About the Nature of Time

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Abstract

This chapter as also other chapters about the notion of time appearing in books about TGD inspired theory of consciousness should be taken as stories about how ideas developed through many tortuous twists and turns. In this abstract I only summarize the outcome and leave the description of the tortuous path to the chapter.

The identification of the experienced time t_e and geometric time t_g involves well-known problems. Physicist is troubled by the reversibility of t_g contra irreversibility of t_e, by the conflict between determinism of Schrödinger equation and the non-determinism of state function reduction, and by the poorly understood the origin of the arrow of t_g. In biology the second law of thermodynamics might be violated in its standard form for short time intervals. Neuroscientist knows that the moment of sensory experience has a finite duration, does not understand what memories really are, and is bothered by the Libet's puzzling finding that neural activity seems to precede conscious decision.

These problems are discussed in the framework of Topological Geometrodynamics (TGD) and TGD inspired theory of consciousness constructed as a generalization of quantum measurement theory. In TGD space-times are regarded as 4-dimensional surfaces of 8-dimensional space-time $H = M^4 \times CP_2$ and obey classical field equations.

The basic notions of consciousness theory are quantum jump and self. Subjective timew as originally identified as a sequence of quantum jumps, which somehow integrate to form single coherent entity, self. Self has as a geometric correlate a fixed volume of H- "causal diamond"- defining the perceptive field of self. This picture leaves however open two key questions. How the arrow of time and localization of contents of sensory experience emerge and what self do really mean? This chapter discusses several approaches to the problem.

The most recent and one might hope also the final proposal involves no ad hoc assumptions and relies on the recent formulation of quantum TGD using zero energy ontology (ZEO) and the understanding of both nature of time and self reduces to a more precise view about what happens in state function reduction in ZEO.

1. The embedding space correlate of self is so called causal diamond (pair of future and past directed light-cones) which is 8-D sub-manifold of the embedding space rather than space-time sheet.
2. In ZEO state function reduction can occur at both boundaries of CD but can occur repeatedly at given CD boundary. In the repeated reduction the already reduced positive/negative energy state remains the same just as the state function remains invariant in ordinary repeated state function reduction. Second boundary of CD corresponds to a wave function in the moduli space of CDs and changes: since the distance between the tips of CD is one particular modular degree of freedom, the average value of this distance tends to increase just as the distance of particle diffusing inside cone increases during diffusion. This gives rise to the experience flow of geometric time identified this temporal distance.
3. Self can be understood as a sequence of repeated state functions at the same boundary - the original identification was as sequence of all quantum jumps. The arrow of geometric time changes at some level of self hierarchy when quantum jump takes at the second boundary of CD and could correspond to volition, act of free will.
4. The notion of negentropic entanglement also leads to a model for self model to be carefully distinguished from self.

1 Introduction

The notion of time remains one of the most problematic concepts of physics. In classical physics the different properties of the time of Newton's equations and thermodynamical time are puzzling. In special relativity and general relativity the notion of simultaneity becomes a problematic concept and challenges the naive Newtonian view about time flow as a motion of 3-D time=constant snapshot of 4-D space-time. The replacement of time=constant 3-surface with past directed light-cone assignable to the world-line of observer resolves this problem. In general relativity the problem is that past light-cones need make sense only locally. In quantum measurement theory the localization of the state function reduction process into a finite space-time volume is in conflict with the determinism of Schrödinger equation. In biology the presence of self-organization processes like self assembly challenge second law of thermodynamics in short time scales. In neuroscience the

finding of Libet suggesting that neural activity seems to precede conscious decision forces to give up the notion of free will or the naive identification of experienced and geometrical time.

In this chapter I will consider a new view about time based on Topological Geometrodynamics [K29], which can be regarded as an attempt to unify fundamental interactions assuming that space-times are representable as 4-dimensional surfaces of certain higher-dimensional space-time $H = M^4 \times CP_2$ (M^4 denotes 4-D Minkowski space and CP_2 complex projective space of 2 complex dimensions) fixed by the requirement that the theory explains standard model symmetries and provides a geometrization of classical gauge fields and gravitational fields.

The construction of quantum TGD leads to a radical revision of space-time concept (many-sheeted space-time and topological field quantization), and forces also to generalize the original view about embedding space. p-Adic physics as physics of cognition is part of TGD inspired theory of consciousness and the need to fuse real and p-adic physics to single coherent whole forces to revise the notions of number and space-time: the outcome seems to be what one could call adelic space-time [K28]. Reals and p-adic number fields together with their extensions are glued together to form a larger structure and same applies to space-time and embedding space. It has been also necessary to replace the standard positive energy ontology with what I call zero energy ontology. These generalizations are of special importance in TGD inspired theory of consciousness and of quantum biology.

There are several first principle approaches to quantum TGD and following gives only a very concise summary of them.

1. Generalization of Einstein's program of geometrizing classical physics so that quantum theory can be seen as a theory of *classical* spinor fields in the world of classical worlds (WCW) consisting of light-like 3-surfaces and possessing Kähler geometry [K6, K31]. By general coordinate invariance (GCI) classical physics becomes an exact part of quantum theory in a well-defined sense. A geometrization of Fermi statistics is obtained, and the Clifford algebra associated with the spinors of WCW can be regarded as a direct sum of von Neumann algebras known as hyper-finite factors of type II_1 (HFFs) closely related to quantum groups and non-commutative geometry.

2. Quantum TGD as almost topological field theory (TQFT) with fundamental objects identified as light-like 3-surfaces and having generalized super-conformal symmetries as symmetries [K5, K4] : the notion of braid is the basic building block of this approach.

3. There are two kinds of conformal symmetries corresponding to the boundary of light-cone of Minkowski space and light-like 3-surfaces, and these symmetries alone dictate to high degree the physics. Quite recently it turned that also a symplectic analog of conformal field theory emerges naturally in TGD framework (super-symplectic symmetries) and this led to a concrete proposal for how to construct n-point functions needed to calculate M-matrix [K25].

   There are two new elements [K25]. The first one is the generalization of twistors from 4-dimensional to 8-dimensional context made possible by the octonion structure of embedding space. $H = M^4 \times CP_2$ has completely unique twistorial properties. Second new element is actually a revival of the old idea that scattering amplitudes are representations for sequences of algebraic operations - product and co-product defining fundamental 3-vertices - connecting two sets of algebraic objects. The algebraic objects are elements of the Yangian associated with super-symplectic algebra realizes as Noether charges assignable to strings connecting partonic 2-surfaces. Universe would be performing quantum algebraic manipulations.

4. Physics as a generalized number theory involves three different threads corresponding to need fuse real and various p-adic physics to single coherent whole by using a generalization of number concept obtained by gluing reals and various p-adic number fields and their extensions together along rationals and common algebraics [K22] ; the observation that standard model symmetries and dynamics of quantum and classical TGD are to high degree dictated by classical number fields [K23] ; and the ideas inspired by the notion of infinite prime [K21].

5. The identification of WCW Clifford algebra elements as hyper-octonion (subspace of complexified octonions spanned by real unit and octonionic imaginary units multiplied by the commuting additional imaginary unit) valued conformal fields having values in HFF provides

a justification for the concept of number theoretic braid needed both in the fusion of real and p-adic physics and in TGD as almost TQFT approach.

What number theoretic braid is has remained unclear. Now it is however clear that string world sheets belong in a well-defined sense to the intersection of reality and various p-adicities defining adelic embedding space and space-time as its surface. Number theoretic braids identified as boundaries of string world sheets would be very simple: they would consist of segments which are light-like geodesics of embedding space. Whether they can be braided without consisting of this kind of pieces remains unclear.

Discretization is not so simple as one might think: the problem is that standard discretization defines only 0-dimensional objects consisting of points. What I call co-dimension two rule tells how the discretization is achieved for higher-dimensional objects. Partonic 2-surfaces are mapped to a discrete set of points- the ends of string boundaries carrying fermion number, their 3-D light-like orbits are replaced with the boundaries of string world sheets whose defining parameters are algebraic numbers, space-time surfaces in turn are replaced by string world sheets whose parameters are again algebraic numbers. Thus discretizations defined abstraction hierarchy. This brings in mind category theoretical construct of n-objects with $n = 1, 2, 3$ giving three hierarchy levels. Remarkably the hierarchy ends at the third step and string world sheets are the highest dimensional objects that can reside in the intersection of realities and p-adicities.

6. The hierarchy of Planck constants $h_{eff}/h = n$ realizing quantum criticality [K11] in terms of infinite number dark matter phases suggests a generalization of the notion of embedding space by replacing it with a book like structure having as its pages singular coverings and factor spaces of H and allowing to realize geometric correlates for the choice of quantization axis in quantum measurement: the particles at different pages of this book are "relatively dark" since they do not possess local interaction vertices which means a radically new way to interpret dark matter. It has turned out that this generalization is only an auxialiary tool. The proper notion is space-time surface with a structure of n-dimensional covering and the sheets of covering are due to the non-determinism of Kähler action. There are n conformal equivalence classes of space-time surfaces connecting the space-like surfaces at opposite boundaries of causal diamond (CD). One allows not only space-time surface with one such sheet but also those consisting of several sheets and this should lead to charge fractionization.

   There is infinite fractal hierarchy of breakings of super-symplectic symmetry having structure of conformal symmetry: the elements of the sub-algebra have conformal weights are n-ples of those for the full algebra act as gauge symmetries so that it is isomorphic to the entire algebra. There is infinite number of inclusion series for these algebras such that n_i divides n_{i+1} and they correspond to reduction of criticality. Therefore TGD Universe is like a hill at the top of hill at the top of hill....The phase transitions increasing h_{eff} and generating dark matter occur spontaneously. Living systems however tend to stay at criticality defined by particular h_{eff} and the phase transition changing it can be said to mean death of self and its re-incarnation at opposite boundary of CD. In the phase transition some gauge degrees of freedom transform to physical ones. The interpretation is as improvement of measurement resolution. Basically this measurement resolution is cognitive and derives from number theoretic constraints and reflects the character of algebraic extension of p-adic numbers.

7. Zero energy ontology and the notion of finite measurement resolution formulated in terms of inclusions of HFFs fix quantum dynamics highly in terms of Connes tensor product allowing to interpret quantum theory as a square root of thermodynamics [K29, K4]: finite measurement resolution has number theoretic braid as its space-time correlate so that various approaches to TGD are closely related. The hierarchies of super-symplectic symmetry breakings define hierarchies of inclusions for HFFs.

8. Quantum theory of consciousness as a generalization of quantum measurement theory to include observer to the theory [L6].

The article series about TGD and its applications to biology and consciousness [**?**, K26] , [L6, L5, L2, L4, L3, L1] gives an overall view about quantum TGD. In the following I will concentrate

only on the aspects of quantum TGD relevant for the notion of time. I will first describe zero energy ontology and p-adicization program and after that consider the problem of time.

The TGD based vision about how the arrow of geometric time is by no means fully developed and final. I will describe also the approaches which look now partially wrong.

1. What seems clear now is the decisive role of ZEO and hierarchy of CDs, and the fact that the quantum arrow of geometric time is coded into the structure of zero energy states to a high extent. The still questionable but attractively simple hypothesis is that U matrix connects two basis with opposite quantum arrows of geometric time: is this assumption really consistent with what we know about the arrow of time? If this is the case, the question is how the relatively well-defined quantum arrow of geometric time implies the experienced arrow of geometric time. Should one assume the arrow of geometric time separately as a basic property of the state function reduction cascade or more economically- does it follow from the arrow of time for zero energy states?

2. The first idea was that state function reductions occur alternately at the two boundaries of CD. If the reduction occurs at given boundary is immediately followed by a reduction at the opposite boundary, the arrow of time alternates: this does not conform with intuitive expectations: for instance, this would imply that there are two selves assignable to the opposite boundaries!

3. Zero energy states are however de-localized in the moduli space CDs (size of CD plus discrete subgroup of Lorentz group defining boosts of CD leaving second tip invariant). One has quantum superposition of CDs with difference scales but with fixed upper or lower boundary belonging to the same light-cone boundary after state function reduction.

   In standard quantum measurement theory the repetition of state function reduction does not change the state but now it would give rise to the experienced flow of time. Zeno effect indeed requires that state function reductions can occur repeatedly at the same boundary. In these reductions the wave function in moduli degrees of freedom of CD changes. This implies "dispersion" in the moduli space of CDs experienced as flow of time with definite arrow. This view lead to a precise definition of self as sequence of quantum jumps to the reducing to the same boundary of CD.

   Each reduction leaves the passive boundary of CD invariance and also the part of zero energy state associated with it but can induce localization to single CD. The reduction must have some effect on state and it might be that the localization is this effect.

4. This approach codes also the arrow of time at the space-time level: the average space-time sheet in quantum superposition increases in size as the average position of the "upper boundaries" of CDs drift towards future state function reduction by state function reduction.

5. In principle the arrow of time can temporarily change and probably takes place in elementary particle scales and living matter routinely. Phase conjugate laser beam is a non-biological example about reversal of the arrow of time. The act of volition would correspond to the first state function reduction to the opposite boundary so that the reversal of time arrow at some level of the hierarchy of selves would take place in the act of volition.

This vision involves minimal number of assumption and is the most convincing one found hitherto and the challenge is to invent objections in order to develop it in more detail.

In the following different views about how the arrow of time is generated, how self experiences the quantum jumps at lower levels of self hierarchy as a continuous flow of time, and how the contents of sensory experience seem to be localized around a rather narrow interval of geometric time.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L7].

2 The Most Recent Vision About Zero Energy Ontology And P-adicization

The generalization of the number concept obtained by fusing real and p-adics along rationals and common algebraics is the basic philosophy behind p-adicization. One must be able to speak about rational points common to real and various p-adic variants of H. The basic objection is the necessity to fix some special coordinates in turn implying the loss of a manifest general coordinate invariance. The isometries of the embedding space could save the situation provided one can identify some special coordinate system in which isometry group reduces to its discrete subgroup. The loss of the full isometry group could be compensated by assuming that WCW is union over sub- WCW s obtained by applying isometries on basic sub- WCW with discrete subgroup of isometries.

The combination of zero energy ontology realized in terms of a hierarchy of causal diamonds (CDs) and hierarchy of Planck constants providing a description of dark matter and leading to a generalization of the notion of embedding space suggests that it is possible to realize this dream. The article [K29] provides a brief summary about recent state of quantum TGD helping to understand the big picture behind the following considerations.

2.1 Zero Energy Ontology Briefly

1. The basic construct in the zero energy ontology is the space $CD \times CP_2$, where the causal diamond CD is defined as an intersection of future and past directed light-cones with time-like separation between their tips regarded as points of the underlying universal Minkowski space M^4. In zero energy ontology physical states correspond to pairs of positive and negative energy states located at the boundaries of the future and past directed light-cones of a particular CD.

2. CDs form a fractal hierarchy and one can glue smaller CDs within larger CDs. This construction recipe when combined with TGD inspired theory of consciousness allows to understand the asymmetry between positive and negative energies and why the arrow of experienced time corresponds to the arrow of geometric time and why the contents of sensory experience is located to so narrow interval of geometric time. One can imagine evolution to occur as quantum leaps in which the size of the largest CD in the hierarchy of personal CDs increases in such a manner that it becomes sub-CD of a larger CD. p-Adic length scale hypothesis [K29] follows if the values of temporal distance T between tips of CD come in powers of 2^n: $T = 2^n T_0$. This is probably too strong an assumption: a more realistic hypothesis is that the distances are integer multiples of T_0.

   All conserved quantum numbers for zero energy states have vanishing net values. The interpretation of zero energy states in the framework of positive energy ontology is as physical events, say scattering events with positive and negative energy parts of the state interpreted as initial and final states of the event.

3. In the realization of the hierarchy of Planck constants $CD \times CP_2$ is replaced with a Cartesian product of book like structures formed by almost copies of CDs and CP_2s defined by singular coverings and factors spaces of CD and CP_2 with singularities corresponding to intersection $M^2 \cap CD$ and homologically trivial geodesic sphere S^2 of CP_2 for which the induced Kähler form vanishes. The coverings and factor spaces of CDs are glued together along common $M^2 \cap CD$. The coverings and factors spaces of CP_2 are glued together along common homologically non-trivial geodesic sphere S^2. The choice of preferred M^2 as subspace of tangent space of X^4 at all its points and interpreted as space of non-physical polarizations, brings M^2 into the theory also in different manner. S^2 in turn defines a subspace of the much larger space of vacuum extremals as surfaces inside $M^4 \times S^2$.

4. WCW (the world of classical worlds, WCW) decomposes into a union of sub- WCW s corresponding to different choices of M^2 and S^2 and also to different choices of the quantization axes of spin and energy, color isospin and hyper-charge for each choice of this kind. This means breaking down of the isometries to a subgroup. This can be compensated by the fact that the union can be taken over the different choices of this subgroup.

5. p-Adicization requires a further breakdown to discrete subgroups of the resulting sub-groups of the isometry groups but again a union over sub- WCW s corresponding to different choices of the discrete subgroup can be assumed. Discretization relates also naturally to the notion of number theoretic braid.

2.2 WCW Spinor Fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW . The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub- WCW s association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future light-cone M^4_+ is quantized for positive energy states. For negative energy states this happens to the lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that first tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of second tip - or rather the space M^4_+ representing the relative position of the tips- to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [K19]. Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub- WCW s with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M^4_\pm$. These degrees of freedom generalize those of a quantum field in Minkowski space. If the upper tip is assigned with observer, the sub-CDs in the interior of CD correspond to astrophysical objects and M^4_+ as empty Robertson-Walker cosmology predicts automatically cosmic redshift.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [A3]. Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ("orbital") degrees of freedom, which can be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

Is it really possible to speak about zero energy states for a given sector defined by generalized embedding space with fixed M^2 and S^2? Classically this is possible and conserved quantities are well defined. In quantal situation the presence of the light-cone boundaries breaks full Poincare

invariance although the infinitesimal version of this invariance is preserved. Note that the basic dynamical objects are 3-D light-like "legs" of the generalized Feynman diagrams glued together along their ends at generalized vertices.

2.3 Definition Of Energy In Zero Energy Ontology

The approach relying on the two super conformal structures of quantum TGD gives hopes of defining the notion of energy for positive and negative energy parts of the state.

1. CD allows translational invariance only in its interior and since partonic two surfaces are located to the boundary of CD, one can argue that translations assigned to them lead out from CD. One can however argue that if it is enough to assign eigenstates of four-momentum to partons and require that only the total four-momentum generators acts on the physical state by shifting CD. Since total four-momentum vanishes for CD this would mean that wave function in cm degrees of CD is just constant plane wave. Super-conformal invariance would indeed allow to assign momentum eigenstates to the super-conformal representations.

2. A more stringent condition would be that four-momentum generators act as translation like operators on partons themselves. Since light-like 3-surfaces assignable to incoming and outgoing legs of the generalized Feynman diagrams are the basic objects, one can hope of having enough translational invariance to define the notion of energy. If translations are restricted to time-like translations acting in the direction of the future (past) then one has local translation invariance of dynamics for classical field equations inside $\delta M^4_{\pm}$ as a kind of semigroup. Also the M^4 translations leading to interior of X^4 from the light-like 2-surfaces surfaces act as translations. Classically these restrictions correspond to non-tachyonic momenta defining the allowed directions of translations realizable as particle motions. These two kinds of translations can be assigned to super-symplectic conformal symmetries at $\delta M^4_{\pm} \times CP_2$ and and super Super-Kac-Moody type conformal symmetries acting as super-symplectic isometries. Super-symplectic algebra is realized in terms of second quantized spinor fields and covariantly constant modes of right-handed neutrino. Symplectic group has as sub-group symplectic isometries and the Super-Kac-Moody algebra associated with this group and represented in terms of spinor modes localized to string world sheets plays also a key role in TGD.

   Finite M^4 translations to the interior of CD do not respect the shape of the partonic 2-surface. Local M^4 translations vanishing at the boundary of CD however act as Kac-Moody symmetries of the light-like 3-surfaces and reduce physically to gauge transformations: hence one could allow also the deformations of the partonic 2-surface in the interior of the light-like 3-surface. This corresponds to the effective metric 2-dimensionality stating that all information both about the geometry of WCW and quantum physics is carried by the partonic 2-surfaces X^2 resulting as intersections of the light-like 3-surfaces X^3_l and space-like 3-D surfaces X^3 at the boundaries of CD and the distribution of 4-D tangent planes of X^2.

3. The condition selecting preferred extremals of Kähler action is induced by a global selection of $M^2 \subset M^4$ as a plane belonging to the tangent space of X^4 at all its points [K5] and interpreted as a plane of nonphysical polarizations so that direct connection with number theory and gauge symmetries emerges. The M^4 translations of X^4 as a whole in general respect the form of this condition in the interior. Furthermore, if M^4 translations are restricted to M^2, also the condition itself - rather than only its general form - is respected. This observation, the earlier experience with p-adic mass calculations, and also the treatment of quarks and gluons in QCD encourage to consider the possibility that translational invariance should be restricted to M^2 translations so that mass squared, longitudinal momentum and transversal mass squared would be well defined quantum numbers. This would be enough to realize zero energy ontology. Encouragingly, M^2 appears also in the generalization of the causal diamond to a book-like structure forced by the realization of the hierarchy of Planck constant at the level of the embedding space.

4. That the cm degrees of freedom for CD would be gauge like degrees of freedom sounds strange. The paradoxical feeling disappears as one realizes that this is not the case for sub-CDs, which

indeed can have non-trivial correlation functions with either upper or lower tip of the CD playing a role analogous to that of an argument of n-point function in QFT description. One can also say that largest CD in the hierarchy defines infrared cutoff.

2.4 P-Adic Variants Of The Embedding Space And Adelic Structure Of Space-Time And Embedding Space

The need to fuse p-adic physics with TGD emerged originally from the discovery that p-adic mass calculations based on p-adic thermodynamics give excellent predictions for elementary particle masses if one assumes p-adic length scale hypothesis stating that primes near integer powers of 2 are physically favored [K29]. Later came the interpretation of p-adic physics as cognition cognition. The following somewhat technical construction of p-adic variants of the embedding space provides new insights concerning the understanding of the arrow of geometric time.

1. Rational values of p-adic coordinates are non-negative so that light-cone proper time $a_{4,+} = \sqrt{t^2 - z^2 - x^2 - y^2}$ is the unique Lorentz invariant choice for the p-adic time coordinate near the lower tip of CD. For the upper tip the identification of a_4 would be $a_{4,-} = \sqrt{(t-T)^2 - z^2 - x^2 - y^2}$. In the p-adic context the simultaneous existence of both square roots poses additional conditions on T. For 2-adic numbers $T = 2^n T_0$, $n \geq 0$ (or more generally $T = \sum_{k \geq n_0} b_k 2^k$), would allow to satisfy these conditions, which would be one additional reason for $T = 2^n T_0$ implying p-adic length scale hypothesis. The remaining coordinates of CD are naturally (hyperbolic) cosines and sines of the spherical coordinates θ and ϕ (hyperbolic angle $\eta_{\pm,4}$).

2. The existence of the preferred plane M^2 of un-physical polarizations would suggest that 2-D light-cone proper times $a_{2,+} = \sqrt{t^2 - z^2}$ $a_{2,-} = \sqrt{(t-T)^2 - z^2}$ can be also considered. The remaining coordinates would be naturally $\eta_{\pm,2}$ and cylindrical coordinates (ρ, ϕ).

3. The p-adically transcendental values of a_4 and a_2 are literally infinite as real numbers and could be visualized as points in infinitely distant geometric future so that the arrow of time might be said to emerge number theoretically.

4. The selection of the preferred quantization axes of energy and angular momentum unique apart from a Lorentz transformation of M^2 would have purely number theoretic meaning in both cases. One must allow a union over sub-WCWs labeled by points of $SO(1,1)$. This suggests a deep connection between number theory, quantum theory, quantum measurement theory, and even quantum theory of mathematical consciousness.

5. In the case of CP_2 there are three real coordinate patches involved [A4]. The compactness of CP_2 allows to use cosines and sines of the preferred angle variable for a given coordinate patch.

$$\begin{aligned} \xi^1 &= tan(u) exp(i\frac{(\Psi+\Phi)}{2}) cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= tan(u) exp(i\frac{(\Psi-\Phi)}{2}) sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{2.1}$$

   The ranges of the variables u, Θ, Φ, Ψ are $[0, \pi/2], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively. Note that u has naturally only positive values in the allowed range. S^2 corresponds to the values $\Phi = \Psi = 0$ of the angle coordinates.

6. The rational values of the (hyperbolic) cosine and sine correspond to Pythagorean triangles having sides of integer length and thus satisfying $m^2 = n^2 + r^2$ ($m^2 = n^2 - r^2$). These conditions are equivalent and allow the well-known explicit solution [A2]. One can construct a p-adic completion for the set of Pythagorean triangles by allowing p-adic integers which are infinite as real integers as solutions of the conditions $m^2 = r^2 \pm s^2$. These angles correspond to genuinely p-adic directions having no real counterpart. Hence one obtains p-adic continuum also in the angle degrees of freedom. Algebraic extensions of the p-adic numbers bringing

in cosines and sines of the angles π/n lead to a hierarchy increasingly refined algebraic extensions of generalized embedding space. Since the different sectors of WCW directly serve as correlates of selves, this means a direct correlation with the evolution of the mathematical consciousness. Trigonometric identities allow to construct points which in the real context correspond to sums and differences of angles.

7. Negative rational values of the cosines and sines correspond as p-adic integers to infinite real numbers and it seems that one use several coordinate patches obtained as copies of the octant $(x \geq 0, y \geq 0, z \geq 0,)$. An analogous picture applies in CP_2 degrees of freedom.

How the different variants of p-adic embedding space and real embedding space relate to each other? The original guess was that one can speak about real and p-adic space-time sheets and that in intentional action the p-adic space-time sheet transforms to a real one and in the formation of cognitive representation the opposite transformation occurs. The formulation of quantum transition amplitudes to describe this process might be however impossible. Rather, cognition and sensory aspects of the geometric existence are simultaneously present: space-time and embedding space are adelic. This indeed conforms with the success of p-adic mass calculations.

1. What seems clear that there must exist kind of chart mappings between them. The notion of p-adic space-time surface is formulated in [K32]. The idea is that p-adic space-time surfaces are cognitive charts of real space-time surface. Both real and p-adic space-time surfaces satisfy the field equations and are thus preferred extremals of Kähler action. There is discretization due to both number theoretic reasons and the points in discretization correspond to points which are common to reals and p-adic number fields. This includes rationals and algebraic numbers in the extension of p-adic number field.

2. At the level of world of classical worlds (WCW) the discretization would be more abstract since the naïve discretization of higher-dimensional objects can be argued to be zero-dimensional as a point set. The parameters defining the geometric object are rational or in the algebraic extensions of rationals.

3. It is now clear the discretization introduced in [K32] might be too naïve. The above described abstraction applies also to the discretization various objects such as partonic 2-surfaces and their 3-D light-like orbits, string world sheets, space-like 3-surfaces, and space-time surfaces. Co-dimension two rule would apply. Partonic 2-surfaces are replaced with discrete point sets at which the fermion lines identified as boundaries of string world sheets meet. The orbits of partonic 2-surface correspond to fermion lines. Space-time surfaces is discretized to a collection of string world sheets which are in the intersection of reality and p-aicities in the sense that the defining parameters belong are in the algebraic extensions associated with p-adic numbers.

   Concerning the construction of preferred extremals this means strong form of holography. One starts from string world sheets (carrying vanishing induced W boson fields so that em charge for the spinor modes is well-defined) and partonic 2-surfaces and continues them to space-time surfaces satisfying field equations for preferred extremals. These include infinite number of conditions stating that the Noether charges of super-symplectic algebra vanish and that the classical conserved charges correspond to the eigenvalues of quantal charges associated with string world sheets. This guarantees the generalization of AdS/CFT correspondence. The preferred extremal is defined only modulo conformal gauge transformations defining $n = h_{eff}/h$ conformal equivalence classes.

4. All p-adic variants of the space-time surface are present and meet each other along string world sheets, which is like a back of a book. Fermions representing Boolean cognition reside in this intersection and are thus number theoretically universal, which conforms with the fact that the anti-commutation relations for the oscillator operators can be written in a form which does not involve any numbers except unity. One can say that string world sheets and fermions define the fundamental cognitive representations in the intersection of realities and p-adicities. In this intersection also the notion of negentropic entanglement makes sense.

5. One can assign to elementary particles definite value of p-adic prime. For this p-adic prime the p-adic preferred extremal should provide a better representation of real space-time surface than others. The reason could that the classical nondeterminism of Kähler action for them is very similar to the p-adic non-determinism for the p-adic prime involved. 4-D spin glass character of the landscape of maxima of Kähler function together with the fact that ordinary spin glass landscape consisting of minima of free energy allows ultra-metric topology about which p-adic topologies are examples. This suggests that real preferred extremal obeys some p-adic topology in discretization in some length scale range.

3 Zero Energy Ontology, Self Hierarchy, And The Notion Of Time

Consider now the formulation of TGD inspired quantum theory of consciousness [L6] and quantum biology [L5] in terms of zero energy ontology.

One should understand the asymmetry between positive and negative energies and between two directions of geometric time at the level of conscious experience, the correspondence between experienced and geometric time, and the emergence of the arrow of time. One should explain why human sensory experience is about a rather narrow time interval of about.1 seconds and why memories are about the interior of much larger CD with time scale of order life time. One should have a vision about the evolution of consciousness: how quantum leaps leading to an expansion of consciousness occur.

Negative energy signals to geometric past - about which phase conjugate laser light represents an example - provide an attractive tool to realize volitional action as a signal inducing neural activities in the geometric past (this would explain Libet's classical findings), a mechanism of remote metabolism, and the mechanism of declarative memory as communications with geometric past. One should understand how these signals are realized in zero energy ontology and why their occurrence is so rare.

In the following I try to demonstrate that TGD inspired theory of consciousness and quantum TGD proper indeed are in tune.

3.1 Space-Time And Embedding Space Correlates For Selves

Quantum jump as a moment of consciousness, self as a sequence of quantum jumps integrating to self, and self hierarchy with sub-selves experienced as mental images, are the basic notions of TGD inspired theory of consciousness. In the most ambitious vision self hierarchy reduces to a fractal hierarchy of quantum jumps within quantum jumps. Quantum classical correspondence demands selves to have space-time correlates both at the level of space-time and embedding space.

At the level of space-time the first guess for the correlates is as light-like or space-like 3-surfaces. If one believes on effective 2-dimensionality and quantum holography, partonic 2-surfaces plus their 4-D tangent space distribution would code the information about the space-time correlates. By quantum classical correspondence one can also identify space-time sheets as the correlates modulo the gauge degeneracy implied by super-conformal symmetries.

It is natural to interpret CDs as correlates of selves at the level of the embedding space. CDs can be interpreted either as subsets of the generalized embedding space or as sectors of WCW . Accordingly, selves correspond to CDs of the generalized embedding space or sectors of WCW , literally separate interacting quantum Universes. The spiritually oriented reader might speak of Gods. Sub-selves correspond to sub-CDs geometrically. The contents of consciousness of self is about the interior of the corresponding CD at the level of embedding space. For sub-selves the wave function for the position of tip of CD brings in the de-localization of sub- WCW .

The fractal hierarchy of CDs within CDs is the geometric counterpart for the hierarchy of selves: the quantization of the time scale of planned action and memory as $T(k) = 2^k T_0$ suggest an interpretation for the fact that we experience octaves as equivalent in music experience. This assumption is however un-necessarily restrictive. In order to understand interactions between selves one must also allow intersections of CDs. The interactions would correspond to the formation of magnetic flux tubes contacts between the 3-surfaces involving also strings connecting the partonic 2-surfaces and defining string world sheets.

It seems that string world sheets can be identified as the intersection of space-time surfaces in various number fields identified as preferred extremals of Kähler action. They would define the fundamental cognitive representations. Therefore partonic 2-surfaces and string world sheets would serve also as cognitive representation of selves and the negentropic entanglement would be associated the fermions at them serving as correlates of Boolean cognition. To be in the intersection of various number fields would mean in the case of string world sheets and partonic two-surfaces that the parameters characterizing them are algebraic numbers in the extension of p-adic numbers. This suggests that the algebraic continuation to all possible p-adic number fields is not possible. Maybe those p-adic primes for which this is possible characterize the particle. By generalized conformal invariance the algebraic values of conformal moduli of partonic 2-surfaces and string world sheets could define the parameters in question so that the situation would reduce to finite-dimensional one.

3.2 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.

3.3 Conscious Entities And Arrow Of Time In TGD Universe

"Fractality from your blog" posed an interesting question about possible asymmetry between boundaries of causal diamond CD. The answer to the question led to recall once again the incomplete understanding of details about how the arrow of time emerges in zero energy ontology (ZEO).

The basic vision is following.

1. CDs form a fractal scale hierarchy. Zero energy states possess a wave function in moduli degrees of freedom characterizing sizes of CDs as well telling what Lorentz boost leaving boundary invariant are allowed for them. Boosts form by number theoretic constraints a discrete subgroup of Lorentz group defining analogs of lattices generated by boosts instead of translations.

2. The arrow of subjective time maps to that of geometric time somehow. The origin of arrow comes from the fact that state function reductions can occur to either boundary of given CD and reduction creates time-asymmetric state since second boundary of CD is in a quantum superposition of different sizes and there is a superposition of many-particle states with different particles numbers and quantum number distributions. It is possible that each state function reduction leaving the passive boundary intact, involves localization in the moduli space of CDs with second boundary fixed.

3. Subjective existence corresponds to a sequence *of moments of consciousness*: state function reductions at opposite boundaries of CDs. State function reduction localizes either boundary but the second boundary is in a quantum superposition of several locations and size scales for CD. This predicts that the arrow of time is not constant. In fact, there is considerable evidence for the variation of the arrow of time in living systems and Fantappie [J8] introduced long time ago the notion of syntropy to describe his view about the situation.

4. The first very naïve proposal was that state function reductions occur *alternately* to the two boundaries of CD. This assumption would be indeed natural if one considered single fixed CD rather than superposition CDs with different size and state function reduction localizing their either boundary: restriction to single CD was what I indeed did first.

5. This assumption leads to the question about why do we do not observe this alternation of the arrow of time all the time in our personal experience. Some people actually claim to have actually experienced a temporary change of the arrow of time: I belong to them and I can tell that the experience is frightening. But why do we experience the arrow of time as stable in the standard state of consciousness?

One possible way to solve the problem - perhaps the simplest one - is that state function reduction to the same boundary of CD can occur many times repeatedly. This solution is so absolutely trivial that I could perhaps use this triviality to defend myself for not realizing it immediately!

I made this totally trivial observation only after I had realized that also in this process the wave function in the moduli space of CDs change in these reductions. Zeno effect in ordinary measurement theory relies on the possibility of repeated state function reductions. In the ordinary quantum measurement theory repeated state function reductions do not affect the state in this kind of sequence but in ZEO the wave function in the moduli space labelling different CDs with the same boundary could change in each quantum jump. It would be natural that this sequence of quantum jumps give rise to the experience about flow of time? This option would allow the size scale of CD associated with human consciousness be rather short, say.1 seconds. It would allow to understand why we do not observe continual change of arrow of time.

Maybe living systems are working hardly to keep the personal arrow of time un-changed - living creatures try to prevent kettle from boiling by staring at it intensely. Maybe it would be extremely difficult to live against the collective arrow of time.

An objection against this picture as compared to the original one assuming alternate reductions to the opposite boundaries of CD is that is that one can understand state preparation as state function reduction to the opposite boundary. This interpetation makes sense almost as such also in the new picture if the average time period for which the reductions occur to a given boundary is shorter in elementary particles scales than in macroscopic scales characteristic for human consciousness. The approximate reversibility in elementary particle scales can be understood as summing up of the two arrows of time to no arrow at all.

This picture allows also to identify self as a continuous entity as the sequence of state function reductions occurring at the same boundary of CD. The average increase of the temporal distance between the tips of cD defines the life-time of self. The number of reductions would give a measure for the subjectively experienced of life-time of self.

In elementary particle time scales reversibility is a good approximation and this suggests that in elementary particle scales the number of state function reductions at the same boundary of CD is small so that the effects due to the change of the arrow of time cancel on the average.

NMP would eventually force "death" of self since the state function reduction at opposite boundary would generate more negentropy. "Death" of self would mean birth of self asssociated with the opposite boundary of CD. The age of self identified as the proper time distance between the tips would increase in statistical sense even when its arrow can change. The act of volition would have a natural identification as the first state function reduction at the opposite boundary of CD.

This picture raises a series of questions. Do our wake-up periods correspond to sequences of state function reductions for self and are sleeping periods wake-up periods of the self at the opposite boundary of CD? The arrow of geometric time should change at some space-time sheet associated with the self hierarchy. How could one demonstrate this? Are the memories of the "other" self predictions of future from our point of view? Do we sleep in order to get information from future, to remember what the future will be?

How the hierarchy of Planck constants defining a hierarchy of quantum criticalities does relate to this picture? The aging of self having has as a correlate the increase of the size scale of CD. Could this increase be due to the increase of h_{eff} expected to occur spontaneously since it corresponds to a reduction of criticality and therefore to the appearance of new physical degrees of freedom as symplectic gauge degrees of freedom transform to physical ones in gauge symmetry breaking. This is not the case. The time evolution must be analogous to shift in time rather than scaling. This of course corresponds to the QFT view about time evolution.

In the first state function reduction to the opposite boundary of CD however scaling of CD is possible and would correspond to the scaling of CD represented by exponent of infinitesimal scaling operator as in conformal field theories. The emergence of bew physical degrees of freedom suggest increasing perceptive and cognitive capabilities. The increase of h_{eff} could be seen as evolution as also the associated increase of resources of negentropic entanglement suggests. The total increase of h_{eff} measured by the ratio $h_{eff}(final)/h_{eff}(initial)$ could be seen as a measure for the progress per single life period of self.

3.4 Why Sensory Experience Is About So Short Time Interval?

CD picture implies automatically the 4-D character of conscious experience and memories form part of conscious experience even at elementary particle level. Amazingly, the secondary p-adic

time scale of electron is $T = 0.1$ seconds defining a fundamental time scale in living matter. The problem is to understand why the sensory experience is about a short time interval of geometric time rather than about the entire personal CD with temporal size of order life-time. The explanation would be that sensory input corresponds to sub-selves (mental images) with $T \simeq .1$ s at the upper light-like boundary of CD in question. This requires a strong asymmetry between upper and lower light-like boundaries of CDs. Certainly this time scale is only minimal CD time scale assignable to electron and the time evolution of electron self should increase this time scale, which would however increase also in the first state function reduction to the opposite boundary of electronic CD.

The localization of the contents of the sensory experience to the upper light-cone boundary and local arrow of time could emerge as a consequence of self-organization process involving conscious intentional action. Sub-CDs would be in the interior of CD and self-organization process would lead to a distribution of CDs concentrated near the upper or lower boundary of CD. The local arrow of geometric time would depend on CD and even differ for CD and sub-CDs.

1. The localization of contents of sensory experience to a narrow time interval would be due to the concentration of sub-CDs representing mental images near the either boundary of CD representing self.

2. Phase conjugate signals identifiable as negative energy signals to geometric past are important when the arrow of time differs from the standard one in some time scale. If the arrow of time establishes itself as a phase transition, this kind of situations are rare. Negative energy signals as a basic mechanism of volitional action and transfer of metabolic energy would explain why living matter is so special.

3. Geometric memories would correspond to sub-selves in the interior of CD, the oldest of them to the regions near "lower" boundaries of CD. Since the density of sub-CDs is small there geometric memories would be rare and not sharp. A temporal sequence of mental images, say the sequence of digits of a phone number, would correspond to a temporal sequence of sub-CDs.

4. Sharing of mental images corresponds to a fusion of sub-selves/mental images to single sub-self by quantum entanglement: the space-time correlate could be flux tubes connecting space-time sheets associated with sub-selves represented also by space-time sheets inside their CDs.

3.5 The Mechanism Of Self Reference

Self reference is perhaps the most mysterious aspect of conscious experience. When formulated in somewhat loose manner self reference states that self can be conscious about being conscious of something. When trying to model this ability in say computer paradigm one is easily led to infinite regress. In TGD framework a weaker form of self referentiality holds true: self can become conscious that it *was* conscious of something in previous quantum jump(s). Self reference therefore reduces to memory. Infinite regress is replaced with evolution recreating Universe again and again and adding new reflective levels of consciousness. It is however essential to have also the experience that memory is in question in order to have self reference. This knowledge implies that a reflective level is in question.

The mechanism of self reference would reduce to the ability to code information about quantum jump into the geometry and topology of the space-time surface and to the quantum entanglement assignable the fermions. This representation defines an analog of written text which can be read if needed: memory recall is this reading process. The existence of this kind of representations means quantum classical correspondence in a generalized sense: not only quantum states but also quantum jump sequences responsible for conscious experience can be coded to the space-time geometry. The reading of this text induces self-organization process re-generating the original conscious experience or at least some aspects of it (say verbal representation of it). The failure of strict classical determinism for Kähler action is absolutely essential for the possibility to realize quantum classical correspondence in this sense.

Consider now the problem of coding conscious experience to space-time geometry and topology so that it can be read again in memory recall. Let us first list what I believe to know about memories.

1. In TGD framework memories corresponds to sub-CDs inside CDs and are located in geometric past. This means fundamental difference from neuroscience view according to which memories are in the geometric now. Note that standard physicist would argue that this does not make sense: by the determinism of field equations one cannot think 4-dimensionally. In TGD however field equations fail to be deterministic in the standard sense: this actually led to the introduction of zero energy ontology.

2. The reading wakes up mental images which are essentially 4-D self-organization patterns inside sub-CDs in the geometric past. Metabolic energy is needed to achieve this wake up. What is needed is generation of space-time sheets representing the potential images making possible memories.

This picture combined with the mechanism for generating the arrow of psychological time and explaining why sensory experience is located to so short time interval as it is (.1 second, the time scale of CD associated with electron by p-adic length scale hypothesis) allows to understand the mechanism of self reference. It deserves to be mentioned that the discussion with Stephen Paul King in Time discussion group served as the midwife for this step of progress.

1. When the film makes a shift to the direction of geometric past in quantum jump sub-selves representing mental images representing the reaction to the "news" are generated. These correspond to sub-CDs contains space-time surfaces as correlates of sub-selves created and the information contents of immediate conscious experiences is about this region of space-time and embedding space. They are like additional comment marks on the film giving information about what feelings the news from the geometric future stimulated.

2. In subsequent quantum jumps film moves downwards towards geometric past and markings defined in terms of space-time correlates for mental images are shifted backwards with the film and define the coding of information about previous conscious experience. In memory recall metabolic energy is fed to these subsystems and they wake up and regenerate the mental images about the remembered aspect sof the previous conscious experience. This would not be possible in positive energy ontology and if determinism in strict sense of the world would hold true.

3. Something must bring in the essential information that these experiences are memories rather than genuine sensory experiences (say). Something must distinguish between genuine experiences and memories about them. The space-time sheets representing self reference define cognitive representations. If the space-time sheets representing the correlates for self-referential mental images are p-adic, this distinction emerges naturally. That these space-time sheets are in the intersection of real and p-adic worlds is actually enough and also makes possible negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) carrying the conscious information. In TGD inspired quantum biology this property is indeed the defining characteristic of life.

4. There is quite concrete mechanism for the realization of memories in terms of braidings of magnetic flux tubes discussed in [K1].

Interesting questions relate to the role of p-adicity and the realization of the active aspects of consciousness. One can consider also quantum jumps in which the space-time surface inside CD does not suffer mere passive shift downwards but is affected also in the geometric past. The mechanism of intentional action, which could have been inspired by Libet's finding that neuronal activity seems to precede conscious decision, can be understood in terms of negative energy signals sent to the geometric past, where they generate neuronal activity replacing the space-time surface with a new one.

If p-adicity is involved, the possibility seems that comes to mind is that the space-time sheets representing the signal to the geometric past are first generated as p-adic space-time sheets representing intention and transformed in quantum jump to their real counterparts representing the "desire" for action in turn generating the action.

3.6 Can Selves Interact And Evolve?

Interesting questions relate to how dynamical selves are.

1. Is self doomed to live inside the same sub- WCW eternally as a lonely god? This question has been already answered: there are interactions between sub-CDs of given CD, and one can think of selves as quantum superposition of states in CDs with wave function having as its argument the tips of CD, or rather only the second one since T is assumed to be quantized.

2. Is there largest CD in the personal CD hierarchy of self in an absolute sense? Or is the largest CD present only in the sense that the contribution to the contents of consciousness coming from very large CDs is negligible? Long time scales T correspond to low frequencies and thermal noise might mask these contributions. Here however the hierarchy of Planck constants and generalization of the embedding space could come in rescue by allowing dark EEG photons to have energies above thermal energy.

3. Can selves evolve in the sense that the size of CD increases in quantum leaps so that the corresponding time scale $T = 2^k T_0$ of memory and planned action increases? Geometrically this kind of leap would mean that CD becomes a sub-CD of a larger CD - either at the level of conscious experience or in absolute sense. The leap can occur in two senses: as an increase of the largest p-adic time scale in the personal hierarchy of space-time sheets or as increase of the largest value of Planck constants in the personal dark matter hierarchy. At the level of individual organism this would mean emergence of new lower frequencies of generalized EEG and levels of personal dark matter hierarchy with larger value of Planck constant.

3.7 Questions And Answers

Answering to question is the best possible manner to develop ideas in more comprehensible form. In this respect the questions of Hamed at my blog have been especially useful. Many questions below are originally made by him and inspired the objections, many of them discussed also in previous discussions. The answers to these questions have changed during latest years as the views about self and the relation between experienced time and geometric time have developed. The following answers are the most recent ones.

Question: The minimalistic option suggests very strongly that our sensory perception can be identified as quantum measurement assignable to state function reductions for upper or lower boundaries of our personal CD. Our sensory perception does not however jump between future and past boundaries of our personal CD (containing sub-CDS in turn containing...)! Why?

Possible answer: The answer to this question comes from the realization that in ordinary quantum theory state function reductions leaving the reduced state invariant are possible. This must have counterpart in ZEO. In ZEO reduces zero energy states are superpositions of zero energy states associated with CDs with second boundary fixes inside light-cone boundary and the position of the second boundary of CD varying: one can speak about wave function in the moduli space of CDs. The temporal distance between the tips of CD and discrete lattice of the 3-D hyperbolic space defined by the Lorentz boosts leaving second tip invariant corresponds to the basic moduli.

The repeated state function reductions leave both the fixed boundary and parts of zero energy states associated with this boundary invariant. They however induce dispersion in the moduli space and the average temporal distance between the tips of CDs increases. This gives rise to the flow of psychological time and to the arrow of time. Self as counterpart of observer can be identified as a sequence of quantum jumps leaving the fixed boundary of CD invariant. Sensory perception gives information about varying boundary and the fixed boundary creates the experience about self as invariant not changed during quantum jumps.

The repeated reductions must do something for the state and the simplest assumption is that they induce localization in the moduli space of CDs. The time evolution operator inducing the superposition could be analogous to exponent of translation generator appearing in quantum field theories.

Self hierarchy corresponds to the hierarchy of CDs. For instance, we perceive from day to day the - say- positive energy part of a state assignable to this very big CD. Hence the world looks rather stable.

Question: This suggests that our sensory perception actually corresponds to sequences of state function reductions to the two fixed boundaries of CDs of superposition of CDs so that our sensory inputs would alternately be about upper and lower boundaries of personal CDs. Sleep-awake cycle could correspond to a flip flop in which self falls asleep at boundary and wakes up at opposite boundary. Doesn't this lead to problems with the arrow of time?

Possible answer: If we measure time relative to the fixed boundary then the geometric time defined as the average distance between tips in superposition of CDs would increase steadily and we get older also during sleep. Hence we would experience subjective time to increase. Larger CDs than our personal CD for which the arrow of time remains fixed in the time scale of life cycle would provide the objective measure of geometric time.

Question: What is the time scale assignable to my personal CD: the typical wake-up cycle: 24 hours? Or of the order of life span. Or perhaps shorter?

Possible answer: The durations of wake-up periods for self is determined by NMP: death means that NMP favors the next state function to take place at the opposite boundary. The first naïve guess is that the duration of the wake up period is of the same order of magnitude as the geometric time scale of our personal CD. In wake-up state we we would be performing state function reduction repeatedly to say "lower" boundary of our personal CD and sensory mental images as sub-CDs would be concentrated near opposite boundary. During sleep same would happen at lower boundary of CD and sensory mental images would be at opposite boundary (dreams, ...).

Question: Are dreams sensory perceptions with opposite arrow of time or is some sub-self in wake-up state and experiences same arrow of time as we during wake-up state? If the arrow is different in dreams, is the "now" of dreams in past and "past" in the recent of wake-upe state

Possible answer: Here I can suggest an answer based on my own subjective experiences and it would be cautious "yes".

Question: Why we do remember practically nothing about sensory perceptions during sleep period? (Note that we forget actively dream experiences).

Possible answer: That we do not have many memories about sleep and dream time existence and that these memories are unstable should relate to the change of the arrow of personal time as we wake up. Wake-up state should somehow rapidly destroy the ability to recall memories about dreams and sleep state. Wake-up memory recall means communications to geometric past, that is to the boundary of CD which remains fixed during wake-up state. In memory recall for dreams in wake-up state these communications should take place to geometric future. Memory recall of dreams would be seeing to future and much more difficult since the future is changing in each state function reduction so that dream memories are erased automatically during wake-up.

Question: Does the return to childhood at old age relate with this time flip-flop of arrow of time in the scale of life span: do we re-incarnate in biologically death at opposite end of CD with scale of life span?

Possible answer: Maybe this is the case. If this boundary corresponds to time scale of life cycle, the memories would be about childhood. Dreams are often located to the past and childhood.

4 What Does Arrow Of Time Mean At The Level Of Quantum States?

The previous discussion does not touch the question what arrow of time means at the level of quantum states. Therefore the notion of negative energy signal propagating backwards in geometric time crucial for TGD inspired quantum biology remains somewhat fuzzy. The recent progress in the understanding of the basic properties of zero energy states makes it possible to understand what arrow of geometric time and the notion of negative energy state and signals propagating to the direction of geometric past mean at the level of zero energy states. This understanding has surprisingly non-trivial philosophical implications.

4.1 Arrow Of Time As An Inherent Property Of Zero Energy States

The basic idea can be expressed in very conscise form. In positive energy ontology arrow of time characterizes dynamics. In zero energy ontology arrow of time characterizes quantum states.

1. The breaking of time reversal invariance means that zero energy states can be localized with respect to particle number and other quantum numbers only for future or past light-like boundary of CD but not both. M-matrix generalizing $S-$matrix provides the time-like entanglement coefficients expressing the state at the second boundary as quantum superposition of states with well-defined particle numbers and other quantum numbers. But only at the second end of CD since one cannot choose freely the states at both boundaries: if this were the case the counterpart of Schrödinger equation would be completely non-deterministic. This is what the breaking of time reversal symmetry means. It occurs spontaneously and assigns to the arrow of subjective time geometric arrow of time.

   This picture gives a precise meaning to the arrow of geometric time and therefore also for the otherwise fuzzy notion of negative energy signals propagating backwards in space-time playing key role in TGD based models of memory, metabolism, and intentional action [**?**]

2. Quantum jump begins with the unitary U-process between zero energy states generating a superposition of zero energy states. After that follows state function reduction cascade proceeding from the level of CD to the level of sub-CDs forming a fractal hierarchy. The reductions cannot take independently at both light-like boundaries of CD as is also clear from the fact that scattering state leads from a prepared state to a quantum superposition of prepared states.

   The first guess is that the cascade takes place for the second boundary of CD only so that the arrow of geometric time would be same in all scales. This need not be the case always: the geometric arrow of time seems to change in some situations: phase conjugate laser light and spontaneous self-assembly of bio-molecules are good examples about this [K28, **?**]. In fact, one of the defining properties of living matter could be just the possibility that the arrow of geometric time is not same in all scales (size scales of CDs) so that memory, metabolism, and intentional action become possible. In any case, the second end remains a superposition of quantum states.

   The lack of quantum measurements at the second end of space-times could explain why the conscious percepts are sharply localized in time at the second end of CD. This could also allow to understand memories as reductions occurring at the second, non-standard, end of sub-CDs in the geometric past.

3. The correspondence between the reduced state and the quantum superposition of states at the opposite boundary of CD allows an interpretation in terms of logical implication arrow with all statements present in the superposition implying the statement represented by the reduced state. Only implication arrow rather than equivalence is possible unless the M-matrix is diagonal meaning that there are no interactions. If it is possible to diagonalize M-matrix then in diagonal basis one has equivalences. It must be however emphasized that the physically preferred state basis fixed as in terms of eigenstates of density matrix does not allow diagonal M-matrix. Number theoretic conditions required that the density matrix corresponds to fixed algebraic extension of rationals can also make possible the diagonalization without leaving the extension and this condition might be highly relevant in the TGD inspired view about cognition relying on p-adic number fields and their algebraic extensions [K22].

4. In classical logic implication corresponds to the inclusion of subset by subset. In quantum case it corresponds to the inclusion for sub-space of state space. The inclusions of hyperfinite factors (WCW spinors define HFF of type II_1) realize the notion of finite measurement resolution, which would suggest that inclusion arrow has also interpretation in terms of finite measurement resolution.

   All quantum states equivalent with a given state in the resolution used imply it. Finite measurement resolution would mean that there would infinite number of instances always in the quantum superposition representing the rule A $\rightarrow$ B. Ironically, both finite measurement

resolution and dissipation implying the arrow of geometric time and usually regarded as something negative from the point of view of information processing would be absolutely essential element of logical thinking in this framework.

5. Conscious theorem proving would has as correlate to building of sequences zero energy states representing A $\rightarrow$ B, B $\rightarrow$ C, C $\rightarrow$ D with basic building bricks representing simple basic rules. These sequences would represent more complex truths.

4.2 Does State Function-State Preparation Sequence Correspond To Alternating Arrow Of Geometric Time?

The state function reduction at light-like boundary of CD implies de-localization at the opposite boundary. This inspires so fascinating questions.

1. Could the state function reduction process take place alternately at the two boundaries of CD so that a kind of flip-flop in which the arrow of geometric time changes back and forth would result, and have interpretation as an alternating sequence of state function reductions and state preparations in the framework of positive energy ontology?

2. State function reductions are needed for sensory percepts. Could the sleep-wake-up period correspond to this kind of process so that during what we call sleep the past boundary of our personal CD would be in wake-up state? Could dreams and memories represent sharing of mental images of this kind of consciousness? Could it be that in the time scale of entire life cycle death is accompanied by birth at the second boundary of personal CD? Could this quantum physics representation for endless sequence of deaths and rebirths? Could the fact that old people often spend they last years in childhood have interpretation in this framework?

3. State preparation-reduction cycle might characterize only living matter whereas for inanimate matter second choice for the arrow of time would be dominant between two U-processes. TGD based reformulation [K27] of entropic gravity idea of Verlinde [B1] in terms of ZEO does not assume the absence of gravitons and the emergence of space-time. The formulation leads to the proposal that thermodynamical stability selects the arrow of the geometric time and that it could be different for matter and antimatter implying that matter and antimatter reside at different space-time sheets. This would explain the apparent absence of antimatter and also support the view that the arrow alternates only in living matter. Note that state preparation also corresponds to intentional action not possible in the world of standard thermodynamics with fixed arrow of thermodynamical time.

4.3 Or Does "Dispersion" At Second Boundary Of CD Cause Generate The Arrow Of Time?

"Fractality from your blog" posed an interesting question about possible asymmetry between boundaries of causal diamond CD. The answer to the question led to recall once again the incomplete understanding of details about how the arrow of time emerges in zero energy ontology (ZEO).

The basic vision is following.

1. CDs form a fractal scale hierarchy. Zero energy states possess a wave function in moduli degrees of freedom characterizing sizes of CDs as well telling what Lorentz boost leaving boundary invariant are allowed for them. Boosts form by number theoretic constraints a discrete subgroup of Lorentz group defining analogs of lattices generated by boosts instead of translations.

2. The arrow of subjective time maps to that of geometric time somehow. The origin of arrow comes from the fact that state function reductions can occur to either boundary of given CD and reduction creates time-asymmetric state since second boundary of CD is in a quantum superposition of different sizes and there is a superposition of many-particle states with different particles numbers and quantum number distributions.

3. Subjective existence corresponds to a sequence *of moments of consciousness*: state function reductions at opposite boundaries of CDs. State function reduction reduction localizes either boundary but the second boundary is in a quantum superposition of several locations and size scales for CD. This predicts that the arrow of time is not constant. In fact, there is considerable evidence for the variation of the arrow of time in living systems and Fantappie introduced long time ago the notion of syntropy to describe his view about the situation.

4. The first very naïve proposal was that state function reductions occur *alternately* to the two boundaries of CD. This assumption would be indeed natural if one considered single fixed CD rather than superposition CDs with different size and state function reduction localizing their either boundary: restriction to single CD was what I indeed did first.

5. This assumption leads to the question about why do we do not observe this alternation of the arrow of time all the time in our personal experience. Some people actually claim to have actually experienced a temporary change of the arrow of time: I belong to them and I can tell that the experience is frightening. But why do we experience the arrow of time as stable in the standard state of consciousness?

One possible way to solve the problem - perhaps the simplest one - is that state function reduction to the same boundary of CD can occur many times repeatedly. This solution is so absolutely trivial that I could perhaps use this triviality to defend myself for not realizing it immediately!

I made this totally trivial observation only after I had realized that also in this process the wave function in the moduli space of CDs change in these reductions. Zeno effect in ordinary measurement theory relies on the possibility of repeated state function reductions. In the ordinary quantum measurement theory repeated state function reductions do not affect the state in this kind of sequence but in ZEO the wave function in the moduli space labelling different CDs with the same boundary could change in each quantum jump. It would be natural that this sequence of quantum jumps give rise to the experience about flow of time? This option would allow the size scale of CD associated with human consciousness be rather short, say.1 seconds. It would allow to understand why we do not observe continual change of arrow of time.

Maybe living systems are working hardly to keep the personal arrow of time changed - living creatures try to prevent kettle from boiling by staring at it intensely. Maybe it would be extremely difficult to live against the collective arrow of time.

An objection against this picture as compared to the original one assuming alternate reductions to the opposite boundaries of CD is that is that one can understand state preparation as state function reduction to the opposite boundary. This interpetation makes sense almost as such also in the new picture if the average time period for which the reductions occur to a given boundary is shorter in elementary particles scales than in macroscopic scales characteristic for human consciousness. The approximate reversibility in elementary particle scales can be understood as summing up of the two arrows of time to no arrow at all.

4.4 Quantum Dynamics For The Moduli Of CDs And The Arrow Of Geometric Time

How the arrow of geometric time at the level of space-time and embedding space is induced from the arrow of subjective time identified in terms of sequence of quantum jumps forming a fractal hierarchy of quantum jumps within quantum jumps? This is one of the long lasting puzzles of TGD and TGD inspired theory of consciousness.

In zero energy ontology (ZEO) the geometry of CD (I often use the sloppy notation $CD \equiv CD \times CP_2$, where the latter CD is defined as the intersection of future and past directed light-cones) is that of double light-cone (double pyramid) and this must relate closely to the problem at hand. An easy manner to obtain absolute arrow of geometric time at least statistically is to assume that embedding space is $M^4 + \times CP_2$- that is product of future like cone with CP_2. The problem is however that of finding a convincing quantal mechanism generating the arrow of time, and also explaining why the geometric arrow of time sometimes changes from the standard one (say for phase conjugate laser beams).

The latest vision about the generation of the arrow of geometric time the level of embedding space and space-time discussed in previous section involves rather radical features but is consistent with the second law if generalized so that the geometric arrow of time at the level of embedding level alternates as state function reduction takes place alternately at opposite light-like boundaries of a fixed CD. If the partially non-deterministic dynamics at space-time level defines a correlate for the dissipative dynamics of quantum jumps, the arrow of geometric time level at space-time level is constant (space-time surface can assignable to the state function reductions can be seen as folded surface spanned between boundaries of CD) and entropy defines monotonically increasing time coordinate. This is rather radical revision of the standard view but makes definite predictions: in particular syntropic aspects of the physics of living matter [J8] could be assigned with the non-standard direction of geometric time at the space-time level.

This approach however still suffers from a defect. CDs are regarded as completely non-dynamical: once CD is created it remains the same from quantum jump to quantum jump and thus serves as a fixed arena of dynamics. This cannot be the case.

4.4.1 Some questions about CDs and their quantum dynamics

One can raise several questions relating to CDs.

1. CDs are assumed to form a fractal hierarchy of CDs within CDs. The size scale of CD has been argued to come as an integer multiple of CP_2 size scale on basis of number theoretic arguments. One can ask whether CDs can overlap and interact and what interaction means.

2. What is the proper interpretation of CD? Could CD correspond to a spotlight of consciousness directed to a particular region of space-time surface, so that space-time surface need not end at the boundaries of CD as also generalized Feynman diagrammatics mildly suggests? Or do the space-time surfaces end at the boundaries of CD so that CD defines a sub-Universe?

3. Should one assign CD to every subsystem - even elementary particles and fermion serving as their building bricks? Can one identify CD as a carrier of topologically quantized classical fields associated with a particle?

As already noticed the picture based on static CDs is too simplistic. This inspires several questions relating to the possible dynamics of CDs.

1. In ZEO one can in principle imagine a creation of CD from and its disappearance to vacuum. It is still unclear whether the space-time sheets associated with CD restricted to the interior of CD or whether they can continue outside CD.

   For the first option appearance of CD would be a creation of sub-Universe contained by CD. CD could be assigned with any sub-system. For the latter option the appearance of CD would be a generation of spotlight of consciousness directing attention to a particular region of embedding space and thus to the portions of space-time surfaces inside it. Quantum superposition of space-time surfaces is actually in question and should be determined before the presence of CD by vacuum functional. How to describe possible creation and disappearance of CDs quantally, is not clear. For instance, what is the amplitude for the appearance of a new CD from vacuum in given quantum jump?

2. CDs have various moduli and one could assign to them quantum dynamics. The position of cm or either tip of CD in M^4 defines moduli as does also the point of CP_2 defining the origin of complex Eguchi-Hanson coordinates in which $U(2) \subset SU(3)$ acts linearly: these points are in general assumed to be different at the two ends of CD. If either tip of CD is fixed the Lorentz boost leaving the tip fixed, moves the other along constant proper time hyperboloid H^3 and the tessellations defined by the factor space H^3/Γ, where Γ is discrete subgroup of $SL(2,C)$, are favored for number theoretical reasons.

   Quantum classical correspondence inspires the question whether the boost is determined completely by the four-momentum assignable to the positive/negative energy part of zero energy states and corresponds to the four-velocity β defined by the ratio P/M of total four-momentum and mass for the CD in question. It seems that this kind of assumption can be justified only in semiclassical approximation.

3. In ZEO cm degrees of freedom of CD cannot carry Poincare charges. One can however assign the Poincare charges of the positive energy part of zero energy state to a wave function depending on the coordinate differences m_{12} defining the relative coordinate for the tips of the CD.

   The most general option is that the size scale of CD is continuous. This would allow to realize momentum eigen state as the analogs of plane waves as a function of the position m_{12} of the (say) upper tip of CD relative to the lower tip.

   The size scale of CD has been however assumed to be quantized. That is, the temporal distance T between the tips comes as an integer multiple of CP_2 time T_{CP_2}: this scale is about 10^4 Planck lengths so that this discretization has not practical consequences. Discretization is suggested both by the number theoretical vision, the finite measurement resolution, and by the general features of the U-matrix expressible in terms of S-matrix and hermitian square roots of density matrices forming orthonormal basis. U-matrix relates M-matrices associated with CDs with different size scales, which correspond to the Lorentz invariant temporal distance $T_n = nT_{CP_2}$ between the tips. The scaling up of the temporal distance would represent scaling of CD in the rest system defined by the fixed tip thus translating the second tip with integer multiple of T_{CP_2} from T_{n_1} to T_{n_2}.

   A further quantization would relate to the tessellations defined by the subgroups Γ. The counterparts of plane waves for the momentum eigenstates would be defined in a discretized version of Minkowski space obtained by dividing it to a sequence of discretized hyperboloids with proper time distance $a = nT_{CP_2}$ from the lower tip of CD.

4. There is evidence that one can assign a CDs with a fixed size scale to a given particle as secondary p-adic length scale: for electron this size scale would correspond to Mersenne prime M_{127} and frequency 10 Hz defining a fundamental biorhythm. This would give a deep connection between elementary particle physics and physics in macroscopic length scales. The integer multiples of the secondary p-adic length size scale would correspond to integer values of the effective Planck constant.

   A natural interpretation of this scale would be as infrared cutoff so that the wave functions approximating momentum eigenstates and depending on the relative coordinate m_{12} would be restricted in the region between light-cone boundary and hyperboloid $a = M_{127}T_0$. Similar restriction would take place for all elementary particles. For particle with effective Planck constant $\hbar_{eff} = n\hbar_0$ the IR cutoff would be n-multiple of that defined by the secondary p-adic time scale.

4.4.2 Could CDs allow to understand the simultaneous wave-particle nature of quantum states?

One of the paradoxical features of quantum theory is that we observe always particles - even with well-defined momentum - to have rather well-defined spatial orbits. As if spatial localization would occur in quantum measurements always and would be a key element of perception and state function reduction process. This raises a heretic question: could it be possible that the localized particles in some sense have a well-defined momentum. In standard quantum theory this is definitely not possible. The assignment of CD with particle - or any physical system - however suggests that this paradoxical looking assignment is possible. Particle would be localized with respect to (say) the lower tip of CD and de-localized with respect to (say) the upper tip and localization of the lower tip would imply de-localization of the upper tip.

It is indeed natural to assume that either tip of CD - say lower one - is localized in M^4 in state function reduction. Unless one is willing to make additional assumptions, this implies not only the non-prepared character of the state at the upper tip, but also a de-localization of the upper tip itself by non-triviality of M-matrix: one has quantum superpositions of worlds characterized CDs with fixed lower tip. The localization at the lower tip would correspond to the fact that we experience the world as classical. Each zero energy state would be prepared at the either (say lower) end of CD so that its lower tip would have a fixed position in M^4. The unprepared upper tip could have a wave function in the space of all possible CDs with a fixed lower tip.

One could also assign the spinor harmonics of $M^4 \times CP_2$ to the relative coordinates m_{12} and their analogs in CP_2 degrees of freedom. The notion of CD would therefore make possible to realize simultaneously the paricle behavior in position space (localization of the lower tip of CD) and wave like nature of the state (superposition of momentum eigenstates for the upper tip relative to the lower tip).

This vision is only a heuristic guess. One should demonstrate that the average dynamical behavior for coordinate differences m_{12} corresponds to that for a free particle with given four-momentum for a given CD and fixed quantum numbers for the positive energy part of the state.

4.4.3 The arrow of geometric time at the level of embedding space and CDs

In the earlier argument the arrow of geometric time at embedding space level was argued to relate to the fact that zero energy states are prepared only at the either end of CD but not both. This is certainly part of the story but something more concrete would be needed. In any case, the experienced flow of time should relate to what happens CDs but in the proposed model CDs are not affected in the quantum jump. Th is would leave only the drifting of sub-CDs as a mechanism generating the arrow of geometric time at embedding space level. It is however difficult to concretize this option.

Could one understand the arrow of geometric time at embedding space level as an increase of the size of the size of CDs appearing in zero energy state? The moduli space of CDs with a fixed upper/lower tip is without discretization future/past light-cone. Therefore there is more room in the future than in past for a particular CD and the situation is like diffusion in future light-cone meaning that the temporal distance from the tip is bound to increase in statistical sense. This means gradual scaling up of the size of the CD. A natural interpretation would be in terms of cosmological expansion.

There are two options to consider depending on whether the embedding space is $M^4 \times CP_2$ or $M^4_+ \times CP_2$. The latter option allows local Poincare symmetry and is consistent with standard Robertson-Walker cosmology so that it cannot be excluded. The first option leads to Russian doll cosmology containing cosmologies within cosmologies in ZEO and is aesthetically more pleasing.

1. Consider first the $M^4 \times CP_2$ option. At each tip of CD one has arrow of geometric time at the level of embedding space and these arrows are opposite. What does this mean? Do the tips correspond to separate conscious entities becoming conscious alternately in state function reductions? Or do they correspond to a single conscious entity with memories?

   Could sleep awake cycle correspond to a sequence of state function reductions at opposite ends of personal CD? It would seem that we are conscious (in the sense we understand consciousness) only after state function reduction. Could we be conscious and have sensory percepts about the other end of CD during sleep state but have no memories about this period so that we would be living double life without knowing it? Does the unprepared and de-localized part (with respect to m_{12}) of zero energy state contribute to the conscious experience accompanying state function reduction? Holography would suggest that this is not the case.

   If CD corresponds to a spotlight of consciousness, the time span of conscious experience could increase in both time directions for the latter option. The span of human collective consciousness has been increasing in both direction all the time: we are already becoming conscious what has probably happened immediately after the Big Bang. Could this evolution be completely universal and coded to the fundamental physics?

2. If the embedding space is assumed to be $M^4_+ \times CP_2$, one obtains only one arrow of time in the long run. The reason is that the lower tip of any CD sooner or later reaches $\delta M^4_+ \times CP_2$ and further expansion in this direction becomes impossible so that only the expansion of CD to the future direction becomes possible.

4.4.4 Summary

The proposed vision for the dynamics of the moduli of CDs is rather general and allows a concrete understanding of the arrow of geometric time at embedding space level and binds it directly to

expansion of CDs as analog of cosmic expansion. The previous vision about how the arrow of geometric time could emerge at the level of space-time level remains essentially un-changed and allows the increase of syntropy [J8] to be understood as the increase of entropy but for a non-standard correspondence between the arrows of subjective time and the arrow of embedding space time.

Embedding space spinor harmonics characterizing the ground states of the representations of symplectic group of $\delta M^4_{\pm} \times CP_2$ define the counterparts of single particle wave functions assignable to the relative coordinates of the second tip of CD with respect to the one fixed in state function reduction. The surprising outcome is the possibility to understand the paradoxical aspects of wave-particle duality in terms of bi-local character of CD: localization of given tip implies de-localization of the other tip.

4.5 The Arrow Of Geometric Time And The Arrow Of Logical Implication

If physics is mathematics in the sense that there is nothing behind quantum states regarded as purely mathematical objects, Boolean logic must have a direct manifestation in the structure of physical states. Physical states should represent quantal Boolean statements which get their meaning via quantum jumps. In TGD framework WCW ("world of classical worlds") spinor fields represent quantum states of the Universe and WCW spinors correspond to fermionic Fock states for second quantized induced spinor fields at space-time surface. Fock state basis has interpretation in terms of Boolean algebra. In positive energy ontology the problem is that fermion number as a super-selection rule would allow very limited number of Boolean statements to be represented. In ZEO the situation changes.

The fermionic parts of positive and negative energy parts can be seen as quantum superpositions of Boolean statements with fermion number in given mode (equal to 0 or 1) representing yes/no or true/false. Also various spin like quantum numbers associated with oscillator operators have same interpretation. Zero energy state could be seen as quantum superposition of pairs of elements of Boolean algebras associated with positive and negative energy parts of the zero energy state.

The first - and incorrect - interpretation is that zero energy state represents a quantum superposition of equivalent statements $a \leftrightarrow b$ and thus abstraction $A \leftrightarrow B$ involving several instances of A and B. The breaking of time reversal invariance allowing localization to definite fermionic quantum numbers at single end of CD only however implies that quantum states can only represent abstraction of logical implication to $A \rightarrow B$ rather than equivalence. p-Adic physics for various primes pc [**?**]ould represent correlates for cognition and intentionality.

4.6 The Roles Of Sensory Perception And Motor Action In TGD Framework

The attempts to define consciousness rely on two basic approaches. The first approach emphasizes direct sensory awareness and formation of cognitive representations from it (phenomenal consciousness and reflective consciousness). Second approach emphasizes volition, motor plans, and motor actions.

The analogs of sensory representations and motor actions emerge at the fundamental level in quantum TGD without mentioning anything about brain. In ZEO state function reduction is replaced with a cascade of state function reductions corresponding to various scales for CDs forming a fractal hierarchy. State function reduction can take place to either of the opposite boundaries of CD in a given length scale. The reduction at given boundary of CD would always force de-localization of the opposite boundary of CD creating quantum superposition of CDs with various sizes. Also new sub-CDs (correlates for sensory mental images) within the resulting bigger CDs are naturally generated. This would explain the arrow of geometric time at embedding space level but the arrows are opposite at the opposite boundaries of CD.

The reduction to opposite boundaries of CD gives rise to zero energy states related by time reversal at the level of embedding space. If "my" conscious experience corresponds to reductions to either "upper" or "lower" boundary of CD of wake-up cycle defining me, I will experience that the arrow of geometric at the level of embedding space arrow is constant and would be basically

due to the scaling up of the average size of "personal" CD. "Upper" "lower" can be fixed by the arrow of time assignable to large enough CD defining environment.

Standard quantum measurement theory assumes that a state function reduction followed immediately by a new one does not affect the reduced state [this gives rise to so called quantum Zeno effect: quantum monitoring of unstable particle prevents its decay (watched kettle does not boil)]. That repeated state function reduction at given boundary of CD does not affect the part of zero energy state at that boundary resulting in the reduction for given CD would generalize this hypothesis. Note that the the parts of zero energy states at the opposite boundary are affected: in particular, the size scale of CD increases.

If this assumption hold true, the subsequent reductions at the same boundary of CD would effectively correspond to single reduction at the passive boundary of CD, and one would effectively have an alternating sequence of cascades of state function reductions beginning from opposite boundaries of CDs. Note however that there a fractal cascade of reductions beginning from sub-CDs the CD is assumed changing the state in smaller scales.

In TGD framework the counterpart of quantum Zeno effect would be achieved by closing an unstable particle inside small enough CD so that the unitary time evolution restricted to CD would not affect the particle appreciably and state function reductions at boundaries of this CD very rarely would give rise to a final state of decay. Watchdog in this case would be the self to which this CD corresponds to.

4.6.1 Motor action as time reversal of sensory perception

In TGD framework motor action could be seen as a time reversal of sensory perception so that sensory-motor pairing could be seen as fundamental element of all conscious existence. This symmetry is very profound and strong prediction and forces to modify dramatically the beliefs about the arrow of geometric time and its relation to the subjective arrow of time. The variation of the arrow of time would be basic feature of living matter.

Just to fix conventions let us fix arrow of time as the arrow of the embedding space time for a very large CD, maybe of cosmic size scale, so that there is unique time direction corresponding to future.

1. All scales for CDs are possible. For sub-CDs of given CD the experiences associated with sub-CD define mental images of CD and the experience can be assigned with either boundary of sub-CD. Let us tentatively agree that for a given CD "lower" and "upper" boundaries are in future and past when seen from the center point of CD (past and future could be permuted in the convention).

   This choice would conform with the interpretation that motor "me" I_m makes a fuzzy prediction of future as superposition of space-time sheets extending from the lower boundary of CD and sensory "me" I_s generates memories represented by superposition of space-time sheets extending downwards from the upper boundary of CD. I do not quite have the courage to completely exclude the second option in which the roles of motor me and sensory me are changed.

2. With this assumption one can assign to a sub-CD near upper *resp.* lower boundary of sub-CD sensory mental images *resp.* their time reversals. In the interior they would represent memories *resp.* predictions. The larger CD would experience these sub-selves as mental images and interpret them in terms of ordinary sensory percepts *resp.* volitions, decisions, and plans. The primary sensory experience, phenomenal experience, involves generation of negentropic entanglement as the sensory mental image combines as a tensor factor with the existing sequence of mental images forming a sensory representation defining memory. The reading of this sequence of mental images using interaction free quantum measurement gives rise to a conscious memory about the mental image sequence.

3. A prediction, which looks rather strange at first glance, follows. "My" CD would be seat for two selves having their own phenomenal experiences seated at the opposite boundaries of my CD. They would be sensory me I_s assignable to sensory perception and motor me I_m assignable to motor action as time reversed sensory perception and assignable to the opposite boundaries of CD when they are localized in state function reduction. The time reversed

sensory percept is interpreted in terms of predictions, volitions, and plans at least by larger CD having the CD as sub-CD. Sensory and motor "mes" would appear in all scales in the hierarchy of sub-CDs.

4. Since the scale of CDs increases quantum jump by quantum jump on the average and new sub-CDs emerge, the size scale of the largest CD in hierarchy increases and the perceptual fields of the two "me" s associated with it shift towards geometric future *resp.* past of the embedding space. The sub-CDs near the boundaries of largest CD give rise to sensory percepts of the two "me" s involved with the largest CD in the hierarchy. Those in the interior define memories. The flow of time would correspond to the gradual shifting of the upper/lower boundary of largest CD to future/past and generation of sensory mental images (sub-CDs) near the boundary. Same would of course occur for the smaller CDs. The time interval about which memories are about and also the time scale for predictions of future increases since the size of the personal CD is gradually scaled up.

4.6.2 Quantitative considerations

One can make also quantitative questions.

1. What is the average increase of the temporal distance between the tips of CD in a pair of state function reductions to opposite boundaries defining the chronon of subjective experience? The duration of this chronon can depend on the level of the self hierarchy.

   For human sensory consciousness this chronon would naturally correspond to the time scale of about.1 seconds having interpretation as a duration of sensory mental image. Each pair of state function reductions would generate a layer of the sensory mental images at the lower and upper boundary of "our" CD.

   This leaves open the size scale of "our" CD and lifetime would represent only the size scale for the increase of "our" CD during life cycle. This would mean that the durations of consciousness for the two "me" s assignable to "our" CD would be measured using.1 second as a natural unit.

2. What can one say about the size scales of CDs themselves? Since the memories are about the time interval, which is roughly the duration of life cycle at most, the first guess is that the size of personal CD is of the order of duration of life cycle. By the previous argument however only the increase of the distance between the tips of "personal" CD naturally corresponds to the duration of life cycle so that the size scale of personal CD could be much larger. Note that the conscious experiences of I_s and I_m assignable to sensory percepts and motor actions should correspond to sub-CD: s with size scale not much larger than.1 seconds. This is consistent with the interpretation of sensory percepts of I_m as plans, decisions, predictions, and volitions. The sub-CDs with time scale of say years are however possible and would correspond to memories and plans in time scales of years.

3. One can imagine also a fractal hierarchy for the increments ΔT_i of the temporal distance T_i between tips of CDs assignable to single pair of quantum jumps to opposite boundaries of CD in given length scale. $\Delta T = .1$ seconds would not be the only possible duration of chronon. This time scale is however very special since it corresponds to the Mersenne prime M_{127} assignable to electron which corresponds to largest Mersenne prime which does not correspond to completely super-astrophysical p-adic length scale. The smaller Mersenne primes - such as M_{107} and M_{89} could correspond to shorter time scales perhaps assignable to nerve pulse in the case of lightest quarks. All primes characterizing elementary particles could define chronons of this kind serving as clocks. The hierarchy of chronons could mean sensory percepts and motor actions have a fractal hierarchy of resolutions identifiable as kind of abstraction hierarchy.

   The clocks defined by these chronons of duration T_i should be synchronized in the sense that there would $N_{ij} = \Delta T_i/\Delta T_j$ quantum jumps with time increment T_j per single quantum jump with time increment T_i.

   Could various periodic phenomena such as diurnal period of 24 hours defining sleep-awake cycle, annual cycle, and various bio-rhythms such as EEG rhythms, define also chronons?

Could cyclicity which seems to appear at the level of sensory and cognitive mental images relate to this kind of chronons: for instance, after images are a good example about mental images having analog of wake-up-sleep cycle.

4.6.3 Questions

There are also questions about the relation to the functioning of brain.

1. How sleep-awake cycle relates to this picture? The above argument suggest that.1 second time scale rather than 24 hour time scale defines the increase of CD scale assignable to single pair of state function reduction assignable to "me". Therefore the period assignable to single moment of human sensory conscious of the two "me" s would be of order.1 seconds.

   This strongly suggests that due to the lack of sensory input and absence of motor actions we are conscious during sleep but do not have memories from this period. Dreams generated by virtual sensory input to retina would produce memories during sleep state. Revonsuo indeed mentions that according to the reports of subject persons after awakenings sleeping period seems to involve either dreams or sleep mentation. Sleep mentation is very simple during nREM sleep: for instance, repetition of some word of internal speech. Sleep mentation would involve motor actions generating internal speech and in some cases also genuine speech. Also genuine motor actions such as sleep walking are possible.

2. Could the sensory-motor dichotomy have some relation to the right-left dichotomy at the level of brain? Right and left brain hemisphere could naturally correspond to parallel CDs of same size scale. Could right and left brain (or parts of them) organize their wake-up periods as in shift work: if left brain hemisphere is awake right hemisphere sleeps (sensorily perceives the opposite end of its CD) and vice versa, an alternating dominance by either hemisphere results, and one could understand sensory rivalry. The time scale of CDs possibly involved would be much shorter than that of sleep-awake cycle in this case. Interestingly, the duration of hemisphere dominance period in some disorders like schizophrenia is anomalously long.

   The CD containing both these CDs - "entire brain CD" - would be also present. The view of "brain CD" about world represented by entangled right and left negentropic mental images would be analogous to initial and final state and thus contain much more information than given by either right or left hemisphere. In the case of visual mental images this would give rise to stereo vision.

   Could this shift work between parts of right and left hemisphere be realized in several time scales of CDs? Even in the scale corresponding to sleep-awake rhythm? It is known that in case of some birds and mammals, which must be motorially and sensorily active all the time, the brain hemispheres have this kind of shift work in long time scale.

4.7 Trying To Understand The Relationship Between Subjective And Geometric Time

I am trying to improve my understanding about the relationship between subjective and geometric time. Subjective time corresponds to a sequence of quantum jumps at given level of hierarchy of selves having as correlates causal diamonds (CDs). Geometric time is fourth space-time coordinate and has real and p-adic variants. This raises several questions.

1. How the subjective times at various levels of hierarchy relate to each other? Should/could one somehow map sequences of quantum jumps at various levels to real or p-adic time values in order to compare them - as quantum classical correspondence indeed suggests?

2. Subjective existence corresponds to a sequence *of moments of consciousness*: state function reductions at opposite boundaries of CDs. State function reduction reduction localizes either boundary but the second boundary is in a quantum superposition of several locations and size scales for CD.

   There are two obvious problems related to the time experience.

(a) If state function reductions occur alternately- one at time- then it is very difficult to understand why we experience same arrow of time continually: why not continual flip-flop at the level of perceptions. Some people claim to have actually experienced a temporary change of the arrow of time: I belong to them and I can tell that the experience is frightening. Why we experience the arrow of time as constant?

One possible way to solve this problem - perhaps the simplest one - is that state function reduction to the same boundary of CD can occur many times repeatedly. This solution is so absolutely trivial that I could perhaps use this triviality to defend myself for not realizing it immediately! I made this totally trivial observation only after only after I had realized that also in this process the wave function in the moduli space of CDs could change in these reductions. Zeno effect in ordinary measurement theory relies on the possibility of repeated state function reductions. In the ordinary quantum measurement theory repeated state function reductions don't affect the state in this kind of sequence but in ZEO the wave function in the moduli space labelling different CDs with the same boundary could change in each quantum jump. It would be natural that this sequence of quantum jumps give rise to the experience about flow of time? This option would allow the size scale of CD associated with human consciousness be rather short, say.1 seconds. It would also allow to understand why we do not observe continual change of arrow of time. Maybe living systems are working hardly to keep the personal arrow of time changed and that it would be extremely difficult to live against the collective arrow of time.

(b) We experience time as a continuous flow rather than sequence of discrete jumps. Is this a problem or not? One could argue that it is not possible to be conscious about being unconscious so that gaps would not be experienced. But is this so simple? We are indeed able to experience the gap in sensory consciousness caused by sleeping over night (this does not mean we have been unconscious: we just do not remember).

3. Subjective time is certainly not metricizable whereas geometric time is and defines a continuum. But are moments of consciousness well-ordered as the values of real variant of geometric time are? This relates closely to the relationship of subjective time to geometric time. Certainly subjective time does not allow any continuous measure in real sense as geometric time does. One can however map moments of consciousness to integers.

   (a) It would seem natural to be able to say about two moments of consciousness - call them A and B, - whether A is before B or vice versa. Moments of consciousness would be well-ordered and could be mapped to *real* integers. But is this the case always? There is experimental evidence for the fact that consciously experience time ordering does not always correspond to the physical one. This was observed already by Libet (see `http://tinyurl.com/yathqkzv`) for my first attempt to understand these findings [K28]).

   (b) What about p-adic integers as labels for moments of consciousness as suggested by the vision about p-adic space-time sheets as correlates for cognition. Given p-adic integers m and n, one can only say whether the p-adic norm of m is larger than, smaller than, or equal to that of n. One can say that p-adic integers are weakly ordered.

p-Adic integers form a continuum in p-adic topology. Could one map the infinite sequence of quantum jumps already occurred to p-adic integers and in this manner to p-adic continuum instead of real one? Could the p-adic cognitive representations allow to achieve this? If so, the experience about conscious flow of time could be due to the p-adic topology for cognitive representation for the sequence of quantum jumps!

4.7.1 Could p-adic integers label moments of consciousness and explain why we experience conscious flow of time?

Next arguments give a more precise formulation for the idea that p-adic integers might label the sequence of quantum jumps at the level of conscious experience, or rather reflective consciousness involving various representations realized as "Akashic records": NMP and ZEO considerably modify the standard quantum measurement theory).

1. Most p-adic integers expressible as $n = \sum_k n_k p^k$ are infinite in real sense and in p-adic topology they form a continuum. Suppose that the infinite sequence of moments of consciousness that have already taken place can be labelled by p-adic integers and look what might be the outcome.

2. Sounds very strange in ears of real analyst but is true: the integers n and $n + kp^N$, for N large are very near to each other p-adically. In real sense they are very far. This allows to fill the gaps between say integers $n = 1$ and 2 by p-adic integers which are very large in real sense.

3. The p-adic correlate of the sequence of discrete quantum jumps/moments of consciousness would define p-adic continuum which in turn can be mapped to real continuum by canonical identification.

This map sequence of moments of consciousness to p-adic continuum would be nice but maybe tricky for any-one accustomed to think in terms of real topology!

This raises two questions.

1. p-Adic integers are not well-ordered. Could one induced the well-ordering of real time to p-adic context by mapping p-adic time axis to real one in a continuous manner and in this manner achieving mapping of moments of consciousness to real time axis?

2. Could canonical identification $\sum_k n_k p^k \to \sum_k n_k p^{-k}$ map (or its appropriate modification) allow to map p-adic integers to real numbers and in this manner induce real well ordering to the p-adic side. The problem is that real number with finite pinary expansion has second infinite expansion (1=.9999... is example using decimal expansion) so that two p-adic time values correspond to any real time value with finite pinary digits. Should one restrict the consideration to integers with finite number of pinary digits (finite measurement resolution) and select either branch? Could the two branches correspond to real time coordinates assignable to the opposite boundaries of CD defining two conscious selves in this scale?

4.7.2 What happens when I type letters in wrong order?

One can speak about sensory and cognitive orderings of events corresponding to reals and p-adics (for various values prime p or course). The cognitive ordering of events would not be well-ordering if cognition is p-adic. Is there any empirical support for this besides Libet's mysterious looking findings?

Maybe. For instance, as I am typing text I experience that I am typing the letters of the word in the correct order but now and then it happens that the order is changed, even the order of syllables and sometimes even that of short words can change. It is probably easy to cook up a very mundane explanation in terms of neuroscience or even electric circuits from keyboard to computer memory, or computer itself. One can however also ask whether this could reflect the fact that p-adic ordering of the intentions to type letter is not well-ordering and does not always correspond to the real number based order for what happened ?

In TGD Universe writing process involves a sequence of transformations of p-adically realized intention to type a letter to a real action (doing it). At space-time level it is therefore a map from p-adic realm to real realm by a variant of canonical identification crucial in the definition of p-adic manifold concept (see `http://tinyurl.com/ydxw3zvm`) assigning to real preferred extremal of Kähler action a p-adic preferred extremal in finite measurement resolution [K32]).

The variant of canonical identification in question defines chart maps from real to p-adic realm and vice versa, and is defined in such a manner that discrete and rationals in a finite subset of rationals are mapped to themselves and defining intersection of real and p-adic realms.

1. In the case of p-adic integers this subset is characterized by a cutoff telling the power of p below which p-adic integers and real integers correspond to each other as such. For the corresponding moments of consciousness (now intentions to type letter) one has same ordering in both realms. For integers containing higher powers of p a variant of canonical identification mapping p-adics to reals continuously is applied. In this case ordering anomalies can appear.

2. Another pinary cutoff comes from physics: real preferred extremals are mapped to p-adic preferred extremals and vice versa: without the cutoff the p-adic image of real extremal would be continuous but non-differentiable so that field equations would not make sense. The cutoff tells the largest power of p up to which the variant of canonical identification is performed for p-adic integers. Also now ordering anomalies appear if one regards p-adic integers as ordinary integers.

3. For the remaining integers the map is obtained by completing the discrete set of points to a preferred extremal of Kähler action on both real and p-adic sides so that physics enters into the game. This assignment need not be unique and the most natural manner to handle the non-uniqueness is to form quantum superposition of all allowed completions with same amplitude: this effective gauge invariance would be very natural from the point of view of finite resolution and conforms with the vision about inclusions of hyper-finite factors (see `http://tinyurl.com/yaye9z3w`) as a representation for finite measurement resolution giving rise to the analog of dynamical gauge symmetry [K30].

Could the strange inconsistencies between cognitive (sequences of intentions) and sensory time orderings (sequence of typed letters) reflect the fact that the ordering of p-adic integers as real integers is not the same as the ordering of their real images under canonical identification? Could it be possible to test this and perhaps deduce the prime p characterizing p-adic topology of cognitive representation in question?

5 In What Sense The Flow Of Time Could Correspond To The Increase Of The Effective Planck Constant?

I like answering questions. It gives a lot of meaning to the life of a theoretician who is not allowed to enjoy the pleasures of academic existence. Career builder would of course argue that writing again and again similar answers is a waste of time: I should be building social networks to important people instead. This activity however allows to make important observations and little discoveries. This time I answered to the questions relating to non-determinism of Kähler action. How this non-determinism relates to quantum non-determinism? How the non-determinism in elementary particle scales relates to that in biology?

The unexpected fruit was a little might-be discovery: the mechanism generating the arrow of geometric time in zero energy ontology might rely in crucial manner to a sequence of phase transitions increasing the value of Planck constant $h_{eff}/h = n$ and hence the size of the causal diamond (CD) characterized by quantum average temporal distance. Since the second boundary of CD is fixed, the second one moves to future in average sense: hence the flow of experienced time and its arrow. Conscious entities become more intelligent as they age! It became also clear that large h_{eff}/h characterizes many-particle system rather than single particle. This leads to view in which intelligent consciousness involving the experienced about the flow of time emerges as the complexity of the systems measured by the number of fundamental particles increases.

The guess was wrong as such. It seems that the time evolution by repeated state function reductions leaving the state at passive boundary of CD invariant should correspond to localizations in the moduli space for causal diamonds with second boundary fixed. It cannot affect the value of h_{eff} since this would scale up the size of CD and affect also the state at the passive boundary by scaling up the sizes of 3-surfaces.

Rather, this time evolution should be analogous to a sequences of time shifts: the time would be the integer valued proper time distance between the tips of CD and the operator acting on zero energy state would be exponent of energy. Each shift would be followed by a localization in the modular degrees of freedom of CD but no state function reduction would occur since this would change the arrow of time and opposite boundary of CD would become the passive boundary.

The scaling of h_{eff} by integer would define the scaling of CD in the first state function reduction to the opposite boundary. This reduction would be preceded by a unitary time evolution defined by exponent of conformal scaling generator. Of course, this scaling could be also trivial! If one considers only these discrete moments of time one obtains a time evolution consisting of discrete time and it is kind if jumping forth and back with increasing amplitude. The repeated birth

and death of mental image could corresponds to this kind of evolution at the level of conscious experience.

5.1 Background

Quantum classical correspondence suggests that the non-determinism of Kähler action could be correlated for quantum non-determinism. An alternative but not exclusive interpretation is as a correlate for quantum criticality.

5.1.1 The non-determinism of Kähler action and quantum non-determinism

The first question was about the relationship between non-determinism of preferred extremals and quantum non-determinism. As a matter of fact, I like to use the phrase "partial failure of determinism for Kähler action" rather than "non-determinism of Kähler action".

A possible interpretation could be as a correlate for quantum non-determinism. Second interpretation would be in terms of quantum criticality implying non-determinism. I do not know whether the interpretations are actually equivalent.

I certainly do not believe that one could get rid of quantum non-determinism and there is no need for it. The generalisation of quantum-classical correspondence is however natural in ZEO, where basic objects are 4-D surfaces- classical time evolutions serving as space-time correlates for quantal evolutions.

The origin of the failure of classical determinism is following.

1. Kähler action has a huge vacuum degeneracy. For instance, for space-time surfaces, which are maps from M^4 to at most 2-D Lagrangian manifold of CP_2 having by definition vanishing induced Kähler form (configuration space and momentum space are Lagrangian manifolds in the context of classical mechanics) induced Kähler form of course vanishes. These vacuum extremals define an analog of gauge degeneracy of Maxwell action for vacuum extremals. For non-vacuum externals it is expected to be lifted at least partially. Hence 4-dimensional spin glass degeneracy is more appropriate analogy. One could say that classical gravitation breaks the analog of gauge invariance for non-vacuum extremals.

2. For CP_2 type vacuum externals one has also non-determinism, which corresponds directly to Virasoro conditions expressing the light-likeness of 1-D M^4 projection of the CP_2 type vacuum extremal. Now induced Kähler form does not vanish.

3. Zero energy ontology (ZEO) and causal diamond (CD) are essential notions concerning the interpretation but leave these notions as an exercise for the reader. The ends of the vacuum extremal at light-like boundaries of CD are connected by infinite number of vacuum extremals.

   One expects that some of the vacuum degeneracy is present also non-vacuum externals. Part of this degeneracy must be analogous to gauge degeneracy since by strong form of general coordinate invariance implying strong form of holography, only the partonic 2-surfaces and their 4-D tangent space data fix the physics since WCW metric depends only on this data. Hence the interiors of 3-surfaces carry very little information about quantum states.

5.1.2 Identification of gauge degeneracy as hierarchy of broken conformal gauge invariances

The conjecture is that conformal symmetries acting as partially broken gauge symmetries realize this vision. TGD allows several kinds of conformal symmetries, and a huge generalisation of string model conformal symmetries (including Kac-Moody) [K6] but I will not go to this here. Suffice it to say that the generalization of conformal symmetries means replacement of AdS/CFT correspondence with a correspondence which looks intuitively much more realistic [K20], [L11].

Classical conformal charges would vanish for sub-algebra for which the conformal weights are multiples of some integer n, $n = 1, 2, \ldots$. These conditions would give the long-sought-for precise content to the notion of preferred extremal. These conditions would be the classical counterparts of corresponding quantum conditions and define a Bohr orbitology. This hierarchy would correspond to the hierarchy of Planck constants $h_{eff} = n \times h$ and to the hierarchy of dark matters [K11].

There would be infinite number of hierarchies $(1, n_1, n_2, ...n_i, ...)$ such that n_i would divide n_{i+1}. They would correspond to the hierarchies of inclusions of hyper-finite factors of type II_1 (HFFs) [K30]. Included algebra defines measurement resolution, which would thus realized as generalized conformal gauge symmetries. Evolution would correspond to a sequence of symmetry breakings: this is not a new idea but emerges naturally if n serves as a quantum "IQ".

The proposal is that that there is a finite number $n = h_{eff}/h$ of conformal equivalence classes of four-surfaces with fizxed 3-D ends at the opposite boundaries of CD so that the non-determinism with gauge fixing would be finite and would correspond to the hierarchy of Planck constants and hierarchy of conformal symmetry breaking defined by the hierarchy of sub-algebras of various conformal algebras with weights comings as integer multiples of integer $n = 1, 2, , ...$ These n surfaces would be analogous to Gribov copies for gauge conditions in non-Abelian gauge theories.

5.2 The Non-Determinisms Of Particle Physics And Biology

There was also a question about the non-determinism of partcle physics contra that of biology, where it manifests itself as partially free will.

5.2.1 NMP

Before continuing it is good make clear that a new principle is involved: Negentropy Maximization Principle (NMP) [K13]. Also a new kind of entanglement entropy based p-padic norm is involved. This entanglement entropy is negative unlike ordinary entanglement entropy and characterizes two-particle system rather than single particle system. By consistency with quantum measurement theory it corresponds to identical entanglement probabilities $p_i = 1/n$.

Negentropic entanglement is assumed to be associated with pairs of n-sheeted coverings (at least these) defined by the space-time surfaces in n conformal equivalence classes associated with $n = h_{eff}/h$ and connecting same 3-surfaces at the ends of space-time surface. Two systems of this kind can entangle negentropically. The entanglement matrix associated with quantum computation proportional to a unitary matrix gives rise to negentropic entanglement. Also n-partite negentropic entanglement makes sense. Note that for hyper-finite factors of type II_1 the entanglement matrix is strictly unitary.

5.2.2 What could be common for particle physics and biology?

Basically the non-determinism of particle physics and of biology could be essentially the same thing but for living matter whose behave is dictated by dark matter the value of $h_{eff}/h = n$ would be large and make possible macroscopic quantum coherence in spatio-temporal scales, which are longer by factor n. Note that n could characterize macroscopic quantum phase rather than single particle system: this distinction is important as will be found.

The hierarchy of CDs brings additional spatio-temporal scale identified as secondary p-adic scale characterising the minimal size of CD. This size scales like $h_{eff}/h = n$ and one can think of a superposition of CDs with different values of n and that the average value of n measuring the age of self increases during the sequence of quantum jumps. Since n is kind of IQ, NMP says that conscious entities should become wiser as they get older: maybe this is too optimistic hypothesis in the case of human kind but maybe electrons are different! I swear that this interpretation is not due to the fact that I have passed the magic threshold of 60 years when one begins to feel that the aging means growing wisdom. I must confess that the interpretation of experience time flow in terms of increasing h_{eff}/h charactering CD scaling has not come into my mind earlier. One could even consider the possibility that there is no superposition - just a sequence of h_{eff}/h increasing (in average sense) phase transitions, kind of spiritual growth even at the level of elementary particles - or rather, the macroscopic quantum phases.

For instance, for electron characterised by Mersenne prime $M_{127} = 2^{127} - 1$ the minimal CD time scale is .1 seconds (note that it defines a fundamental biorhythm of 10 Hz) and thus macrotemporal. Corresponding size scale is of the order of Earth circumference. This size scale could characterize quite generally the magnetic body of the elementary particle or the magnetic body at which macroscopic quantum phase of particles resides. In both cases there would be a direct connection between elementary particle physics and macroscopic physics becoming manifest in living matter via alpha rhythm for instance.

5.2.3 What distinguishes between particle physics and biology?

There are essential differences between elementary particle physics and biology. The first differences comes from quantum measurement theory in ZEO.

1. The repeated state function reduction does nothing for the state in standard ontology. In TGD the state is invariant only at the second boundary at which the reduction occurs. For second boundary of CD the average value if n increases. This gives rise to the experienced flow of geometric time and the arrow of time. Self exists as long as reductions take place on same boundary of CD and dies as the first reduction to opposite boundary is forced by NMP.

2. In particle physics context one expects that the duration of self identified as a sequence of state function reductions at the same boundary of CD is much shorter than in living matter. Otherwise one would have too strong breaking of reversibility in elementary particle time scales. One could also argue that for visible matter the value of h_{eff} should not change in the first state function reduction to the opposite boundary.

   Here one must be very cautious. The flux tubes connecting the wormhole contacts serving as building bricks of the elementary particle could have very large h_{eff} having the p-adic prime characterizing the elementary particle as a factor and that the dynamics of elementary particles corresponds to the ordinary value of Planck constant as long as this flux tube is not involved. If the flux tubes mediate gravitational interaction scaling the size of the gravitational bound state from the naïvely expected Planck scale to Compton length, the effects on other particle interactions would be negligible as gravitational interactions.

Objections usually help to make the formulations more precise. Now the objection is that the increase of average h_{eff}/h so that particles darken gradually, should have been observed long time ago since reaction rates are independent of Planck constant only the lowest order in h_{eff} that is in classical approximation. The attempt to circumvent this objection leads to two crucial questions?

1. Does h_{eff} characterize elementary particle (or fundamental fermion) or a magnetic/field body of physical system which could be also many-particle system.

   If $h_{eff}/h = n$ corresponds to n-sheeted covering which becomes singular at the ends of space-time surface so that sheets coincide at partonic 2-surfaces representing particles, it seems that large h_{eff} is a phenomenon assignable to the field/magnetic body inside CD rather than particle identified as partonic 2-surface or 3-surface at the end of CD. If so large h_{eff} effects would relate to the dynamics associated with the magnetic/field bodies carrying dark matter.

2. Is darkness single particle phenomenon or many-particle phenomenon? For the latter option elementary particle physics would not be any challenge so that it looks the reasonable option. Note that negentropic entanglement requires at least one pair of (say) electrons and suggests macroscopic quantum phase - say high-T_c super-conductivity or super-fluidity.

   The idea about evolution of many-electron systems at dark magnetic body generating increasing value of h_{eff} makes sense, and would conform with the observation that electrons secondary p-adic time scale defines fundamental bio-rhythm. Dark magnetic bodies carrying dark particles are indeed in key role TGD inspired quantum biology. Bose-Einstein condensates and spontaneously magnetized dark phases at magnetic bodies would conform with the idea that dark matter is many-particle phenomenon.

   Large h_{eff} would not be seen in elementary particle physics. This does not seem to support the idea that sparticles in TGD SUSY might have same p-adic mass scale as particles but be more stable in dark phase (this would be due to the scaling up of the size of CD) [K18]. Note however that in TGD already elementary particles are many-fermion systems so that it might be possible to circumvent this objection.

3. The original formulation for darkness was at single particle level so that h_{eff} characterizes elementary particles rather than many-particle systems. In elementary particle reactions the particles in the same vertex would always have the same value of h_{eff}/h. It was assumed that h_{eff} can change only in 2-vertex analogous to mass insertion vertex.

The previous arguments suggest that darkness makes sense only for many-particle systems so that mass insertion vertex becomes phase transition. These phase transitions would occur routinely in living matter but as phase transitions involving large number of particles. For instance, bio-photons would result from dark photons in this manner. This picture seems to make sense at least at the level of many-particle systems but not necessary for Feynman graphs.

This many-particle aspect would explain at very general level why the search for dark particles has been fruitless.

5.2.4 Could one regard elementary particle as a conscious entity?

The previous considerations support the view that it is macroscopic quantum phases of particles at magnetic flux tubes which can be seen as conscious and intelligent evolving entities experience the flow of time. In the case of single elementary particle previous arguments would suggest that only single state function reduction occurs at given boundary of CD so that the lifetime of elementary particle self would have zero duration! This in accordance with the absence of the arrow of time at elementary particle level. Strictly speaking this does not exclude consciousness but excludes intelligence and experience of time flow.

Could already systems with small particle number, be conscious entities and develop - not necessarily large - $h_{eff}/h > 1$. Hadrons consist of quarks and I have considered the possibility that valence quarks and gluons at the color magnetic body are dark. Also nuclei as many-nucleon systems could be dark. In TGD even elementary particles consist of fundamental fermions so that one can ask whether elementary particles possess some elementary aspects of consciousness identified as the possibility of non-vanishing "biological" life-time. This kind of picture would conform with the idea about consciousness as something emerging as the complexity of the system increases.

The average lifetime of elementary particle as a conscious entity cannot be longer than the life-time of particle in the sense of particle physics. In the case of electron having infinite lifetime as elementary particle the "biological" lifetime must be finite since otherwise the irreversibility would manifest itself as a breaking of time reversal invariance in electron scale. The temporal time scale of CD characterising the dimensions of the magnetic body of the elementary particle is the first order of magnitude estimate for the lifetime of elementary particle self. The "biological death" of electron means state function reduction in the sense of ordinary quantum measurement theory implying for instance localization of electron or giving eigenstate of spin in given quantization direction and these quantum jumps meaning re-incarnations of electron certainly occur.

This time scale could give an idea about the geometric duration of elementary particle self (the growth of the temporal distance between tips of CD during the sequence of reductions or equivalently the increase of n). One expects that Δn is by NMP rather small for single particle systems.

5.2.5 Could thermodynamical breaking of time reversal symmetry relate to the CP/T breaking in particles physics?

Could the "thermodynamical" breaking of time reflection symmetry (T) correspond to the breaking of T as it is observed for elementary particles such as neutral kaon? I think that most colleagues tend to be skeptic about this kind of identification, and so do I.

The point is that particle physicist's T breaking could be purely geometric whereas thermodynamical breaking of T involves the notion of subjective time, state function reduction, and consciousness. One could however ask whether the particle physicist's T could serve as space-time correlate for thermodynamicist's T and whether systems showing CP breaking could be seen as conscious entities in very primitive sense of the word ($n_f/n_i > 1$ but small). An important point is that the time evolution for CDs corresponds to scaling so that usually exponential decay laws are replaced with their hyperbolic variants. Hyperbolic decay laws become an important signature of consciousness. For instance, bio-photon intensity decays in hyperbolic manner.

Consider neutral kaon as example.

1. The mean lifetimes are of long-lived and short lived neutral kaon are $\tau_L = 1.2 \times 10^{-8}$ seconds and $\tau_S = 8.9 \times 10^{-11}$ seconds: the ratio of the time scales is roughly 2^7. This does not conform

with the naïvest guess that the size of CD gives estimate for the duration of elementary particle self (increase of the temporal distance between tips of CD): the estimate would be $_L = 10^{-7}$ seconds from the fact that the mass of neutral kaon is roughly 10^3 times electron mass.

2. This is not too far from the lifetime of K_L^0 but is about 2^7 times longer than the life-time of short-lived kaon. Why K_S would be so short-lived? Could the lifetime be dictated by quark level: the longer time scale could be assigned as secondary p-adic time scale with the p-adic prime $p \simeq 2^k$, $k = 104$, characterising b quark. Could the short life-time be understood in terms of loops involving heavier quarks with shorter lifetimes as conscious entities: they indeed appear in the description of CP/T breaking?

6 Time For Time

I was very happy to find that Sean Carroll in Cosmic Variance (see `http://tinyurl.com/p9pvefz`) gave links to really interesting talks in Time conference arranged by fQXI. I have not been too happy for the elitistic nature of these conferences making impossible the communication of really new theoretical ideas. By listening the brilliant talk [J4] by neuroscientist David Eagleman (see `http://tinyurl.com/credoxs`), I however learned that this conference made possible communication of extremely interesting experimental findings about the relation of the time of physicist to the subjective time. I sincerely hope that my colleagues would listen this talk and realize that there are fascinating problems to be solved. There is simply no theory and therefore no list of dead theories among which graduate student is allowed to choose as in theoretical physics.

Eagleman together with other neuro scientists make distinction between time and subjective time and the experimental work has revealed that this relationship looks very complex and is poorly understood. One of the key realizations forced by TGD inspired theory of consciousness - in a well-defined sense a generalization of quantum measurement theory - is that geometric time (the time of field equations) and subjective time (experienced time) are two different notions. The challenge is to understand how they relate and under what conditions and in what approximation their identification performed routinely my the naïve colleagues is possible. This was an excellent reason for continuing listening and I warmly recommend this for the reader. Also the other lectures might be equally rewarding. In the following I just represent TGD based interpretation of the findings and suggest that the reader would not take it too seriously and would try to build his or her own interpretation.

Eagleman talks about what he calls relativity of subjective time. This has of course nothing to do with the relativity of the geometric time. At the basic level subjective time need not even allow any metric measure (as is the case in TGD where subjective time corresponds to a sequence of quantum jumps).

6.1 Flash-Lag Effect And Its Modification

Eagleman tells first about very simple visual illusion known as flash-lag effect. One rotates a small circle around a circular orbit. As the circle passes the horizontal line there is a flash of light in the middle of the circle. If our perception were ideal the flash would be perceived in the middle of the circle. The circle is perceived to be 5 degrees ahead of the flash.

The first explanation to come in mind is that brain anticipates the motion of the flash and represent it to us in a position in which it would be in nearby future. Eagleman decided to test this proposal and studied three different situations. Two of them correspond to a circle rotating in opposite directions and the third one to a situation in which the circle stops at the position of the flash. The theory predicts that the circle is perceived to be ahead in all situations since the perveiver should not know anything about what happens in future. The surprise was that there was no flash-lag when the circle stopped. As if the brain would know what happens in the nearby future.

This kind of observation is not new. I remember more than a decade old experiment studing the galvanic response created by emotionally very provocative picture appearing as an odd-ball in a series of neutral pictures. This kind of response was observed. The mystery was that it was observed before the picture was seen! The result was of course not taken seriously by serious

scientists. When a serious scientist associates something with the word "parapsychology" he loses totally ability to rational thinking and begins to rage.

The conclusion is that our moment of subjective time seems to have a finite duration about 80 ms and all events that occur in this time interval are associated with one and same moment of subjective time. This time interval would correspond to 12.5 Hz frequency. In TGD framework the interpretation could be in terms of the time scale assignable to causal diamond (CD) identified as intersection of future and past directed light-cones, which serves as embedding space-correlate for the moment of consciousness: this time would be the temporal distance between the tips of CD.

The fractal hierarchy of quantum jumps within quantum jumps (identifiable as with a hierarchy of selves withing selves) has the hierarchy of CDs as an embedding space correlate. For electron the time scale of CD is 100 seconds. What is troubling is that 80 ms corresponds to a time interval which is by 20 per cent shorter. One could of course assign this time scale to some cyclotron frequency in TGD framework but I would be very happy if it would correspond to a time duration of electron's CD.

As Eagleman tells, perception involves gaps. For instance, during saccadic motion necessary for visual consciousness (the explanation in TGD framework is that the conscious experience is associated with nondeterministic change, quantum jump) visual system is not on. We do not however perceive these gaps although we perceive the gaps created by putting lights off. Could it be that the gaps are absent because the 100 ms CDs in the sequences have overlap producing on the average 80 ms intervals without overlap? Could the absence of gaps also tell us that it is retina and various sensory organs which build the fundamental qualia and that brain only constructs a cognitive representation about it decomposing the world to objects with certain properties and names and also builds all kinds of useful associations? This picture applies to all sensory qualia in TGD Universe and one can circumvent various objections against it in terms of TGD view about time.

6.2 We Live In The Past: But In What Sense?

One surprising fact about consciousness is that we live in the past. The justification for this in terms of standard neuroscience, where brain builds both sensory and cognitive representations of the external world, does not require refined arguments.

Neural communications are extremely slow using light-velocity as the standard. The velocities of nerve pulses are between 1-100 m/s as compared with the light velocity 3×10^8 m/s. The communication of the sensory data to brain takes time which can be of order second. The data coming from various sensory organs with varying velocities must be processed and combined to single view about external world at associative cortex. This takes time since it is the slowest signalst that determine the time used for the processing. Eagleman gives a humorous example: tall people should live father in past than the short ones since it takes longer time for neural signals from feet to arrive from cortex to the brain! Different sensory inputs must be also combined together in a realistic manner.

Is the brain really able to meet this enormous challenge? The representation about the external world is not enough: this representation must be also realistic and 80 ms seems to represent the maximum duration of moment of sensory consciousness. Is the velocity of nerve pulses quite too slow to achieve this? And is information processing based on nerve pulse conduction really fast enough?

1. These questions could have been motivation for TGD proposal (or almost-prediction) that sensory organs are seats of primary sensory qualia experienced instantanously.

2. They could have also motivated what proposal that quantum entanglement is needed to bind various parts of the body and brain to form single coherent conscious unit. Quantum entanglement makes possible effective signalling with infinite velocity. Of course, genuine signals are not in question. It is better to speak about macroscopic system behaving like an elementary particle. Dark matter realized as a hierarchy of macroscopic quantum phases with a larger value of Planck constant is what would make this possible.

3. Light velocity is ideal for the communication purposes in the scale of biological body. Could it be that biology might have been stupid enough to miss this kind of an opportunity? Could

it be that neuroscientists are the stupid one and simply on a wrong track? In TGD inspired model dark photons with large value of $\hbar$ (bio-photons would be dark photons transformed to ordinary photons) define a central element both in the communications from sensory organs to brain and to magnetic body and from magnetic body to biological body. At the level of body the communications would be practically instantaneous.

4. Even in Earth length scale the time taken by EEG photons to travel from biological body to the corresponding layear of the magnetic body would still be be of order.1 seconds and the experiments of Libet demonstrate among other things that our sensory data is a fraction of second old. This has nothing to do with the conduction velocity of nerve pulses. The purpose of nerve pulses would be quite different: they would create fundamental memory representations and the model for this is based on DNA as topological quantum computer vision.

   Explaining this would however require TGD based view about memory as 4-D perception: causal diamonds are 4-D objects and our conscious experience is always about 4-D space-time region. For sensory perception the scale of this region is.1 seconds. For the perceptions that we call memories the scale is often years or even decades. Our conscious experience is 4-dimensional. Also our motor actions are essentially 4-dimensional: moment of consciousness replaces 4-D world (or quantum superpositions of them) with a new one: also our geometric past is changed in every moment of consciousness. This view resolves many puzzles related to memory but time is far from mature for the revolution. My hope is that the talks of Time conference could open the minds of at least some young colleagues.

5. The communications with light velocity make possible feedback from brain to sensory organs making possible the building of standardized mental images by using the virtual sensory input from brain to create a charicature. Our brain would be an artist using primary sensory input as a raw material.

6.3 Kublai Khan's Problem And Three More Surprises

Eagleman tells about the problem of emperor Kublai Khan. At that time people did not have internet and being a head of an empire of the size of Asia posed many problems. Kublai Khan used emissars travelling around the empire and bringing news about what happened. The problems was the correct integration of these data: the news about ending of some local war somewhere could arrive before the news telling that it had begun! Brain is faced with a similar problem. When the television came, one of the big problems was thought to be the synchronization of pictures and sound. It however turned out that brain takes care of this problem if the picture and sound to be associated with each other are withing 80 milliseconds. The moment of subjective time has this duration.

That we live in past was the first surprise of neuroscience already discussed. Eagleman tells about three more big surprises of neuroscience.

6.3.1 Time perception recalibrates

The brain must build a logical story about sensory data coming through different sensory channels. To achieve this time perception recalibrates. When one comes from bright sunlight to a dim room, the response function of retina gets slower. This does not however happen at the level of conscious experience. A simple test is a sequence of button clicks causing a flash of light. Experimenter can cheat the subject person by producing the light flash with a delay. Surprisingly, the subject person notices nothing. What is even more surprising that when one adds to the sequence of click-flash pairs an odd-ball for which flash is not delayed, the flash is experienced to take place earlier than clicking! Again a direct evidence for the TGD prediction that our perceptive field is 4-dimensional.

In this kind of situation the natural conclusion of subject person would be that it was not me who did the click. Some other agent caused the flash whereas my own attempt fails. Eagleman suggests that schizophrenia might be a disorder of time perception. Person would attribute his own thoughs sometimes heard as internal voices to some external subjects since the time order is pathological. Maybe. What is known that schizophrenics have very sharp sensory perception which cannot be cheated and that there might be no re-calibration. Eagleman talks about temporal

inflexibility. This is of course just a suggestion as Eagleman emphasizes. I am not enthusiastic about this kind of interpretation: the bicameral views of Jaynes fit much better with the idea that magnetic body uses biological body as sensory receptor and motor instrument.

6.3.2 Time is not one thing

Time perception is much more complex than one might think: it involves many aspects such as duration, simultanety, flicker rate, time ordering. What brain does is the analysis of the sensory imput, and its reconstruction from the resulting small pieces. This is very much what is done in the processing of the raw sound (and also pictures) in movies. This applies also to time perception. In TGD framework also the feedback from brain is essential and basic communications would take place using light. Nerve pulse patterns would serve quite different purpose and are also hopelessly slow for building the percept.

6.3.3 The rate of time flow correlates with the rate of neural metabolism

There is large number of findings supporting the few that the experienced rate for the flow of subjective time correlates with the rate of neural metabolism and therefore with the intensity of consciousness.

1. Slowing down of the subjective time

Slowing down of subjective time flow is familiar to anyone. This can happen in troublesome situation or in so called flow state. Interestingly, also in very boring situations (say waiting for someone to come) the same can happen. From my own experience I would say that the slowing down of subjective time characterizes very intense conscious experiences involving intense concentration. But why it would occur when you are bored: perhaps just because you are so intensely conscious about how boring your life is just now. You are not drowsy: you are inpatient and irritated.

Various explanations have been proposed. The proposal that the slowing down of time is analogous to the slowing down of the magnetic tape reducing the frequencies of sounds fails. Another explanation could be in terms of increased time resolution and also I have proposed this explanation. This explanation was tested.

Eagleman did an experiment which could be also seen as a tongue-in-cheek variant of Galileo's famous experiment in which he dropped various objects from the tower or Pisa and measured the time of fall and observed that it does not depend on the weight of the material object. Eagleman dropped subject persons instead of stones!

First of all Eagleman constructed an instrument which he calls perceptive chronometer producing random sequence of digits. In the simplest situation only single digit appeared alternatively as its positive or negative. As the rate of digits exceeds certain critical rate -presumably rather near to 12.5 Hz under normal circumstances- it becomes impossible to distinguish between subsequent digits: one sees only single fuzzy digit. The critical duration for the digit defines a natural unit of subjective time. The idea is to calibrate the rate of the chronometer in such a way that the subject person is not able to distinguish between digits but that only a small reduction of the digit rate makes this possible. In this kind of situation it is enough to make the person scared and see whether he becomes able to distinguish between subsequent digits.

What Eagleman wanted to test was whether this time resolution increases when a person is really scared. If so, the subjective time measured using this critical unit would be longer in scaring situations. The method of really scaring was ingenious: drop the person from quite high a tower! During the free fall the person first found the critical time resolution of his visual perception which became the time unit used to measure the time of fall. The rate for Person reported his time resolution in two cases: when another person was falling and during own fall. The resolution increased during own fall: the falling time was estimated to be about 36 per cent longer for own falling down using the resolution as a unit.

What does this mean? It seems that the rate of the experienced time flow depends on the level of neural activity. In TGD framework the proper measure of subjective time is single quantum jump (recall that they form fractal hierarchy): this would be the tick of subjective clock. The larger the number of these ticks in a given interval of geometric time, the longer the experienced

time duration is. More abstractly: the number of sub-CDs within CD representing mental images of self would provide a measure for the number of ticks during single CD.

Since metabolic energy is the necessary prerequite for the build-up of sensory and cognitive representations (mental images), the prediction is that the rate with which metabolic energy is used by brain correlates directly with the rate of the experienced time flow. When the subject person is falling from a tower, the rate of brain metabolism is higher than normally so that the observations can be understood in terms of the theory. As a matter fact, the correlation of the subjective duration with neural activity is well-known in neuroscience and Eagleman gives a long list of examples.

2. Odd ball effect

In this experiment the subject person perceives a series of figures. The figures are identical apart from some odd-balls between the repeating ones. The duration of odd-ball is experienced to be longer than that of the repeating picture although it is the same. The explanation would be that brain wants to save energy. Less metabolic energy for repeating items and nore metabolic energy for odd-balls, which literally wake-up the partially sleeping brain. The rate of neural metabolism correlating with the intensity of conscious experience (and number of quantum jumps per unit of geometric time/density of sub-CD: s within CD) seems to correlated directly with the experienced slowing down of time.

To sum up, the findings discussed by Eagleman are not easy to understand in the standard conceptual framework of neuroscience. The basic assumptions of TGD inspired theory of consciousness make the explanation trivial. In particular, the hierarchy of quantum jumps containing quantum jumps (of selves having sub-selves with sub-selves interpreted as mental images of self) and having as an embedding space correlate the hierarchy of CDs within CDs, explains the correlation of neural metabolic energy consumption with the experienced rate for the flow of subjective time. The higher the density of sub-CDs within CD representing mental images, the higher the intensity of conscious experience, the higher the consumption of metabolic energy to build mental images, and the shorter the average time interval taken by given mental image and serving as a natural unit of subjective time and the longer the experienced duration of time interval.

7 Some comments related to quantum measurement theory according to TGD

In the following some comments on quantum measurement theory inspired by FB discussions. The TGD view about time is involved because measurement theory in TGD relies crucially on zero energy ontology (ZEO).

7.1 Does the analog of repeated second quantization take place at the level of WCW?

The world of classical worlds (WCW) is the basic structure of quantum TGD. It can be said to be the space of 3-surfaces consisting of pairs of (not necessarily connected 3-surfaces) at the boundaries of causal diamond (CD) and connected by a not necessarily connected 4-surface. 4- surface defines the interaction between the states associated with the 3-surfaces. The state associated with given 3-surface correspond to WCW spinor and one has modes of WCW spinor fields. WCW decomposes to sub-WCWs assignable to CDs and effectively the universe reduces to CD.

The key idea is that the WCW spinor fields are purely classical spinor fields. No second quantization is performed for them. Second quantization of induced spinor fields at space-time level is however carried out and gamma matrices of WCW anticommuting to its Kähler metric are linear combinations of fermionic oscillator operators.

The classicality of WCW spinor fields looks somewhat problematic.

1. The classicality of WCW spinor fields has implications for quantum measurement theory. State function reduction involves reduction of entanglement between systems at different points of space-time and therefore also many-particle states and second quantization are involved. However, second quantization does not take place at the level of WCW and it

seems that entanglement between two 3-surfaces is not possible. Therefore measurements at WCW level should correspond to localizations not involving a reduction of entanglement. Measurements could not be interpreted as measurements of the universal observable defined by density matrix of subsystem. This looks problematic.

2. At the space-time level second quantization is a counterpart for the formation of many-particle states. Particles are pointlike and one of the outcomes is entanglement between point like particles. Since the point of WCW is essentially point-like particle extended to 3-surface, one would expect that second quantization in some sense takes place at the level of WCW although the theory is formally purely classical.

3. Also the hierarchy of infinite primes suggests an infinite hierarchy of second quantizations. Could it have counterpart at the level of WCW: can WCW spinor field be second quantized and classical simultaneously?

Could the counterpart for the hierarchy of infinite primes and second quantization be realized automatically at WCW level? 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 $WCW = WCW \times WCW = ... = WCW^n = ...$

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 $Z^3 = X^3 \cup Y^3 \in WCW$.

7.2 About the notion of observable

In ordinary quantum theory observables are hermitian operators and their eigenvalues representing the values of observables are real.

In TGD using $M^4 \times CP_2$ picture the gauge coupling strengths are complex and therefore also classical Noether charges are complex. This should be the case also for quantum observables. Total quantum numbers could be still real but single particle quantum numbers complex. I have proposed that this is true for conformal weights and talked about conformal confinement.

Also in ordinary twistor approach virtual particles are on mass shell and thus massless but complex. Same is expected in TGD for 8-momenta so that one obtains particles massive in 4-D sense but massless in 8-D sense: this is absolutely crucial for the generalization of twistor approach to 8-D context. Virtual momenta could be massless in 8-D sense but complex but *total* momenta would be real. This would apply to all quantal charges, which for Cartan algebra are identical with classical Noether charges.

I learned also a very interesting fact about normal operators for which operator and its hermitian conjugate commute. As the author mentions, this trivial fact has remained unknown even for professionals. One can assign to a normal operator real and imaginary parts, which are commuting as hermitian operators so that - according to the standrd quantum measurement theory - they can be measured simultaneously.

For instance, complex values of various charge predicted by twistor lift of TGD would therefore in principle be allowed even without the assumption that the total charges are real (*total* charges as hermitian operators). Combining the two ideas one would have that single particle charges are complex and represented by normal operators and total charges are real and represented by hermitian operators.

7.3 What does amplification process in quantum measurement mean?

Quantum measurement involves an amplification process amplifying the outcome of state function reduction at single particle level to a macroscopic effect. This aspect of quantum measurement theory is poorly understood at fundamental level and is usually though to be unessential concerning the calculation of the predictions of quantum theory.

The intuitive expectation is that the amplification is made possible by criticality - I would suggest quantum criticality - and involves the analog of a phase transition generated by seed. This is like the change for a direction of single spin in magnet at criticality inducing change of the magnetization direction.

Quantum criticality [K7, K8, K9, K10] involves long range fluctuations and correlations for which $h_{eff}/h = n$ serves as a mathematical description in terms of adelic physics in TGD framework. Long range correlations would make possible the classical macroscopic state characterizing the pointer. This large $h_{eff}/h = n$ aspect would naturally correspond to the presence of intelligent observer: h_{eff} indeed closely relates to the description of not only sensory but also cognitive aspects of existence and has number theoretic interpretation as a measure for what might be called IQ of the system.

If this is tge case, one cannot build proper quantum measurement theory in the framework of standard quantum mechanics, which is unable to say anything interesting about cognition and observer. A theory of consciousness is required for this and ZEO based quantum measurement theory is also a theory of consciousness.

7.4 Zero energy ontology and Afshar experiment

Afshar experiment [**?**] challenges Copenhagen and many-universe interpretations (see `http://tinyurl.com/ycsttpb9`) and it is interesting to look how it can be understood in ZEO.

Consider first the experimental arrangement of Afshar.

1. A modification of double slit experiment is in question. One replaces the screen with a lense, which reflects from slit 1 to detector 1' and from slit 2 to detector 2'. Lense thus selects the photon path that is the slit through which the photon came.

   The detected pattern of clicks at detectors consists of two peaks: this means particle behavior. One can say that at single photon level either detector/path/slit is selected.

2. One adds a grid of obstacles to the nodes (zeros) of the interference pattern at imagined screen behind the lense. The photons entering the points of grid are absorbed. Since grid is at nodes of the interference pattern this does not affect the detected pattern, when both slits are open but affects the pattern when either slit is closed (grids points are not nodes anymore). This in turn means wave like behavior. This conflicts with principle of complementary stating that either of these behaviors is realized but not both.

Consider the analysis of the situation in the usual positive energy ontology and assuming that state function reduction occurs at the detectors.

1. Photon wave function Ψ in the region between slits and lense is superposition of two parts: $\Psi = \Psi_1 + \Psi_2$ with Ψ_i assignable to slit $i = 1, 2$. The lense guides Ψ_1 to detector 1 and Ψ_2 to detector 2. State function reduction occurs and Ψ is projected to Ψ_1 or Ψ_2. Either detector 1 or 2 fires and photon path is selected.

   It however seems that state function reduction - choice of the path/slit - can occur only in the region in front of the grid. In the region between slits and grid one should still have $\Psi 1 + \Psi_2$ since for Ψ_i the grid would have effect to the outcome. This effect is however absent. This does not fit with Copenhagen interpretation demanding that the path of photon is selected also behind the grid. This is the problem.

2. What about the interpretation in ZEO? After state function reduction - detection at detector 1 say - the time evolution between opposite boundaries of CD is relaced with a time reversed one. To explain the observations of Afshar (no deterioration of the pattern at detector caused by grid), one must have time evolution in which the photons coming from the detectors in reversed time direction have wave functions which vanish at the points of grid. This determines the "initial" values for the reversed time evolution: they are most naturally at grid so that grid corresponds naturally to a surface at boundary of CD in question. This is of course not the only choice since one can use the determinism of classical field equations to choose the intersection with CD differently. If time reversal symmetry holds true, the final state in geometric past corresponds to a signal coming from slit 1 (in the

case considered as example). There would be no problem! Afshar experiment would be the first laboratory experiment selecting between Copenhagen interpretation and ZEO based quantum measurement theory.

8 Maxwell's demon from TGD viewpoint

In Facebook I received a link to an interesting popular Science News article titled "*A New Information Engine is Pushing the Boundaries of Thermodynamics*" (see `http://tinyurl.com/y74bfrpu`). The article told about the progress in generalizing the conventional second law of thermodynamics to take information as an additional parameter.

Carnot engine is the standard practical application. One has two systems A and B, both in thermal equilibrium but with different temperatures T_A and $T_B \geq T_A$. By second law one has heat flow Q from A to B the two systems, and Carnot's engine transforms some of this heat to work. Carnot's law gives an upper bound for the efficiency of the engine as $\eta \equiv W/Q \leq (T_2 - T_1)/T_2$. The possibility to transform information to work forces to generalize Carnot's law.

Since information is basically conscious information, this generalization is highly interesting from the point of view of quantum theories of consciousness and quantum biology. Certainly the generalization is highly non-trivial. Especially so in standard physics framework, where only entropy is defined at fundamental level and is regarded as ensemble entropy and basically has very little to do with conscious information. Therefore the argumentation is kind of art work.

8.1 Maxwell's demon in its original form

Maxwell's demon (see `http://tinyurl.com/q829my5`) is a thought experiment in which one considers a system consisting of two volumes A and B of gas in thermal equilibrium at same temperature. At the boundary between A and B having a small hole sits a demon checking whether a molecule coming from A has velocity above some threshold: if so it allows the molecule to go to B. Demon monitors also the molecules coming from B and if the velocity is below the threshold it allows the molecule to continue to A. As a consequence, temperature and pressure differences develop between A and B. Pressure difference can do work very much voltage between the cathode and anode of battery. One can indeed add a tube analogous to wire between ends of the entire system and pressure difference causes a flow of mass doing thus work: one has pump.

The result is in conflict with the second law and one can ask what goes wrong. From the Wikipedia article one learns that a lot of arguments have been represented con and pro Maxwell's demon. Biologist might answer immediately. Demon must measure the states of molecules and this requires cognition and memory, which is turn require metabolic energy. When one takes this into account this, paradox should disappear and second law should remain true in a generalized form in which one takes into account the needed metabolic energy.

8.2 Experimental realization of Maxwell's demon

The popular article describes an experiment actualizing Maxwell's demon carried out by Govind Paneru, Dong Yun Lee, Tsvi Tlusty, and Hyuk Kyu Pak (see `http://tinyurl.com/y9sn9j7o`). Below is the abstract of the article *Lossless Brownian Information Engine* published in Phys Rev Letters.

We report on a lossless information engine that converts nearly all available information from an error-free feedback protocol into mechanical work. Combining high-precision detection at a resolution of 1 nm with ultrafast feedback control, the engine is tuned to extract the maximum work from information on the position of a Brownian particle. We show that the work produced by the engine achieves a bound set by a generalized second law of thermodynamics, demonstrating for the first time the sharpness of this bound. We validate a generalized Jarzynski equality for error-free feedback-controlled information engines.

Unfortunately, the article is behind paywall and I failed to find it in arXiv. The popular article uses notions like "particle trapped by light at room temperature" and photodiode as "light trap" without really defining what these expressions mean. For instance, it is said that the light trap

would follow particles moving in definite direction (from A to B in Maxwell's thought experiment). I must admit that I am not at all sure what the precise meaning of this statement is.

8.3 TGD view about the situation

TGD inspired theory of consciousness can be regarded as a quantum measurement theory based on zero energy ontology (ZEO) and it it is interesting to try to analyze the experiment in this conceptual framework.

8.3.1 TGD view about the experiment

The natural quantum interpretation is that the photodiode following the photon is performing repeated quantum measurements, which in standard quantum theory do not affect the state of the particle after the first measurement. From the viewpoint of TGD inspired consciousness, which can be regarded as a generalization of quantum measurement theory forced by zero energy ontology (ZEO), the situation could be as follows.

1. Photo-diode following the particle by would be like conscious entity directing attention its to the particle and keeping it in focus. In TGD Universe directed attention has as classical space-time correlates flux tubes connecting attendee and target of attention: in ER-EPR correspondence the flux tubes are replaced with wormholes, which suit better to GRT based framework. Flux tubes make also possible entanglement between attendee and target. The two systems become single system during the period of attention and one could say that the attention separates the particle from the rest.

2. Directed attention costs metabolic energy. Same would be true also now - photo-diode indeed requires energy feed. Directed attention creates mental image the conscious entity associated with the mental images can be regarded as a generalized Zeno effect or as a sequence of weak measurements.

   Tracking would thus mean that particle's momentum is measured repeatedly so that the particle is forced to continue with the same momentum. Gradually this would affect the thermal distribution and generate temperature and pressure gradients. Directed attention could be also seen as a mechanism of volition in quantum biology.

3. This looks nice but one can ask what about the collisions of the particle with other molecules of gas: don't they interfere with the Zeno effect? If the period between repeated measurements is shorter than the average time between the collisions of particles, this is not a problem. But is there any effect in this case? The directed attention or a sequence of quantum measurements could separate the particle from the environment by de-entangling it from the envirobment. Could it be that collisions would not occur during this period so that attendee and target would form a subsystem de-entangled from rest of the world?

8.3.2 ZEO variant of Maxwell's demon

Zero energy ontology (ZEO) [L15] forces to consider different arrangement producing energy somewhat like in perpetuum mobile but not breaking the conservation of energy in any obvious manner. The idea pops into my mind occasionally and I reject it every time and will do so again.

1. Zero energy states (ZESs) are like physical events: pairs of positive and negative energy state with energy E and $-E$: this codes for energy conservation.

2. One can have quantum superposition of ZESs with different values of energy E and with average value $\langle E \rangle$ of energy. In state function reduction $\langle E \rangle$ can change and in principle this does not break conservation of energy since one has still superposition of pairs with energies E and $-E$.

3. For instance, the probabilities for states with energy E could be given by thermal distribution parameterized by temperature parameter T: one would have "square root" of thermodynamic distribution for energies. "Square root" of thermodynamics is indeed forced by ZEO. One

would have essentially entanglement in time direction. Single particle states would realize square root of thermodynamical ensemble, which would not be a fictive notion anymore.

The coefficients for the state pairs would have also phases and these phases would bring in something new and very probably very important in living matter. System characterized by temperature T would not be so uninteresting as we think, there could be hidden phase information.

If T increases in reduction then $\langle E \rangle$ increases in state function reduction. Reduction could also measure the value of E. Could the system increase its $\langle E \rangle$ in state function reductions? My proposal for an answer is "No".

In ordinary thermodynamics energy should be fed from environment to increase $\langle E \rangle$: how environment would enter into the game now?

1. State function reduction always reduces the entanglement of system S with environment, call it S_{env}. Could the increase of $\langle E \rangle$ be compensated by compensating change of $-\langle E \rangle$ in S_{env}. Indeed, the conservation of energy for single state is expected have statistical counterpart: energy would come from environment as a kind of metabolic energy. Therefore also the "square root" of thermodynamics would prevent perpetuum mobile.

2. This would be the case if the reduction measures the energy of the entire system $S_{tot} = S + S_{env}$ - so that S_{tot} is always in energy eigenstate with eigenvalue E_{tot} and E_{tot} does not change in reductions and in unitary evolutions between them. Can one pose this condition?

8.3.3 Time reversal and apparent breaking of second law in zero energy ontology (ZEO)

ZEO based theory of consciousness [L15] forces to consider also a genuine breaking of the second law.

1. In ZEO self as a conscious entity corresponds to a generalized Zeno effect or equivalently a sequence of analogs of weak measurements as "small" state function reductions. The state at passive boundary of CD is unaffected as also the members of state pairs at it.

   Second boundary of CD (active boundary) shifts farther away from the passive one and the members of state pairs at it change giving rise to the conscious experience of self. Clock time time identified as temporal distance between the tips of CD increases. This gives rise to the correspondence between clock time and subjective time identified as sequence of weak reductions.

2. Also "large" state function reductions are possible and also unavoidable. The roles of active and passive boundary are changed and time reversal occurs for the clock time. One can say that self dies and re-incarnates as a time-reversed self.

   At the next re-incarnation self with the original arrow of clock time would be reborn and continue life from time value shifted towards future from the moment of death: its identity as a physical could be however very different. One can of course wonder whether sleep could mean a life in opposite direction of clock time and wake-up a reincarnation in the usual sense.

   The time-reversed self need not have conscious memories about its former life cycle: only the collections of un-entangled subsystems at passive boundary carry information about this period. A continuation of conscious experience could however take place in different sense: the contents of consciousness associated with the magnetic body of self could survive the death as near-death-experiences indeed suggest.

3. The time reversed system obeys second law but with opposite time direction as normally. Already Italian physicist Fantappie proposed that this occurs routinely in living matter and christened the entropy for time reversed systems syntropy [J8]. Processes like spontaneous assembly of complex molecules from their building bricks could be controlled by time reversed selves.

   In TGD inspired biology motor actions could be seen as generation of signal propagating backwards in time and defining sub-system with revered arrow of time and inducing the

activity preceding motor activity before the conscious decision leading to it is made: this with respect to geometric time. There are many effects supporting the occurrence of these time reversals.

4. How the possibility of time reversals relates to the second law? One might argue that second law emerges from the non-determinism of state function reduction alone. Second law would transform to its temporal mirror image when one looks the system from outside with unchanged arrow of clock time.

   But does the second law continue to hold in statistical sense as one takes average over several incarnations? One might think that this is the case since generalized Zeno effect generalizes ordinary Zeno effect and at the limit of positive energy ontology one would effectively have a sequence of ordinary state function reductions leading leading to second law.

8.3.4 Negentropy Maximation Principle (NMP)

TGD also predicts what I call Negentropy Maximization Principle (NMP) [K13] [L15].

1. Entanglement coefficients belong to extension of rationals allowing interpretation as both real and p-adic numbers in the extension of p-adics induced by the extension of rationals defining the adele.

   One can assign ordinary entanglement entropy to the real sector of adele and entanglement negentropy with the p-adic sectors of adelic physics: for latter the analog of ordinary Shannon entropy is negative and thus the interpretation as conscious information is possible. The information is assigned with the pairing defined by entanglement whereas entropy is associated with the loss of precise knowledge about the state of particle in entangled state.

2. One can also consider the difference of sum of p-adic entanglement negentropies and real entanglement entropy as the negentropy. This quantity can be positive for algebraic extensions of rationals and its maximal value increases with the complexity of the extension and with p-adic prime.

   Also the information defined in this manner would increase during evolution assignable to the gradual increase of dimension of algebraic extension of rationals, which can take place in "large" state function reductions (re-incarnations of self): if the eigenvalues of density matrix are algebraic numbers in an extension of the extension of rationals, the "large" state function must take place.

3. NMP would hold true in statistical sense - and mathematically very much analogous to second law - and would relate to evolution. In particular, one can understand why the emergence of intelligent systems is - rather paradoxically - accompanied by the generation of entropy. To have large entanglement negentropy in p-adic sectors one must have large entanglement entropy in real sector since same entanglement defines both.

8.3.5 Dark matter as phases of matter labelled by the hierarchy of Planck constants

The hierarchy of Planck constants $h_{eff}/h = n$ [K7, K8, K9, K10, K14] is a further key notion in TGD inspired quantum biology.

1. The hierarchy of Planck constants $h_{eff}/h = n$ implied by adelic physics as physics of both sensory experience (real numbers) and cognition (p-adic number fields) is basic prediction of TGD [L14]. Planck constant characterizes the dimension of the algebraic extension of rationals characterizing the cognitive representations, and is bound to increase since the number of extensions with dimension larger than given dimension is infinite whereas those with smaller dimension is finite.

2. The ability to generate negentropy increases during evolution. System need not however generate negentropy and can even reduce it. In statistical sense negentropic resources however increase: things get better in the long run. In biology metabolic energy feed brings to system molecules having valence bonds with $h_{eff}/h = n$ larger than that for atoms [L13], and this increases the ability of the system to generate negentropy and in statistical sense this leads to the increase of negentropy.

8.3.6 The most recent ZEO based view about demonic activities in TGD Universe

Maxwell's demon is at the boundary of the region which can be seen as physics disregarding totally the observer. Maxwell's demon allows only particles with velocity above threshold to travel from A to B. This leads to generation of pressure gradient in conflict with the second law.

The basic objection against Maxwell's demon is that the demon is an intelligent living being which thinks and although there is no mainstream physical theory about cognition, the empirical fact is that this requires metabolic energy feed. This must be taken in account also and means that the development of the gradient requires metabolic energy.

In zero energy ontology (ZEO) one must reconsider the situation since time reversal occurs in ordinary state function reductions (BSFRs) [L20]. This means time reversed dissipation and forces a generalization of the second law [L19]. For the observer with the standard arrow of time, this shows itself as a generation of various gradients, demonic activity.

Living matter is full of examples of self-organization in which such this seems to happen and the explanation is in terms of non-equilibrium thermodynamics and thermodynamical fluctuations basically. Essential is that energy flows are involved as in the example of Maxwell demon and metabolic energy feed explains this partially. But eventually the energy flows are gradients and eventually disappear and heat death of the Universe occurs. The emergence of life therefore seems very implausible: England [**?**] would be thus incorrect [L9].

Usually the energy flow to the system is taken as passive - arranged from outside. In ZEO the opposite arrow of time makes it active. System extracts energy from the environment, "eats" rather than waiting for the food to flow into its mouth spontaneously and to creep to the stomach without help. This leads to what I call remote metabolism or credit card mechanism as a way to extract radiative energy from the environment or from systems analogous to population inverted lasers able to provide it.

Living matter is also full of examples about self-organized criticality (SOC) very difficult to understand in standard thermodynamics. System manages to stay near a critical state which is by definition unstable. This is nothing but homeostasis [L43]. What in standard biology looks like extremely tightly planned programs involving endlessly various biochemical pathways is unplanned spontaneous dissipation with a reversed arrow of time: this simplifies enormously the biological modelling. In time reversed direction critical state is an attractor rather than repeller and time reversal would be the basic mechanism of homeostasis.

There are specific molecules - stress proteins (SPs) specialized to act as coolers, heaters, and heat engines using the thermal energy at their magnetic body (MB), whose temperature has maximum - presumably near physiological temperature - by the fact the number of degrees of freedom is infinite [L43]. SPs a near this maximal temperature known as Hagedorn temperature and have very large heat capacity. Stress molecules provide in the case of cold shock energy to DNA and basic proteins to heat them so that they remain functional. In the case of heat shock they reduce the temperature of the environment by sucking thermal energy by time reversal for their magnetic body serving as an energy reservoir. They can act also as heat engines driving molecular motors.

8.4 About information thermodynamics and Maxwell's demon in TGD

Information thermodynamics includes information as an analogy of negative entropy. The associated temperature can be assumed to be the same as the usual temperature but this need not be the case. Information thermodynamics leads to a generalization of the second law taking into accout the presence of quantum information. Whether this information corresponds to conscious information, is left open.

Sciencedaily article (see this) tells about the article of Minagawa et al [B4] (see this) published in Nature, in which a more rigorous proof than before is represented for the statement that that the second law of thermodynamics is also valid in quantum theory with information included. The presence of information makes possible an apparent local violation of the second law in the sense that the system can do more work than the Carnot law allows. However, Maxwell's demon requires metabolic energy to function and it loses it when demonizing. This energy must be compensated and the conclusion is that the second law of thermodynamics is valid.

I have discussed Maxwell's demon earlier in [K2]. In the following information dynamics and Maxwell's demon are discussed in light of the recent results related to TGD [L33, L35, L40, L37,

L38]. The discussion relies on the geometric vision of physics involving holography= holomorphy principle and the number theoretic vision of physics involving p-adic number fields and adeles as mathematical correlates for cognition and the evolutionary hierarchy of extensions of rationals. Negentropy Maximization Principle (NMP) for cognitive information replacing second law and implying it. Zero energy ontology (ZEO) provides the new quantum ontology.

8.4.1 Some basic ideas of TGD relevant to Maxwell's demon

1. Geometric vision

Consider first briefly the geometric vision.

1. In the classical TGD, holography= holomorphy vision is a new element not present in the earlier discussion of Maxwell's demon discussed in [K2]. Space time surfaces as roots of analytic function pairs $f = (f_1, f_2) : H = M^4 \times CP_2 \to C^2$ with Taylor coefficients in some extension E of rationals provide exact solution of field equations by reducing them from partial differential equations to algebraic equations. [L33] Polynomial solutions are obtained as an important special case.

   Also the roots $g \circ f = (0, 0)$, $g : C^2 \to C^2$ define space-time surfaces. The hierarchy obtained as composites of maps g gives rise to a hierarchy of field bodies. This hierarchy of maps of maps of ... is analogous to an abstraction hierarchy. For $g(0, 0) = (0, 0)$ the lowest level $(f_1, f_2) = (0, 0)$ belongs to the hierarchy [L40].

   The algebraic complexity of the surfaces increases with the number of composites g_i and their inherent complexity measured by degrees with respect to the 3 complex coordinates of H. When g reduces to map $C \to C$ one has ordinary polynomials and one can assign Galois group and ramified primes to it. The "world of classical worlds" (WCW) decomposes to a union of sub-WCWs with f_2 fixed.

2. Field/field body [L28, L30] serves as a carrier phases of the ordinary matter with non-standard value of effective Planck constant $h_{eff} \geq h$ making it a quantum coherent system in arbitrarily long scales. The proposal is that h_{eff} corresponds to the dimension of an algebraic extension of rationals as the order of the Galois group. In the TGD inspired quantum biology, the temperature of the field body is not necessarily the same as the temperature of the biological body, but could be lower and would gradually increase with aging [L44] so that the field body would gradually lose control.

3. Zero energy ontology (ZEO) [L20, L16], forced by the holography, in turn forced by the general coordinate invariance, makes classical physics an exact part of quantum TGD.

   Holography involves space-time surfaces identified as classical Bohr orbits for particles of 3-surfaces as generalization of point-like particles and localized inside CD. These Bohr orbits are slightly non-deterministic already for 2-dimensional minimal surfaces. This forces the replacement of quantum states with superpositions of Bohr orbits and brings in new degrees of freedom related to classical non-determinism. These degrees of freedom are essential for understanding cognition. The identification of quantum states as superpositions of Bohr orbits allows us to solve the basic problem of quantum measurement theory. In ZEO both arrows of time are possible in all scales.

   The hierarchy of causal diamonds $CD = cd \times CP_2$, where cd is causal diamond of M^4 is the geometric correlate of ZEO. CD has interpretation as a 4-D perceptive field of a conscious entity associated with the quantum superpositions of 4-surfaces inside CD. CDs form a scale hierarchy [L32].

   In the TGD framework, information means potentially conscious information and involves TGD view of memory based on the classical non-determinism [L34].

2. Number theoretic vision and the two Galois groups

Number theoretic vision is complementary to the geometric view about TGD. p-Adicization and adelization of the mahematical correlates of cognition is the key idea. Negentropy could correspond to information in information thermodynamics. The production of negentropy requires metabolic energy. This view leads to the proposal of negentropy maximization principle [K13] [L31]. Cognitive negentropy as the sum of p-adic negentropies increases, but so does real entropy. This fits [L9] [K2] with Jeremy England's observations [I3]. Classical non-determinism could correspond to p-adic non-determinism.

In the TGD framework, one can speak of the Galois group in two different senses [L33, L38, L40]. It is convenient to speak about internal Galois group and external Galois group.

1. Internal Galois group

The 4-D Galois group, the internal Galois group, is assumed to permute the regions of a single connected component of the space-time surface realized as roots of the pair (f_1, f_2) defining the space-time surface. The internal Galois group would act as analytic flows of H transforming the regions as roots to ech other so that the action is analogous to that of a braid group.

1. It is easy to see that the space-time surface in general consists of several disjoint regions if (f_1, f_2) is expressible as the composite $(f_1, f_2) = (g_1(h_1, h_2), g_2(h_1, h_2))$. In this case the space-time surface is union of disjoint surfaces $h_i = r_i$, where r_i correspond to the roots of g_i. The permutations of the roots for a connected component of the space-time surface would realized as analogs of braidings.

2. The space-time regions identified as roots of (f_1, f_2) for a single connected component would have string world sheets as interfaces having hypercomplex time coordinates u, v. Suppose that there are n string world sheets. The number of string world sheets/folds can be larger than n. If folds are between any pair i, j are present then the number of folds cannot be larger than $(n-1)n$: in this case all pairs i, j would have two folds. Circle is a simple example: it has 2 sheets and 2-folds: 1,2 and 2,1.

   Since the M^4 complex coordinates w and roots as its values labelling the string world sheets are in general complex, one can say that the fold is complexified. For a cusp (see this) the two folds can be ordered. Fold would now involve a string world sheet and cusp would combine two folds. At the vertex of the cusp where 3 roots co-incide, two folds would disappear. This suggests that the string world sheets connect at their ends associated with the disappearing folds and form a single string world sheet.

3. Catastrophe theory suggests that all catastrophes and hence also the space-time surfaces can be constructed from complexified cusps. The folds, which appear on a cloth, can be ordered. If so, folds between roots $i, i+1$ and $i-1, i$ are possible and would come from a single cusp but folds with $|i-j \geq 1$ would not be possible. This could give rise to the ordering of the roots w_i. Does this mean that the Galois group is cyclic?

4. This brings in mind twistor amplitudes and planar diagrams, which correspond to Feynman diagrams with no crossing lines and therefore embeddable in plane. Non-planar Feynman diagrams are a problem of the twistor Grasmannian approach [B3, B2] since they have no twistorial representation. The Feynman diagrams with crossing lines can be embedded in the plane with holes, whose boundaries are connected by cylinders as kinds of wormholes. In string models, the corresponding diagrams involve this kind of wormholes. This suggests that if the 2-D projection of the space-time sheets with constant values of hypercomplex coordinates has a topology with a genus g larger than 0, the space-time surface contains wormholes connecting roots with $|i-j \geq 1$. In this case also the generalized Galois group is non-Abelian. Wormhole contacts defining Euclidean regions (CP_2 type extremals) could be such connections.

   To include wormhole contacts as connectors of the Minkowskian space-time sheets, one should allow besides the Minkowskian folds also the presence of the Euclidean CP_2 type extremals with a light-like M^4 curve, possibly geodesic, as M^4 projection. For these Euclidean regions the string world sheet would reduce to this curve since the second hypercomplex coordinate would be constant.

The internal Galois group could relate to the TGD view of topological qubits [L40].

1. The quantum-mechanical transfer of fermions between regions corresponding to roots of (f_1, f_2) does not require a continuous path. Classical transfer requires a path going through a fold at which the two roots as space-time regions meet. Fold corresponds to a boundary of a string world sheet identified as fermion line. Folds are labelled by the values of the complex coordinate w having interpretation as roots.

2. There is a direct analogy to the case of condensed matter majorana fermions suggested to define topological qubits. For a Majorana fermion two branches of the Fermi surface touch each other at point and the energy difference for the branches is zero at this point. Majorana fermions are assigned with these points and they would be located at the ends of a wire [L40]. In the TGD framework the folds would correspond to the seats of topological qubits.

2. Outer Galois group

The element-wise multiplication of the function for pairs (f_1, f_2) is essential for the identification of the outer Galois group and gives an algebra, which is enough for identifying the Galois group as group of automorphisms for the algebraic extension of rationals involved. Outer Galois group permutes the roots of g, which are algebraic numbers in the extension of E and label the disjoint components of the spacetime surfaces. These two Galois groups commute and the outer Galois group relates to the internal Galois group in the same way as the Galois group of an extension of rationals to the Galois group of complex rations generated by complex conjugation.

The outer Galois group is natural for the TGD realization of the Langlands duality.

1. A simpler version of the outer Galois group is associated with dynamical complex analytic symmetries $g : C \to C$: $(f_1, f_2) \to (g_1 \circ f_1, f_2)$. Here g_1 does not have a parametric dependence on f_2. The outer Galois group relates to each other *disjoint* space-time surfaces. When g reduces to map $g : C \to C$, one can assign to it an ordinary Galois group relating to each other the disjoint roots of $g \circ f$ realized as disjoint 4-surfaces $(f_1, f_2) = (r_1, 0)$.

2. The notion of outer Galois group generalizes to the general situation $g = (g_1, g_2)$. Also now the roots of $g \circ f$ are disjoint space-time surfaces representing roots as pairs of algebraic numbers $(f_1, f_2) = (r_{i,1}, r_{i,2})$. Is it possible to assign to the roots the analog of the Galois group?

   This group should act as a group of automorphisms of some algebraic structure. This structure cannot be a field but algebra structure is enough. These arithmetic operations would be component-wise sum $(a, b) + (c + d) = (a + c, b + d)$ and componentwise multiplication $(a, b) * (c, d) = (ac, bd)$. The basic algebra would correspond to the points of $(x, y) \in E^2$ or rationals and the extension would be generated by the pairs $(f_1, f_2) = (r_{i,1}, r_{i,2})$. This structure has an automorphism group and would serve as a Galois group. The dimension of the extension of E^2 could define the value of the effective Planck constant.

   Also the notion of discriminant can be generalized to a pair (D_1, D_2) of discriminants using the component-wise product for the differences of root pairs. Could D_i be decomposed to a product of powers of algebraic primes of the extension of E^2?

3. Some implications

The number theoretic notions have profound implications.

1. In [L33] the idea that the space-time surfaces can be regarded as numbers was discussed. For a given g, one can indeed construct polynomials having any for algebraic numbers in the extension F of E defined by g. g itself can be represented in terms of its n roots $r_i = (r_{i,1}, r_{i,2})$, $i = 1, n$ represented as space-time surfaces as a product $\prod_i (f_1 - r_{i,1}, f_2 - r_{i,2})$ of pairs of monomials. One can generalize this construction by replacing the pairs $(r_{i,1}, r_{i,2})$ with any pair of algebraic numbers in F. Therefore all algebraic numbers in F can be represented as space-time surfaces. Also the sets formed by numbers in F can be represented as unions of the corresponding space-time surfaces.

2. This picture also leads to a vision about physics laws as being analogous to laws of logic and time evolution of the physical system as analogous to a proof of theorem [L38]. Different meta levels defined by the maps $g : C^2 \to C^2$ are analogous to hierarchy of statements about statements in mathematics. This applies also to the more general maps. The interpretation is that the surfaces at the higher levels of the meta hierarchy represent statements about the surfaces $(f_1, f_2) = (0, 0)$ at the lowest level of the hierarchy.

3. The creation of algebraic complexity, i.e. increasing the value of h_{eff}, requires metabolic energy. The value of h_{eff} tends to spontaneously decrease, which gives rise to a dissipation as a competing effect and one should understand how these two tendencies relate to each other.

4. Negentropy Maximization principle [L31] states that the algebraic complexity measured by the sum of p-adic negentropies increases in a statistical sense during the number theoretic evolution and NMP states this fact. Also the ordinary entropy increases as a result of the increase of the negentropy and this conforms with the view of Jeremy England [I3] [L9]. The maximum value for h_{eff} partially characterizes algebraic complexity. Also Galois groups, the degree(s) of the polynomials defining the space-time surface, and ramified primes (when they are defined) characterize the complexity. Galois groups generalize the group Z_2 assigned with condensed matter fermions in topological quantum computation [L40].

8.4.2 The TGD view of Maxwell's demon

The basic vision is as follows.

1. A field body can act as a Maxwell's demon. As a carrier of potentially conscious information realized as memories about previous SSFRs [L34], the field body can transfer negentropy, basically energy, to lower levels and seemingly help to break the second law. As a result, an additional term from information to the basic equation expressing the second law. The h_{eff} for the field body however decreases in the process.

   Also the classical fields associated with the field body can do work on the biological body and the classical gravitational/electric fields are characterized by gravitational/electric Planck constants [L28, L30].

2. In presence of the field bodies, perhaps assignable to the hierarchy of abstractions defined by the maps g, more work can be obtained from the system than the second law would otherwise allow. This is only apparent because the h_{eff} of the field body decreases so that the algebraic complexity measuring the level of consciousness decreases. Therefore h_{eff} must be increased to its original value. Metabolic energy is needed for this purpose.

Consider now the TGD view of Maxwell's demon as a conscious entity in light of the recent results not yet taken into account in the discussion of [L36].

1. Consider first the notion of a cognitive measurement [L36]. The Galois group for $g_1 \circ g_2 \circ ...$, $g_i : C \to C$ is characterized by a hierarchy of coset groups defined by the hierarchy of its normal subgroups. The irreps of the Galois group can be decomposed to tensor products of the coset groups and the entanglement between the coset groups can be measured in cognition SFRs.

   In particular, the hierarchy formed by functional composition of polynomials $g : C \to C$ is accompanied by a hierarchy of extensions of extensions ... of E and the hierarchy of normal subgroups for the Galois groups.

2. Prime groups are simple groups having no normal groups and prime polynomials do not allow functional decomposition $P \circ Q$. If the degree of the polynomial is prime this is the case but this is not a necessary condition. Space-time surfaces of this kind are fundamental objects and the polynomial in question would have prime degree with respect to the 3 complex coordinates of H. The composites formed of maps g and of these fundamental function pairs f would define cognitive representations of the surface defined by f as kind of statements

about statements. An interesting question is whether these surfaces could correspond to elementary particles. The primes orders of polynomials involved do not probably correspond to p-adic primes assigned in p-adic mass calculations to elementary particles and identified as ramified primes [L29].

3. What happens when the value of h_{eff} descreases? Does it decrease only apparently? If the highest levels in the tensor product of irreps of the coset groups become singlets, these levels effectively drop away. Or could the space-time surface itself become simpler as some maps g in the composite $g_1 \circ g_2 ...$ become identity maps? Field body would lose some of its levels. Indeed, in the TGD based view of biocatalysis, the temporary reduction of h_{eff} is essential for the biocatalysis [L39].

8.4.3 How could the time reversal in BSFR relate to the second law?

Time reversal in BSFRs represents new physics. What are the implications?

1. Entanglement entropy and p-adic negentropies are associated with a pair of systems. Thermodynamic entropy is associated with an ensemble. A single BSFR cannot reduce ensemble entropy. It reduces entanglement entropy. Quantum entanglement with the environment is the cause of BSFR. Ensemble entropy, however, corresponds to entanglement entropy after a quantum measurement when quantum entanglement has disappeared.

2. In the ZEO based theory of consciousness, falling asleep (or biological death) corresponds to a BSFR and waking up to another BSFR. Sleeping restores resources and heals. What does this mean? Does the field body gain new metabolic energy resources that appear after the second BSFR? Does the BSFR violate the second law or does the energy needed come from outside the process as metabolic energy?

   During sleep, metabolic energy is not used for normal bodily purposes such as movement and sensation. It could go to the field body to restore the values of h_{eff} to their original values. For example, protons are transferred back to dark protons by the Pollack effect. That would require metabolic energy. This would be visible as the presence of an unknown energy sink during sleep. Metabolic energy consumption would not be reduced.

   During sleep, the second law applies in the opposite direction of time. This would only allow for an *apparent* violation of the second law.

3. BSFR would correspond to the loss of entanglement between the system and the environment, which for an ensemble means an increase in ordinary entropy. The produce thermodynamic entropy would be equal to as entanglement entropy transformed into ensemble entropy in BSFRs. Thermodynamic entropy for the ensemble would increase for both arrows of time in BSFRs.

4. The subsystems as smaller space-time sheets topologically condensed on the space-time sheet of the system can form a thermodynamic ensemble. The entropy of this ensemble increases in both directions of time. If it is possible to observe its increase occurring in the opposite direction of time, it would look like a decrease in entropy in the standard time direction and give rise to apparent violation of the second law. In the Pollack effect [I2, I1, I5, I4] this kind of effect is observed for the negatively charged exclusion zones at EZs throw impurities out. This looks like time reversed diffusion and can be understood in the ZEO [L39].

   In the case of SSFRs it is not meaningful to talk about an ensemble. The SSFRs cannot not therefore affect the ensemble entropy. The sequences of SSFRs define the analog of an adiabatic time evolution.

5. In biosystems the metabolic energy input makes it possible to maintain the h_{eff} distribution. At lower levels, entropy of the field body however increases gradually and eventually leads to death. Is it possible to maintain the metabolic energy feeds or are the metabolic energy currents gradually reduced during the evolution so that there is no metabolic energy feed increasing the complexity for subsystems anymore? This would be reduction of gradients

leading to thermal equilibrium and loss of information. Could this be the TGD counterpart of heat death?

Could the pairs of BSFRs solve the problem by allowing a fresh start with the original arrow of geometric time with the field body having a pure state and low entropy after the second BSFR? Sleep begins and ends with a BSFR. Sleeping overnight indeed allows one to wake up full of energy which is dissipated during the day. Could BSFRs generate the necessary gradients needed to avoid heat death? Could BSFRs take care that the system's form kind of flip flops exchanging metabolic energy by dissipating.

9 Why the outcome of an event would be more predictable if it is known to occur?

I learned from Reza Rastmanesh about highly interesting findings of Armor and Sackett, and this section is essentially the article [L45] written together with him about the topic.

Past research in experimental psychology has brought evidence showing that certain changes in internal neurocognitive environments of human subjects can influence their predictions of near future events. In the series of experiments published in a recognized psychological Journal of Personality and Social Psychology, Armor and Sackett [J2] examined how the nature of future events influence the participants´ predictions about their future performance in different tasks.

In Study 1, half of participants were informed that they will complete a scavenger hunt task, i.e. finding particular objects at the university campus during 30 minutes, whereas the second half of participants were not informed. Thus, the expectations of participants were manipulated in terms of real versus hypothetical future events and this manipulation also causes different changes in internal neurocognitive environments in each half of participants. The participants were asked "How well will you do on the scavenger hunt?" or "How well would you do, if you were asked to complete the scavenger hunt?". After that, all the participants completed the scavenger hunt task and their predictions were compared with their real performance in this task. Strikingly, participants who did expect to complete the task predicted their own performance quite accurately. In contrast, participants who believed that the task is only a hypothetical future event showed much higher prediction-performance discrepancy, i.e. they were not able to predict their future performance accurately.

These findings were replicated also in Study 2, where another kind of task was used (a completion of test used for Graduate Record Examination). One may ask how it is possible that participants that were informed about their future life event predicted their real performance in the task better than non-informed participants. The authors of this study were quite surprised by obtaining these results and labeled them as "seemingly anomalous findings". If this finding is real it provides a difficult challenge for model builders.

In the context of Minkowski spacetime, several possible explanations can be theoretically conceptualized:

1. In classical GRT, the causal structure is the structure of light cones of the space-time metrics. As the matter-energy degrees of freedom determine the metric through Einstein's equations, the causal structure of a region of space-time is dynamical: it depends on the state of the matter energy in its past light cone. If one identifies the causality of human actions experienced as acts of free will with the deterministic causality of field equations, the ability to predict the near future is theoretically possible. This applies also to person's own behavior if it does not involve free will: if this is the case, the two causalities cannot be identified.

2. Also a general quantal explanation may be considered. Quantum measurement provides information. In the context of the above-outlined experiments, the participants who were told about the purpose of the experiment gained information. Could this action have involved state function reduction of some kind improving the ability to predict their own future? Also this option would assume that HOs are passive inspectors of their own fate and does not conform to the direct experience of having (partially) free will.

3. One can consider also an explanation in terms of precognition based on future-to-past communications requiring change of the arrow of time and therefore also violation of standard

thermodynamics. Precognition is classified as belonging to the field of parapsychology by materialists accepting only a single arrow of time. Also this explanation fails if one accepts free will: precognizing of own unpredictable acts of free will is impossible.

In the sequel the problems of various physicalistic explanations are discussed in more detail and the TGD based model relying on zero energy ontology (ZEO) [L20] replacing the standard ontology of quantum theory in TGD framework and solving the basic paradox of quantum measurement theory. The basic prediction is that the arrow of time changes in "big" (ordinary) states function reductions (BSFRs) but is preserved in "small" SSFRs as analogs of "weak" measurements. This forces to distinguish between geometric and subjective time.

This leads to an understanding of the findings of Libet [J3] about active aspects of consciousness challenging the reality free will: in BSFR the arrow of causality changes and the outcome of BSFR causes the neural activity rather than vice versa. Also the findings of Armor and Sackett seem to give direct support for the physicalistic picture: the members of group A would be passive inspectors of their own future actions and therefore would have not free will. Precognition, which is not accepted in the physicalistic framework, is however required, which suggests that BSFRs transforming precognition to memory recall might be involved.

In the sequel the findings of Armor and Sackett are taken at face value and an explanation based on TGD inspired theory of consciousness relying on zero energy ontology (ZEO) allowing to get rid of the basic paradox of quantum measurement theory is proposed. There are 2 new elements essential for the explanation.

1. There is a hierarchy of magnetic bodies carrying dark matter as $h_{eff} = nh_0$ phases of ordinary matter and defining a self-hierarchy.

2. The time reversal in BSFRs makes memory recall in reversed time direction possible: these memories need not be personal and it is possible to get information about the memories of MB at a higher level of hierarchy with a reversed arrow of time after BSFR.

In the scavenger hunt BSFR at higher level would be assignable to the experiment which had already occurred with respect to subjective time at a higher level of the hierarchy in the geometric future of participants. This BSFR would be followed by a cascade of BSFRs proceeding to shorter scales in subjective future but located in the geometric past.

The subject persons who were told that that they will participate a scavenger hunt would have received non-personal memories about those abstract aspects of the scavenger hunt at higher level of hierarchy, which they could not affect by BSFRs: the number of objects found by the participant would have been this kind of aspect and already determined by a BSFR at a higher level of hierarchy. Ordinary motor action would be very similar process involving communications to lower levels of self hierarchy in the geometric past.

This explanation is akin to the earlier TGD based explanation [L8] [K24] for psychedelic experiences in which subject persons experience meeting of representatives of advanced civilizations of outer space. That these encounters could be actual telepathic contacts was proposed in a book about psychedelic induced experiences titled as "Inner paths to outer space" (`http://tinyurl.com/gnb4bp9`) written by Rick Strassman, Slawek Wojtowicz, Luis Eduardo Luna and Ede Frecska [J7]. In ZEO the arrow of time is not fixed so that instantaneous communications over arbitrarily long distances become possible by what might be called time reflection involving BSFR.

The explanation relies on sending a signal, which is reflected back as a time reversed signal (involving BSFR): this allows to circumvent the barrier caused by finite speed of light. In principle this would make signalling with arbitrarily distant civilizations possible.

9.1 Why the standard physics based explanation for the findings of Armor and Sackett looks implausible?

What seems clear to me is that it is very difficult to understand the findings of Armor and Sackett [J2] - if real - in the standard physics framework.

1. Standard physics excludes precognition: the thermo-dynamical arrow of time is fixed and also the quantization procedure of quantum field theory fixes the arrow of time. Creation operators create states and annihilation operators destroy them. The change of arrow of time would change the roles of these operators. Classically this corresponds to the fact that signals propagate in preferred direction only. It is difficult to see how quantum effects according to standard QM could help. State function reductions happen in standard physics only in very short scales and have no effect in macroscales. They do not make possible effective precognition.

2. The idea that the persons in group A got bored after they had found the number of objects that they had estimated to find does not work since the same should have happened in group B.

3. The experimenter effect [K12] is encountered in parapsychology experiments and also in experiments involving living subjects (testing of drugs). There are extremely successful parapsychology experimenters and often their findings cannot be replicated. Could the experimenters somehow affect the subject persons so that the outcome of the experiment is what the experimenter would regard as desired? Physicalists deny the possibility of this kind of effect so that fraud or bad experimentation remains the only explanation. The reality of Placebo effect cannot be denied and suggests that the state of mind of the patient affects the healing in conflict with the physicalistic expectations. These effects are discussed from the TGD point of view in an article [K12] prepared in the project organized by Lian Sidoroff. Experimenter effect leads to ask whether the strong belief of experimenter on the expected result could induce the result also in the experiment of Armor and Sackett. This hypothesis could be tested by replicating the experiment sufficiently many times by other experimenters.

4. The causal reference frame model of Guerin and Bruckner [J2] involves a rather speculative proposal that classical GRT could allow anomalies in which the order of events is different for different observers modelled in terms of lightcones. One can ask whether it could differ in the recent experiments between participants a in group A and participants b in group B. For persons in group A it would have been changed and they could "remember" their performance whereas the participants in B only estimated it since they did not know that effective memory recall is possible! The information would have entered as classical signals in reversed time direction to the participants in group A. Somehow the information about the participation to the actual experiment would have made possible this effective change of arrow of time.

   Classical Relativity predicts that gravitation is extremely weak interaction so that the explanation does not look plausible to me. There are however some black-hole like solutions of Einstein's equations known as Kerr-Newman metrics [B6] describing rotating objects having opposite arrows of time in near-field and far-field regions but these solutions do not seem relevant in the recent case.

   It is difficult to see how standard quantum physics could help. One must however notice that there is no generally accepted quantum theory of gravitation.

9.2 A model for the findings of Armor and Sackett based on the notions of magnetic body (MB) and zero energy ontology (ZEO)

TGD based explanation of the findings relies on the notions of magnetic body (MB) and zero energy ontology (ZEO).

9.2.1 The notion of magnetic body (MB)

The notion of classical field differes from that it classical field theories. Gauge potentials - in particular electromagnetic gauge potential - are induced from the spinor connection of embedding space $M^4 \times CP_2$ as defining static and non-dynamical gauge potentials. Sama applies to gravitational field as deviation from flat metric of Minkowski space. The dynamics of space-time surface makes the induce gauge potentials and metric dynamical. Locally the dynamics is however extremely

simple since only 4 field like variables are involved. Even approximate superposition of fields is lost and possible only for massless modes propagating in the same direction and is replaced with superposition of effects.

This extreme local simplicity is compensated by the extremely complex topology of the many-sheeted space-time distinguishing TGD from standard model plus General Relativity. Many-sheeted space-time prevailing in long length scales means that there is very large number of space-time sheets parallel in the sense that they intersecting 4-D M^4 projections. This is crucial for all applications. Any system the induced gauge fields at space-time sheets characterizing the system and since these sheets are separate for separate system, these induce fields do not interfere. One can say that the system has field body, in particular magnetic body (MB). In gauge theories this is not the case.

How does this picture relate to ordinary field theoretic description. Particle like entity as a small 3-surface touches all space-time sheets with 4-D M^4 projection and therefore experiences the sum of induced gauge fields associated with the space-time sheets. Effects superpose and this superposition corresponds basically to a set theoretic union of space-time surface with intersection M^4 projections. In ordinary field theory this is used as justification for the assumption that fields superpose. Field theory limit of TGD is defined by replacing the many-sheeted space-time with single regions of M^4 with gauge fields and gravitational fields defined as superpositions of the induced fields.

Also brain has MB. Quite generally MB is assumed to contain dark matter identified as ordinary matter characterized by extension of rationals with dimension $h = h_{eff}/h_0 = n$ measuring algebraic complexity and having interpretation as a kind of universal IQ. Also the scales of quantum coherence increase with h_{eff}. The layers of MB characterized by the value of n form naturally a slaving hierarchy in which ordinary matter with smallest Planck constant is at the bottom and controlled by higher levels. The energies of systems increase with h_{eff} and since h_{eff} tends to be spontaneously reduced, energy feed is needed to preserve the distribution of h_{eff}: the interpretation is as metabolic energy feed.

In the TGD framework the onion-like hierarchical structures of MB of brain would correspond to brain regions. The structure of MB with levels labelled by extensions of rationals characterized partially by $n = h_{eff}/h_0$ measuring the scale of quantum coherence, would also reflect the geometric and topological structure of the brain. There is evidence that functionally similar neurons can be modelled using statistically determined hyperbolic geometry [J6]. Functionally similar neurons not necessarily near to each other physically would be near to each other in the effective hyperbolic geometry.

In TGD framework MB could realize this hyperbolic geometry quite concretely as an abstract representation of the hierarchical functional structure of brain [L23]: functionally similar neurons and also higher level structures would be connected to nearby points at MB by flux tubes. Classification experienced as putting similar things to the same box is one of the basic cognitive functions and hierarchy of MBs could realize classification geometrically: functionally similar neurons would be connected by flux tuges to points near each other at MB - they would belong to the same box.

There is an astonishing finding supporting the notion of MB. The neurons of the brain of salamander were shuffled like a pack of cards. The salamander however recovered and preserved its memories (identified as learned behaviors) [J10]. In [K15, K16] this finding was considered as a support for the view about the brain as an analog of hologram (for the idea about TGD Universe as a conscious hologram see [K3]). It is however clear that a single neuron cannot represent the information content of the entire brain. However, if memories are represented by the images of neurons at the level of MB, the shuffling of neurons has no effect on memories as indeed found. Neurons would represent the analog of RAM in computer science.

9.2.2 What does ZEO mean?

The TGD based explanation would be based on ZEO allowing to solve the basic paradox of quantum measurement theory. First a brief summary of ZEO [L20].

1. In ZEO quantum states are not 3-dimensional but superpositions of 4-dimensional deterministic time evolutions connecting ordinary initial 3-dimensional states. By holography they

are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced with a new superposition. Classical determinism of individual time evolution is not violated and this solves the basic paradox of quantum measurement theory. There are two kinds of quantum jumps: ordinary ("big") state function reductions (BSFRs) changing the arrow of time and "small" state function reductions (SSFRs) (weak measurements) preserving it and giving rise to the analog of Zeno effect [L20].

2. To avoid confusion it is good to emphasize some aspects of ZEO.

   (a) ZEO does not mean that physical states in the usual 3-D sense as snapshots of time evolution would have zero energy state pairs defining zero energy states as initial and final states have same conserved quantities such as energy. Conservation implies that one can adopt the conventions that the values of conserved quantities are opposite for these states so that their sum vanishes: one can think that incoming and outgoing particles come from geometric past and future is the picture used in quantum field theories.

   (b) ZEO implies *two* times: subjective time as sequence of quantum jumps and geometric time as space-time coordinate. These times are identifiable but are strongly correlated.

3. In BSFRs the arrow of time is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. BSFRs can occur in all scales since TGD predicts a hierarchy of effective Planck constants with arbitrarily large values. There is empirical support for BSFRs.

   (a) The findings of Minev *et al* [L17] in atomic scale can be explained by the same mechanism [L17]. In BSFR a final zero energy state as a superposition of classical deterministic time evolutions emerges and for an observer with a standard arrow of time looks like a superposition of deterministic smooth time evolutions leading to the final state. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution in which case the process does not lead to anywhere: the interpretation would be that BSFR back to the initial state occurs!

   (b) Libets' experiments about active aspects of consciousness [J3] can be understood. Subject person raises his finger and neural activity starts before the conscious decision to do so. In the physicalistic framework it is thought to lead to raising of the finger. The problem with the explanation [J1] is that the activity beginning .5 seconds earlier seems to be dissipation with a reversed arrow of time: from chaotic and disordered to ordered at around .15 seconds. ZEO explanation is that macroscopic quantum jump occurred and generated a signal proceeding backwards in time and generated neural activity and dissipated to randomness.

   (c) Earthquakes involve a strange anomaly: they are preceded by ELF radiation. One would expect that they generate ELF radiation. The identification as BSFR would explain the anomaly [L18]. In biology the reversal of the arrow of time would occur routinely and be a central element of biological self-organization, in particular self-organized quantum criticality (see [L19, L43].

9.2.3 Some implications of ZEO

ZEO has profound implications for understanding self-organization [L19] and self-organized quantum criticality [L43] in terms of dissipation with non-standard arrow of time looking like a generation of structures. ZEO could also allow understanding of what planned actions - like realizing the experiment under consideration - could be.

1. Second law in the standard sense does not favor - perhaps even not allow - realization of planned actions. ZEO forces a generalization of thermodynamics: dissipation with a non-standard arrow of time for a subsystem would look like self-organization and planned action and its realization.

Could most if not all planned action be like this - induced by BSFR in the geometric future and only apparently planned? There would be however the experience of planning and realizing induced by the signals from geometric future by a higher level in the hierarchy of conscious entities predicted by TGD! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than agents with completely free will.

2. The notion of magnetic body (MB) serving as a boss of ordinary matter would be central. MB carries dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n serving as a measure for algebraic complexity of extension of rationals as its dimension and defining a kind of universal IQ. There is a hierarchy of these phases and MBs labelled by extension of rationals and the value of n.

   MBs would form a hierarchy of bosses - a realization for master slave hierarchy. Ordinary matter would be at the bottom and its coherent behavior would be induced from quantum coherence at higher levels. BSFR for higher level MB would give rise to what looks like planned actions and experienced as planned action at the lower levels of hierarchy. One could speak of planned actions inducing a cascade of planned actions in shorter time scales and eventually proceeding to atomic level.

3. This interpretation is actually not new. I proposed in [L41, L42] that motor actions could correspond to BSFRs and sensory percepts to their time reversals. It took still some time to realize that sensory perceptions naturally correspond to SSFRs ("weak" measurements), and that both BSFRs and SSFRs can occur with both arrows of time. Motor action would be a cascade of BSFRs with each BSFR inducing sensory perceptions as SSFRs at lower level inducing in turn motor actions as BSFRs in shorter time and length scales. The above model is a generalization of this picture.

9.2.4 The model

Could one apply ZEO also to the experiment under consideration?

1. Could one think that the experiment involving BSFR had in some sense already occurred (with respect to subjective time) when the experimenters got the idea to perform the experiment as a control signal from the geometric future? Experimenters and participants would have been like neurons in the brain of participants of Libet's experiment demonstrating that neural activity precedes experience about act of free will [J3]. They did what the already occurred experiment forced them to do. They of course had a lot of free will but not at this level of hierarchy of conscious entities but in shorter time scales and this made possible the needed preparations.

2. Experimenter informed the members of group A about the arrangement of the experiment. Therefore the members of group A concentrated on a process which was actually an attempt to remember in a reversed time direction and they were successful. The participants in group B did not know that the experiment would be arranged and made only guesses.

3. The objection is that in applications to atomic systems, Libet's experiments and earthquakes, one speaks of what an outsider with the standard arrow of time observed. Now one however talks about the participants of experiments and BSFR would now affect them. Does this really make sense?

   Here the notion of MB could come in rescue. BSFR would occur at the level of a collective MB of the system involving participants and experimenters and induce the outcome of BSFR and would change the arrow of time only at this level of MB. The participants at lower levels of hierarchy would receive information from the collective MB as time reversed control and communication signals. The signals would be received if the participant tunes herself to the correct wavelength - that is performs a memory recall, which would become possible after learning that the experiment will be actually performed.

9.3 How could the higher levels of MB use the brain to realize their free will?

The proposed model assumes that the experienced long terms goals (in the recent case the goal of experimenter to perform the experiment) correspond to SFRs that have already occurred at some higher layer of MB controlling the brain.

Neuroscience supports the view that frontal lobes are responsible for long term planning and decision making. They are involved also with the self model. This suggests that the highest layers of MB control frontal lobes. There would be a hierarchy of layers of MB having frontal lobes at the bottom.

9.3.1 Model for the coupling of MB with frontal lobes in terms of cognitive entanglement

A natural assumption is that the control of biological body by MB involves entanglement. Since frontal lobes are associated with high level cognition, this entanglement could be cognitive entanglement discussed in [L25]. Cognitive entanglement is a hierarchical entanglemen between wave functions in hierarchy of sub-groups in the factorization of Galois group to a product $G_1G_2...G_n$ of sub-groups reflecting directly the representationof extension as extension of extensions of .... of rationals.

What is special is that entanglement is directed like attention and hierarchical just like for the slaving hierarchy. The entanglement between states in group algebras of G_1 and $G_2...G_n$ is directed from boss G_1 to slave $G_2..G_n$. Cognitive SFRs are cascades proceeding downwards and reducing entanglement. Negentropy Maximization Principle can however prevent the cognitive measurement cascade from proceeding down to G_n [L27] if it does not give rise to negentropy gain.

Long term goals could involve this kind of cognitive entanglement assignable to directed attention and motor actions as BSFRs at this layer of MB would produce what is experienced by the levels of the hierarchy with the standard arrow of time as a behavior with long term goals. This would produce what could be regarded as analog of precognition [L41] and identifiable as sensory perception of signals propagating to non-standard direction of time. Precognitive dreams would be an example of this.

9.3.2 What happens when frontal lobes are damaged?

This vision conforms with what happens when frontal lobes are damaged. Although intellectual abilities are not lost, long term planning is not possible and the patient loses the ability to initiate actions. Damage can also lead to idiot savant phenomenon [J5]. Although the person seems to lack conceptual thinking completely, he/she can possess miraculous looking mathematical skills [L12] [K17] or artistic gifts [L10] [L10]. In some poorly understood sense idiot savants can be extremely intelligent.

Is the character of the cognitive entanglement changed or replaced with something totally different in these situations? TGD predicts two kinds of information related to two different representations of genetic code which relate to each other like function represented by its local values to its Fourier transform as a non-local and holistic representation [L24, L26]. The local representation of the genetic code is in terms of bits and using sequences of genetic codons as units of 6 bits. The second representation is in terms of 3-chords of light defining the allowed chords of a bio-harmony. Music expresses and induces emotions and bio-harmony would characterize a mood. Emotional intelligence would relate to this representation. Could it be that for idiot savants non-verbal emotional intelligence dominates.

The duality of these two representations of genetic code is highly analogous to the duality of momenta and position coordinates in wave mechanics. In quantum TGD this duality has as an analog $M^8 - H$ duality [L21, L22] stating that space-time surfaces can be regarded as 4-surfaces in $H = M^4 \times CP_2$ or in M^8. $M^8 - H$ duality relates these representations. H corresponds to ordinary differential geometric space-time representation involving also the notion of field. M^8 identifiable as 8-D momentum space corresponds to non-local algebraic and number theoretic representation, which is non-local and holistic since the momenta are analogous to frequencies. Scattering amplitudes in particle physics provide an example of this representation.

Both representations can be used and it depends on the situation which representation is more appropriate. Could it be that for ordinary *resp.* emotional intelligence H *resp.* M^8 representation is more appropriate? Could one exaggerate and say that not only idiot savants but also people in timeless meditative state and experiencing no separations (produced by cognitive SFRs), and maybe also children "live" in M^8 whereas the ordinary people with their tight time schedules and busily performing comparisons "live" in H? Momentum eigenstates are delocalized.

9.3.3 Are meditative states labelled by finite simple groups?

What could be the counterpart of meditative state without cognition be at the level of cognitive representations? Could it correspond to a situation in which it is not possible to create separations as decompositions to unentangled system pairs by reducing the entanglement between the factors of the Galois group G?

This is certainly the case if G is simple, that is does not allow this factorization at all. Simple finite groups are the basic building bricks of finite groups: the classification theory for simple groups [A1] (`https://cutt.ly/Pj2i2Nx`) states that simple finite groups is cyclic and of prime order, alternating group consisting of even permutations of n objects, group of Lie type or one of the 26 sporadic groups or Tits group. The meditative states of pure consciousness would correspond to finite simple groups!

A question about possible classification of meditative states definitely raises eyebrows. But the power of mathematics is miraculous: if one agrees that thinking means SFRs (thought generates separations and comparisons) and that in meditative states thinking ceases, this is the conclusion. Rather paradoxically, the "idiot savant state" would be cognitively irreducible in the same sense as the states of Hilbert space with prime dimension do not allow a representation as entangled states. They would represent elementary particles of cognition - fundamental ideas - from which more complex thoughts are composed by performing repeated extensions. The basic advice of meditative practices is to stop thinking: maybe this is indeed the manner to achieve the state of understanding.

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