded by neural activity in geometric time). Note that motor action does not proceed from brain to muscles but in reversed time direction from muscles to brain! This conforms with the vision in which magnetic body is intentional agent.
2. To proceed one must identify EEG correlates for the sub-selves (mental images) and their time reversed re-incarnates. Here the work of Fingelkurts brothers (see <http://tinyurl.com/jpszfpy>) working in Finland helps [J3]. They postulate what they call operational architecture of brain (OA) having operations (O) and operational modules (OM) as building bricks. Quasi-stationary EEG segments are assumed to serve as correlates for operations and synchrony of these segments associated with various locations in brain tells that they belong to the same OM.

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

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

3. One can check whether these EEG segments appear as pairs with first member assignable to sensory mental image and second one to motor mental image. Time reversal implies that second law is obeyed in "wrong" time direction for EEG segment assignable to the motor output and this can be tested. Already Fantappie [J6] 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.

### 5.5.2 Do conscious entities with different time arrows interact?

Zero Energy Ontology (ZEO) predicts conscious entities with both arrows of geometric time. I find that forcing myself to think and write about this is difficult. The fear is that the whole nice scenario falls down by predicting something totally absurd. The questions that I try to avoid are following. What could these ghostly time-reversed entities be? Do they interact with those with standard time orientation? How could they do so?

Let us first briefly recall what ZEO based theory of consciousness says.

1. In ZEO self corresponds to a generalized Zeno effect that is sequence of state function reductions leaving the passive boundary of CD unaffected as also the members of state pairs associated with 3-surfaces at it. At active boundary the members of state pairs change and the active boundary drifts reduction by reduction farther away from passive boundary. The temporal distance between the tips of CD increases gradually and corresponds to the experience about flow of time.
2. Negentropy Maximization Principle (NMP) [K12] forces eventually self to die by making the first reduction to the passive boundary of its causal diamond (CD), which now becomes the active boundary: a new time reversed self is born. This option is forced because it produces more negentropy. For this self the arrow of geometric time would be opposite since now the formerly passive boundary would be active and shift in opposite direction of time: in this manner CD would steadily increase in size.

Also the time-reversed self would eventually die and make the first reduction to the opposite - the original - boundary of CD. The position of the boundary of active boundary in first reduction would be shifted to the geometric future from the original position. The first and - as will be found - probably wrong guess for the size of shift towards geometric future from the position at the moment of previous death would be as the average increase of the temporal distance between tips of CD during Zeno period. This increment could be rather small as compared to the size of CD itself.

This picture raises questions.

1. Do we make this kind jump to time-reverse life at some level of our personal self hierarchy as we fall sleep? If wake-up period corresponds to re-incarnation in the original time direction, time increment of CD from its previous value would be the duration of sleeping period as seen by a larger conscious system. This is much longer than the subjective chronon for sensory mental images about .1 seconds.

**Remark:** Note that EEG splits to pieces of duration about 300 ms and it might be possible to identify in EEG periods, which correspond to mental images and their time reversals. These periods could differ by a phase conjugation although the power spectrum would have the same typical behavior (sound wave and its phase conjugate have same power spectrum but we can distinguish sound and its time-reversal from each other).

Could the first big reduction correspond to a time increment, which is of the same order of magnitude as the total time duration of life-cycle of the time-reversed self? The size of 3-surfaces at the boundary of time-reversed CD has increased by about life-time. Could the first reduction to the opposite boundary increase the size of the 3-surface at this boundary by the same amount? If so, the re-incarnations for human life cycles would take roughly life-time after the death.

Could one identify negative energy time reversed signal as time-reversed self at some level of hierarchy? If so then the selves associated with CDs could gradually increase their energy by dying and re-incarnating repeatedly since the opposite boundary would increase also the magnitude of the negative energy at the opposite boundary. This is in principle possible since conservation laws hold true by the very definition of zero energy states as well as for classical time evolutions appearing in their quantum superposition. The average energy for a given member of pair defining zero energy state would increase gradually. The size of the CD associated with re-incarnating self could become arbitrary large and gain an arbitrary high total energy: the wildest speculation is that cosmologies correspond to very large selves [L2].

2. Could selves/systems living in opposite directions of time have direct interactions? If the vision that motor actions are realized as negative energy signals travelling to brain of the geometric past and induce neural activity fraction of second earlier than the conscious decision was made (Libet's finding), this could be the case. Motor action could correspond to a death of sensory self, reincarnation as time-reversed motor-self, and a re-incarnation as sensory self in time scale of .1 seconds. Sensory-motor cycle would correspond to a sequence of re-incarnations as time reversed sub-self.
3. How the time reversed selves could reveal themselves? If their presence can be indeed detected, a key signature would be the opposite direction of the thermodynamical arrow of time for them. Heat would be apparently transferred in wrong direction: from cold to hot. This kind of apparent breakings of second law have been observed: phase conjugate laser waves and acoustic signals represent examples of this. Fantappie suggested that they occur routinely in living matter and introduce the notion of syntropy as time reverse counterpart of entropy [J6]. The strange cooling of the air at magnetic walls associated with the rotating magnetic systems [L8] provides second example.
4. Good music is claimed to send cold shivers in spine and sensations of cold are assigned also with the perception of ghosts. Could the claims about encounters of ghosts be due to a perception of time reversed selves? I remember that in my personal great experience for three decades ago the entire body went into a state analogous to that created by a good music. Did I interact with a time reversed conscious entity? My experience indeed was that I was in contact with what I called Great Mind. This is of course just a subjective experience and the skeptic scientist knows that I was in a psychotic state since it is completely obvious from my scientific work even without reading it that I am a madman.

## 6 Appendix: TGD and quantum biology

The ontology behind the applications involves the notion of many-sheeted space-time, ZEO, hierarchy of Planck constants identified in terms of dark matter, and p-adic physics as physics of cognition. Also magnetic body (MB) carrying dark matter and energy having non-standard value of Planck constant  $h_{eff} = n \times h$  identified as intentional agent represents new ontology. The additional assumption  $h_{eff} = h_{gr}$  identifying  $h_{eff}$  with gravitational Planck constant is rather powerful. Also p-adic length scale hypothesis is also central in applications. NMP is the basic variational principle of consciousness and means that living systems must do their best to build negentropy resources to avoid the first reduction to the opposite boundary of personal CD. This strongly suggests that metabolic energy necessary for survival is needed to transfer NE from the nutrients and the ADP-ATP cycle is essentially transfer of NE in molecular scale.

### 6.1 The notion of magnetic body (MB)

MB is assumed to be carrier of dark matter.

1. The flux tubes of MB can suffer  $h_{eff}$  changing phase transitions inducing the change of the length of flux tube. This leads to a view about living matter as a network of bio-molecules connected by magnetic flux tubes. The ability of biomolecules to find each other in the dense molecular soup would rely on the reduction of  $h_{eff}$  bringing molecules near each other. The reconnections of flux tubes possible if the field strengths are same and therefore also cyclotron frequencies are identical are also expected to be 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 [K15, K16]. 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.

#### 6.1.1 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 with 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 [K33]. 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 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 [J4] 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 [K15]. These communications would be essential in living matter.
4. The formation of reconnections and phases transitions  $n \rightarrow m$  changing  $h_{eff} = n \times h$  would be a basic mechanism behind biocochemistry. 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.

### 6.1.2 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 [K27].

Morphogenesis provides examples of this kind of phenomena [I2, I3, I5]. The first key idea is that DNA and cell replication is induced by the replication of MBs serving as information carriers (see <http://tinyurl.com/ydg6okkk>) [K27]. The second key idea is that in ZEO MB is 4-dimensional and represents behavioral patterns rather than only 3-dimensional patterns.

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

1. The first approach to this problem relies on a self-organization paradigm in which the local dynamics of cells leads to large scale structures as self-organization patterns. In TGD framework 3-D self-organization is replaced with 4-D self-organization (the failure of strict determinism of the classical dynamics is essential motivating zero energy ontology (ZEO)). One can speak about 4-D healing: expressing it in somewhat sloppy manner, the space-time surface serving as a classical correlate for the patient is as a whole replaced with the healed one: after the 4-D healing process the organism was never ill in geometrical sense! Note that in quantal formulation one must speak of quantum superposition of space-time surfaces.
2. Second approach could be seen as computational. The basic idea is that the process is guided by a template of the target state and morphogenesis and healing are computational processes. What Levin calls morphogenetic fields would define this template. It is known that organisms display a kind of coordinate grid providing positional information that allows cells to “decide” about the profile of genetic expression (for references see [I3]). 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.

### 6.1.3 $h_{gr} = h_{eff}$ hypothesis

Nottale [E1] introduced originally the notion of gravitational Planck constant  $\hbar_{gr} = GMm/v_0$ , where  $M$  is large mass such as that of Earth or Sun and  $m$  the mass of quantum coherent object and  $v_0$  is a parameter with dimensions of velocity [E1]. Nottale did not propose macroscopic quantum coherence in astrophysical scales but in TGD framework this is a natural option [K18, K14].

The obvious question is whether the gravitational Planck constant deduced from the Nottale's considerations and the effective Planck constant  $h_{eff} = n \times h$  deduced from ELF effects on vertebrate brain and explained in terms of non-determinism of Kähler action could be identical. At first this seems to be non-sensical idea since  $\hbar_{gr} = GMm/v_0$  has a gigantic value. The hypothesis  $h_{eff} = \hbar_{gr}$  leads to much stronger predictions [K34, K33] than either hypothesis alone. One can also introduce analogs of  $\hbar_{gr}$  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  $\hbar_{gr}$  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  $\hbar_{gr}$  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 [K31] 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  $\hbar_{gr}$  associated with Earth-Cooper pair system and assumes that the velocity parameter  $v_0$  appearing in it corresponds to the Earth's rotation velocity around its axis, one obtains correct order of magnitude for the effect requiring  $r \simeq 3.6 \times 10^{14}$ .

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

1. This result allows by Equivalence Principle the identification  $h_{gr} = h_{eff}$  at elementary particle level at least so that the two views about hierarchy of Planck constants would be equivalent. If the identification holds true for larger units it requires that space-time sheet identifiable as quantum correlates for physical systems are macroscopically quantum coherent and gravitation causes this. If the values of Planck constant are really additive, the number of parallel space-time sheets corresponding to non-determinism evolution for the flux tube connecting systems with masses  $M$  and  $m$  is proportional to the masses  $M$  and  $m$  using Planck mass as unit. Information theoretic interpretation is suggestive since hierarchy of Planck constants is assumed to relate to negentropic entanglement very closely in turn providing physical correlate for the notions of rule and concept.
2. That gravity would be fundamental for macroscopic quantum coherence would not be surprising since by EP all particles experience same acceleration in constant gravitational field, which therefore has tendency to create coherence unlike other basic interactions. This in principle allows to consider hierarchy in which the integers  $h_{gr,i}$  are additive but give rise to the same universal dark Compton length.
3. An interesting question is how large systems can behave as coherent units with  $\hbar_{gr} = GMm/v_0$ . In living matter one might consider the possibility that entire organism might be this kind of system. Interestingly, for larger masses the gravitational quantum coherence would be easier. For particle with mass  $m$   $\hbar_{gr}/h > 1$  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 blob 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.

#### 6.1.4 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 [K15, K16]. 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.

#### 6.1.5 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 [J4] (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 [K26]. 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.

## 6.2 MB and biology

MB could play a key role in biology as intentional agent using biological body as motor instrument. MB could even serve as a template for biomolecules and even that fundamental bio-chemical processes are induced by those for MB. Dark cyclotron photons transformed to ordinary photons would be the fundamental control tool of MB. Also reconnection of flux tubes, change of length of flux tubes induced by the change of the value of  $h_{eff} = h_{gr}$ , superconductivity associated with a pair of flux tubes could be fundamental control mechanisms.

### 6.2.1 MB, biophotons, and biochemistry

The model for quantum biology relying on the notions of MB and dark matter as hierarchy of phases with  $h_{eff} = nh$ , and biophotons [K29, K28] identified as decay products of dark photons. The assumption  $h_{gr} \propto m$  becomes highly predictable since cyclotron frequencies would be independent of the mass of the ion.

1. If dark photons with cyclotron frequencies decay to biophotons, one can conclude that biophoton spectrum reflects the spectrum of endogenous magnetic field strengths. In the model of EEG [K4] it has been indeed assumed that this kind spectrum is there: the inspiration came from music metaphors suggesting that musical scales are realized in terms of values of magnetic field strength. The new quantum physics associated with gravitation would also become key part of quantum biophysics in TGD Universe.
2. For the proposed value of  $h_{gr}$  1 Hz cyclotron frequency associated to DNA sequences would correspond to ordinary photon frequency  $f = 3.6 \times 10^{14}$  Hz and energy 1.2 eV just at the lower limit of visible frequencies. For 10 Hz alpha band the energy would be 12 eV in UV. This plus the fact that molecular energies are in eV range suggests very simple realization of biochemical control by MB. Each ion has its own cyclotron frequency but same energy for the corresponding biophoton.
3. Biophoton with a given energy would activate transitions in specific bio-molecules or atoms: ionization energies for atoms except hydrogen have lower bound about 5 eV (<http://tinyurl.com/233vcad>). The energies of molecular bonds are in the range 2-10 eV (<http://tinyurl.com/yccmm7mm>). If one replaces  $v_0$  with  $2v_0$  in the estimate, DNA corresponds to 6.2 eV photon with energy of order metabolic energy currency and alpha band corresponds to 6 eV energy in the molecular region and also in the region of ionization energies.

Each ion at its specific magnetic flux tubes with characteristic palette of magnetic field strengths would resonantly excite some set of biomolecules. This conforms with the earlier vision about dark photon frequencies as passwords.

It could be also that biologically important ions take care of their ionization self. This would be achieved if the magnetic field strength associated with their flux tubes is such that dark cyclotron energy equals to ionization energy. EEG bands labelled by magnetic field strengths could reflect ionization energies for these ions.

It must be made clear that TGD has had an interpretational problem related to the identification of biophotons as decay product of dark photons [K33, K34]. The resolution of this problem

leads to conclusion that both Earth's and galactic MBs control living matter with EEG related by scaling. This would be rather dramatic realization of non-locality.

The problem is following. If one wants bio-photon spectrum to be in visible-UV range assuming that bio-photons correspond to cyclotron photons, one must reduce the value of  $r = h_{gr}B_{end}/mv_0$  for Earth particle system by a factor of order  $k = 2 \times 10^{-4}$ .  $r$  does not depend on the mass of the charged particle. One can replace  $B_{end}$  with some other magnetic field having value which is considerably smaller. One can also increase the value of  $v_0$ .

1. For  $h_{gr}$  determined by Earth's mass and  $v_0 = v_{rot}$ , where  $v_{rot} \simeq 1.55 \times 10^{-6}c$  is the rotation velocity of Earth around its axis and for  $B_{end} \rightarrow B_{gal} = 1$  nT, where  $B_{gal}$  is typical strength of galactic magnetic field, the energy of dark cyclotron energy is 45 eV (UV extends to 124 eV). This is roughly by a factor 50 higher than the lower bound for the range of bio-photon energies. One possibility is that  $B_{gal}$  defines the upper limit of the dark photon energies and has variation range of at least 7 octaves with lower limit roughly 1/50 nT.

One can also consider the possibility  $B_{gal}$  defines lower bound for the magnetic field strengths involved and one has  $v_0 > v_{rot}$ . For sun the rotation velocity at Equator is  $v_{rot} = 2 \times 10^{-5}$  m/s and  $v_0$  is  $v_0 \simeq 5.8 \times 10^{-4}c$ . One has  $v_0/v_{rot} \simeq 29.0$ . If same is true in case of Earth, the value of the energy comes down from 25 eV to 1.6 eV which corresponds to visible wave length.

The assignment of  $B_{gal}$  to gravitational flux tubes is very natural. Now however the frequencies of dark variants of bio-photons would not be in EEG range: 10 Hz frequency would correspond to  $5 \times 10^{-4}$  Hz with period of 42 min. The time scale of 42 min is however very natural concerning consciousness and could be involved with longer bio-rhythms. Scaled EEG spectrum with alpha band around 46 min naturally assignable to diurnal sub-rhythms could be a testable prediction. Natural time would be sidereal (galactic) time with slightly different length of day and this allows a clear test. Recall the mysterious looking finding of Spottiswoode that precognition seems to be enhanced at certain time of sidereal day [J5]. Cyclotron frequency 1 Hz would correspond to 7 hours. One can ask whether 12 hours (25) is the natural counterpart for the cyclotron frequency 1 Hz assignable to DNA. This would correspond to lower bound  $B_{gal} \rightarrow 7B_{gal}/12 \simeq .58$  nT or to  $v_0 \rightarrow 1.7v_0$ .

2. The idea has been that it is dark EEG photons, which correspond to bio-photons. Could one assign bio-photons also to dark EEG so that magnetic fields of Earth and galaxy would correspond to two different control levels? If  $B_{end} = .2$  Gauss is assumed to determine the scale of the magnetic field associated with the flux tubes carrying gravitational flux tubes, one must reduce  $h_{gr}$ . The reduction could be due to  $M \rightarrow M_D = kM$  and due to the change of  $v_0$ .  $k$  could characterize the dark matter portion of Earth but this assumption is not necessary.

This would require  $k = M_{dark,E}/M_E \simeq 5 \times 10^{-5}$  if one does not change the value of  $v_0$ . This value of  $k$  equals to the ratio of  $B_{gal}/B_{end}$  and would be 1/4th of  $k = 2 \times 10^{-4}$ . One might argue that it is indeed dark matter to which the gravitational flux tubes with large value of Planck constant connect biomatter.

3. Suppose that one does not give up the idea that also Earth mass gives rise to  $h_{gr}$  and scaled analog of EEG. Then  $M_D$  must correspond to some mass distinguishable from and thus outside Earth. The simplest hypothesis is that a spherical layer around Earth is in question. TGD based model for spherical objects indeed predict layered structures [K23]. There are two separate anomalies in the solar system supporting the existence of a spherical layer consisting of dark mass and with radius equal to the distance of Moon from Earth equal to 60.3 Earth radii [K18]. The first anomaly is so called Flyby anomaly and second one involves a periodic variation of both the value of the measured Newton's constant at the surface of Earth and of the length of the day. The period is about 6 years and TGD predicts it correctly.

One can imagine that dark particles reside at the flux tubes connecting diametrically opposite points of the spherical layer. Particles would experience the sum of gravitational forces summing up to zero in the center of Earth. Although the layer would be almost invisible (or completely invisible by argument utilizing the analogy with conducting shell) gravitationally

in its interior,  $h_{gr} = M_D m / v_0$  would make itself visible in the dynamics of dark particles! This layer could represent magnetic Mother Gaia and EEG would take care of communications to this layer.

The rotation velocity  $v_{rot,M} \simeq 2.1 \times v_{rot,E}$  of Moon around its axis is the first guess for the parameter  $v_0$  identifiable perhaps as rotation velocity of the spherical layer. A better guess is that the ratio  $r = v_0 / v_{rot,M}$  is the same as for Sun and as assumed above for Earth. This would give for the ratio of cyclotron frequency scales  $r = (B_{end} / B_{gal}) \times 2.1$ . 66.7 min, which corresponds to  $B_{gal} = .63$  nT, would correspond to .1 s. For this choice 1 Hz DNA cyclotron frequency would correspond 11.7 h rather near to 12 h. This encourages the hypothesis that 72 min is the counterpart of .1 s cyclotron time. The cyclotron time of DNA (very weakly dependent on the length of DNA double strand) in  $B_{gal}$  (or its minimum value) would be 12 h.

Magnetic body of Earth controlling bio-dynamics would be a dramatic manifestation of non-locality to say nothing about the control performed by galactic magnetic body.  $M_D$  would be associated with the magnetic Mother Gaia making life possible at Earth together with magnetic Mother Galactica. Both MBs would be in continual contact with biomolecules like ATP and the molecules for which ATP attaches or provides the phosphate. Metabolic energy would be used to this process. These MBs would be Goddesses directing its attention to tiny bio-molecules. If this picture is correct, the ideas about consciousness independent on material substrate and assignable to a running computer program can be safely forgotten.

### 6.2.2 Model for the flux tube connections between biomolecules

A more concrete TGD based model for the flux tubes connections between molecules relies on the general ideas of TGD inspired quantum biology [K37].

1. Biomolecules containing aromatic rings are known to play a fundamental role. For instance, most neurotransmitters and psychoactive drugs involve aromatic rings). All DNA nucleotides contain them and there are 4 proteins, which also have them. Trp and phe are of special importance and form a pair structurally analogous to a base pair in DNA strand. The rings are assumed to carry the analog of supra current and be in or at least be able to make transition to a state with large  $h_{eff} = n \times h$ . The delocalization of electron pairs in aromatic ring could be a signature of  $h_{eff} / h > 1$ .
2. Trp-phe pairing [K37] would be responsible for information molecule-receptor pairing. Information molecule and receptor would be at the ends of flux tubes serving as communication lines, and the attachment of info molecule to receptor would fuse the two flux tubes to longer one. After that communication would become possible as dark photon signals and dark supra currents. Formation of info molecule-receptor complex would be like clicking icon generating a connection between computers in net. Info molecules would generate the communication channels - they would not yet be the signals. This distinguishes TGD view from standard neuroscience.
3. All quantum critical phenomena involve generation of large  $h_{eff}$  phases and changes of  $h_{eff}$  in the sense that their values are different at different ends of space-time surface at boundaries of CD. Folding emerges or disappears at QC possible in certain temperature range of width about 40 K and depending on pH. The flux tubes associated with phe and trp containing aromatic rings carrying "supra current" would become dark (either  $h \rightarrow h_{eff}$  or  $h_{eff} > h$  increases) and thus much longer and reconnect temporarily and force phe and trp in a close contact after the reverse transition inducing shortening. This is a general mechanism making biomolecules able to find each other in what looks like molecular soup in the eyes of standard biochemist. The contacts between amino-acids phe and trp formed in this manner would be structurally identical with the hydrogen bonding between members of DNA base pairs and they would fix the final folding pattern to high degree.

### 6.2.3 Pollack's mechanism

The discovery of negatively charged exclusion zone formed in water bounded by gel phase has led Pollack to propose the notion of gel like fourth phase of water [L1, I6, I4] (see <http://tinyurl.com/oyhstc2>). The proposal is that the fourth phase corresponds to negatively charged regions - exclusion zones - with size up to 100-200 microns generated when energy is fed into the water - say as radiation, in particular solar radiation. The stoichiometry of the exclusion zone is  $H_{1.5}O$  and can be understood if every fourth proton is dark proton residing at the flux tubes of the MB assignable to the exclusion zone and outside it [L1] [K37].

This leads to a model for prebiotic cell as exclusion zone. Dark protons are proposed to form dark nuclear strings whose states can be grouped to groups corresponding to DNA, RNA, amino-acids, and tRNA and for which vertebrate genetic code is realized in a natural manner [K13, K8]. The voltage associated with the system defines the analog of membrane potential, and serves as a source of metabolic energy as in the case of ordinary metabolism. The energy is liberated in a reverse phase transition in which dark protons transform to ordinary ones. Dark proton strings serve as analogs of basic biopolymers and one can imagine analog of bio-catalysis with enzymes replaced with their dark analogs.

Pollack's exclusion zones (EZs) might for instance explain why DNA is negatively charged. EZs or their generalization could play fundamental role in metabolism with protons running through mitochondrial membrane being dark as also other biologically important ions involved. EZs could be important even in electrolysis and allow to explain what happens in cold fusion. These hypothesis could be tested.

### 6.2.4 Why metabolism is needed?

The simplest and at the same time most difficult question that innocent student can make about biology class is simple: "Why we must eat?". Or using more physics oriented language: "Why we must get metabolic energy?". The answer of the teacher might be that we do not eat to get energy but to get order. The stuff that we eat contains ordered energy: we eat order. But order in standard physics is lack of entropy, lack of disorder. Student could get nosy and argue that excretion produces the same outcome as eating but is not enough to survive.

We could go to a deeper level and ask why metabolic energy is needed in biochemistry. Suppose we do this in TGD Universe with dark matter identified as phases characterized by  $h_{eff}/h = n$ . At deeper level metabolic energy should closely relate to negentropic entanglement (NE) and thus information. Identification of these two is however not possible. I have considered several answers to the question why metabolic energy is needed. Here two answers will be discussed.

1. Conscious information could be the basic currency and the transfer of metabolic energy and metabolites would make possible transfer of NE. Is the transfer of metabolic energy essentially transfer of NE? Could the transfer of NE require metabolic energy? NE transfer could be transfer of systems consisting of negentropically entangled parts or it could be transfer of NE with larger system, even Earth. NMP would force the systems to fight for NE and this would lead to the fight for metabolic resources. The transfer of entanglement is the basic mechanism in quantum computation and would mean in biology stealing of NE, the fundamental crime! The ideas related to metabolism in TGD Universe are discussed in detail in [K10].
2. Could metabolic energy needed to generate NE from scratch? For this option the molecules providing the metabolic energy contain dark atoms. Of course, the nutrients could already contain the negentropic entanglement and photosynthesis could serve as fundamental generator of NE. The following naive model for dark atoms obtained by replacing  $h$  with  $h_{eff}$  supports this view.
  - (a) The binding energy spectrum of dark hydrogen atom is scaled by  $1/n^2$ ,  $n = h_{eff}/h$  (do not confuse this  $n$  with the integer  $n$  labelling the states of hydrogen atom!) so that generation of dark hydrogen atoms would require energy. Dark atoms have smaller binding energies and their creation by a phase transition increasing the value of  $n$  demands a feed of energy - metabolic energy! If the metabolic energy feed stops,  $n$  is gradually reduced. System gets tired, loses consciousness, and eventually dies. Also in

case of cyclotron energies the positive cyclotron energy is proportional to  $h_{eff}$  so that metabolic energy is needed to generate larger  $h_{eff}$  and prerequisites for negentropy.

- (b) The analogy of weak form of NMP following from mere adelic physics makes it analogous to second law. Could one consider the purely formal generalization of  $dE = TdS - ..$  to  $dE = -TdN - ...$ , where  $E$  refers to metabolic energy and  $N$  refers to entanglement negentropy? No: the situation is different. The system is not closed system;  $N$  is not the negative of thermodynamical entropy  $S$ ; and  $E$  is the metabolic energy feeded to the system, not the system's internal energy.  $dE = TdN - ...$  might however make sense for a system to which metabolic energy is feeded.

The identification of  $N$  is still open:  $N$  could be identified either as  $N = \sum_p N_p - S$ , where one has sum of p-adic entanglement negentropies and real entanglement entropy  $S$  or as  $N = \sum_p N_p$ . For the first option one would have  $N = 0$  for rational entanglement and  $N \geq 0$  for extensions of rationals. Could rational entanglement be interpreted as that associated with dead matter in this case?

- (c) Bio-catalysis and  $ATP \leftrightarrow ADP$  process need not require metabolic energy. A transfer of negentropy from nutrients to ATP to acceptor molecule would be in question. Metabolic energy would be needed to reload ADP with negentropy to give ATP by using ATP synthase as a mitochondrial power plant. Metabolites could be carriers of dark atoms of this kind possibly carrying also NE. They could also carry NE associated with the dark cyclotron states as suggested earlier and in this case the value of  $h_{eff} = h_{gr}$  would be much larger than in the case of dark atoms.
- (d) What is remarkable that the scale of atomic binding energies decreases with  $n$  only in dimension  $D = 3$ . In other dimensions it increases and in  $D = 4$  one cannot even speak of bound states! This can be easily found by a study of Schrödinger equation for the analog of hydrogen atom in various dimensions [L3]. Life based on atomic metabolism seems to make sense only in spatial dimension  $D = 3$ . Note however that there are also other quantum states than atomic states with different dependence of energy on  $h_{eff}$ .

### 6.2.5 Identification of NE possibly transferred in metabolism

I have considered several identifications of NE.

1. NE could be small scale entanglement - say between molecules having dark atoms. The short scale of entanglement does not conform with the large values of  $h_{gr}$ . One can however have also  $h_{eff}/h = h_{em}/h = Z_1 Z_2 \alpha_{em}$ . This would give rise to NE in short scales. The transfer of metabolic energy in  $ATP \leftrightarrow ADP$  process could correspond to the transfer of short ranged NE.
2. NE could be between nutrient and larger structure - say Earth, Sun, or some other large enough structure to give a value of  $h_{gr} = GMm/v_0$  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 [K34]. Also long range entanglement could be present and correspond to a higher evolutionary level. A possible candidate for the larger structure could be a spherical layer at the distance of Moon from Earth would give correct value for  $h_{eff} = h_{gr}$  [K34].

Nutrients could be carriers of both metabolic energy and of NE - both short and long ranged. Even electrons can provide metabolic energy and in TGD framework therefore also NE for some bacteria (see <http://tinyurl.com/o8xqh6g>): in this case only short range entanglement would be involved.

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

information but it would be assignable to the flux tube between phosphate and mass  $M$ . Magnetic Mother Gaia would have very concrete meaning.

### 6.2.6 What happens in bio-catalysis?

Bio-catalysis is key mechanism of biology and its extreme efficacy remains to be understood. Enzymes are proteins and ribozymes RNA sequences acting as biocatalysts.

#### 1. *Conditions on bio-catalysis*

What catalysis demands?

1. Catalyst and reactants must find each other. How this could happen is very difficult to understand in standard biochemistry in which living matter is seen as soup of biomolecules. I have already already considered the mechanisms making it possible for the reactants to find each other. For instance, in the translation of mRNA to protein tRNA molecules must find their way to mRNA at ribosome. The proposal is that reconnection allowing U-shaped magnetic flux tubes to reconnect to a pair of flux tube connecting mRNA and tRNA molecule and reduction of the value of  $h_{eff} = n \times h$  inducing reduction of the length of magnetic flux tube takes care of this step. This applies also to DNA transcription and DNA replication and bio-chemical reactions in general.
2. Catalyst must provide energy for the reactants (their number is typically two) to overcome the potential wall making the reaction rate very slow for energies around thermal energy. The TGD based model for the hydrino atom having larger binding energy than hydrogen atom claimed by Randell Mills [?] suggests a solution [L3]. Some hydrogen atom in catalyst goes from (dark) hydrogen atom state to hydrino state (state with smaller  $h_{eff}/h$  and liberates the excess binding energy kicking the either reactant over the potential wall so that reaction can process. After the reaction the catalyst returns to the normal state and absorbs the binding energy.
3. In the reaction volume catalyst and reactants must be guided to correct places. The simplest model of catalysis relies on lock-and-key mechanism. The generalized Chladni mechanism forcing the reactants to a two-dimensional closed nodal surface is a natural candidate to consider. There are also additional conditions. For instance, the reactants must have correct orientation. For instance, the reactants must have correct orientation and this could be forced by the interaction with the em field of ME involved with Chladni mechanism.
4. One must have also a coherence of chemical reactions meaning that the reaction can occur in a large volume - say in different cell interiors - simultaneously. Here MB would induce the coherence by using MEs. Chladni mechanism might explain this if there is there is interference of forces caused by periodic standing waves themselves represented as pairs of MEs.

#### 2. *Phase transition reducing the value of $h_{eff}/h = n$ as a basic step in bio-catalysis*

Hydrogen atom allows also large  $h_{eff}/h = n$  variants with  $n > 6$  with the scale of energy spectrum behaving as  $(6/n)^2$  if the  $n = 4$  holds true for visible matter. The reduction of  $n$  as the flux tube contracts would reduce  $n$  and liberate binding energy, which could be used to promote the catalysis.

The notion of high energy phosphate bond is somewhat mysterious concept and manifests as the ability provide energy in ATP to ADP transition. There are claims that there is no such bond. I have spent considerable amount of time to ponder this problem. Could phosphate contain (dark) hydrogen atom able to go to the a state with a smaller value of  $h_{eff}/h_i$  and liberate the excess binding energy? Could the phosphorylation of acceptor molecule transfer this dark atom associated with the phosphate of ATP to the acceptor molecule? Could the mysterious high energy phosphate bond correspond to the dark atom state. Metabolic energy would be needed to transform ADP to ATP and would generate dark atom.

Could solar light kick atoms into dark states and in this manner store metabolic energy? Could nutrients carry these dark atoms? Could this energy be liberated as the dark atoms return to

ordinary states and be used to drive protons against potential gradient through ATP synthase analogous to a turbine of a power plant transforming ADP to ATP and reproducing the dark atom and thus the “high energy phosphate bond” in ATP? Can one see metabolism as transfer of dark atoms? Could possible negentropic entanglement disappear and emerge again after  $\text{ADP} \rightarrow \text{ATP}$ .

Here it is essential that the energies of the hydrogen atom depend on  $\hbar_{eff} = n \times h$  in as  $\hbar_{eff}^m$ ,  $m = -2 < 0$ . Hydrogen atoms in dimension  $D$  have Coulomb potential behaving as  $1/r^{D-2}$  from Gauss law and the Schrödinger equation predicts for  $D \neq 4$  that the energies satisfy  $E_n \propto (\hbar_{eff}/h)^m$ ,  $m = 2 + 4/(D - 4)$ . For  $D = 4$  the formula breaks since in this case the dependence on  $\hbar$  is not given by power law.  $m$  is negative only for  $D = 3$  and one has  $m = -2$ . There  $D = 3$  would be unique dimension in allowing the hydrino-like states making possible bio-catalysis and life in the proposed scenario.

It is also essential that the flux tubes are radial flux tubes in the Coulomb field of charged particle. This makes sense in many-sheeted space-time: electrons would be associated with a pair formed by flux tube and 3-D atom so that only part of electric flux would interact with the electron touching both space-time sheets. This would give the analog of Schrödinger equation in Coulomb potential restricted to the interior of the flux tube. The dimensional analysis for the 1-D Schrödinger equation with Coulomb potential would give also in this case  $1/n^2$  dependence. Same applies to states localized to 2-D sheets with charged ion in the center. This kind of states bring in mind Rydberg states of ordinary atom with large value of  $n$ .

The condition that the dark binding energy is above the thermal energy gives a condition on the value of  $\hbar_{eff}/h = n$  as  $n \leq 32$ . The size scale of the dark largest allowed dark atom would be about 100 nm, 10 times the thickness of the cell membrane.

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