Exploration

TGD Perspectives of Nonlocality in Quantum theory, Biology, Neuroscience & Remote Mental Interactions

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Abstract

Nonlocality seems to be a basic aspect of what it is to be living. Living system is elementary particle-like coherent unit. The phenomenon of memory suggests temporal nonlocality. Also, remote mental interactions, if real, suggest nonlocality. In fact, nonlocality, both spatial and temporal, is the basic element of entire quantum TGD and, in particular, its applications in quantum biology, neuroscience, theory of consciousness and remote mental interactions. In this series of articles, I suggest pictures in Topological Geometrodynamics (TGD). I will begin from empirical findings related to nonlocality rather than problems of General Relativity or of particle physics. The hope is that this could make the basic ideas of TGD easier to grasp. Further, the mathematical framework and its interpretation in current state of TGD are briefly described and some applications of TGD inspired theory of consciousness and quantum biology are discussed.

Keywords: Nonlocality, TGD framework, quantum theory, quantum biology, neuroscience, remote mental interaction.

1 Introduction

Non-locality seems to be a basic aspect of what it is to be living. Living system is elementary particle like coherent unit. The phenomenon of memory suggests temporal non-locality. Also remote mental interactions - if real - suggest non-locality. In fact, non-locality - both spatial and temporal - is the basic element of entire quantum TGD, and in particular, of its applications to quantum biology, neuroscience, theory of consciousness, and also of remote mental interactions.

In the following I make kind of pseudo deduction of the picture provided by Topological Geometrodynamics (TGD) by starting from empirical findings loosely related to non-locality rather than problems of General Relativity or of particle physics. The hope is that this could make the basic ideas of TGD easier to grasp.

1.1 What does non-locality mean physically?

Both spatial and temporal non-locality are possible and manifested as spatio-temporal coherence not expected on basis of classical and standard QM considerations.

There are many hints about the nature of non-locality.

1. Spatial non-locality manifest itself as a coherent behavior: organisms behave like independent coherent units. The idea about sacks of water containing some chemicals able to climb in trees and write poems does not look plausible. At the level of brain spatial coherence manifests itself as synchronous behavior of brain regions.

2. Temporal non-locality manifests itself as temporal synchrony, especially so in the dynamics of brain. Also memories suggest temporal non-locality. Also various functions/behavioral patterns meaning intentional goal-directed action reflect temporal non-locality. In EEG quasi-stationary segments separated by rapid transients appear [24].

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3. Libet's findings [22] about anomalous time ordering of conscious decision and neural correlates of associated action suggest that signals can propagate backwards in time. Motor actions would involve signals propagating backwards in time and sensory-motor dichotomy could correspond to two arrows of time.

4. Fantappie [28] suggested long time ago that the arrow of time is not always the same in living matter and christened the entropy increasing in reverse direction of time syntropy. Spontaneous self assembly could be example of process taking place in reverse direction of time as a decay process. This would however imply that experienced time having always the same direction cannot be equated with the geometric time. There are also other reasons for distinguishing between these two times.

   Questions: Do we really understand the notion of time, in particular the relationship between geometric time and the experienced time? What experienced time is? Is the arrow of time always the standard one?

Temporal non-locality is very difficult if not impossible to understand in the standard physics framework, where 3-D snapshot of reality together with initial values for generalize positions and velocities determine everything. Are the basic objects 4-dimensional? Should one consider generalized positions at two values of time as basic data. Could kind of generalize Bohr orbits be in question. Could the basic entities be events - pairs of 3-D snapshot at different values of geometric time?

Should ordinary positive energy ontology (PEO) be replaced with something different, in which pairs of states - physical events - or equivalently the 4-dimensional space-time evolutions connecting them, are basic entities. One can think that these pairs of initial and final states are zero energy states in the sense that the values of various conserved quantum numbers for the positive and negative energy parts sum up to zero. This would allow to have deterministic dynamics for connecting time evolutions without loss of laws of physics. I call this ontology Zero Energy Ontology (ZEO). ZEO would be much more general than PEO but consistent with conservation laws and solve the to-be-or-not-to-be question of theoretician: why to see the pains of constructing a theory if only one particular solution of equations is realized in Nature: one cannot test the theory without additional assumptions. In ZEO based quantum theory any zero energy state could be created from vacuum.

1.2 Living systems have shape

Living organisms have shape, which is non-local property. All physical systems have shape. These shapes appear in all scales and in the case of fundamental biomolecules the shapes have crucial significance for the functioning of living matter. For instance, the dynamical folding of DNA double strand is essential for transcription.

In standard physics the shape is described in terms of densities of particles as something phenomenological. In the modelling the shape is fed in as a phenomenological geometric input and there is no attempt to really deduce the shape from microscopic physics as reductionism would demand. It is highly questionable whether this attempt could be even successful.

Could shape as something non-local be something real?

1. Geometry and topology provide two definitions of shape. Could the space-time topology and geometry - its shape - be non-trivial in even macroscopic scales? This idea does not conform with the general relativistic view according to which space-time would be topologically rather uninteresting above Planck scale. One would lose the energy momentum conservation as consequence of lost space-time symmetries (translations and Lorentz transformations). Also topology change for 3-space, which takes place routinely in living matter systems, is impossible in this framework.

2. How could one modify the general relativistic view? The hint comes from superstring models in which string world sheets are 2-D space-times represented as 2-D surfaces - sub-manifolds - in 10-D

space-time. String models fail but one could perhaps modify them. The basic problem of string models is how to get the 4-D space-time from string models. Why not replace 2-D surfaces with 4-D ones in some higher-D space-time, which could be taken to be fixed because the dynamics of space-time would be coded by its geometric shape. One would avoid the notorious landscape problem and loss of predictivity.

The identification of space-time as 4-surface would change completely the view about what space-time is. The good news is that one does not lose classical conservation laws if the higher-dimensional space-time is chosen properly. Space-time surfaces can contain even Euclidian regions (time and space in the same role) without loss of basic conservation laws. This means huge flexibility.

3. The visible world is also hierarchical: shapes within shapes. Biological body consists of organs consists of cells consists of biomolecules consists of ... . This fractal like structure should have counterpart as the structure of space-time surface. Space-time surface indeed turn out to have this kind of structure: ... space-time sheets glued to larger space-time sheets glued to.... I refer to this structure as many-sheeted space-time and we indeed see it directly!

Question: Could space-time be 4-D surface in some higher-D space-time - many-sheeted space-time. The shape of spacetime would have meaning also as shape in this higher-D space-time.

1.3 Does coherence in long spatial and temporal scales reduce to macroscopic quantum coherence?

Coherence could be understood as macroscopic quantum coherence if living systems are macroscopic quantum systems. But how?: Planck constant is too small? There are several hints suggesting that Planck constant could have actually a spectrum.

1.3.1 Effects of ELF em fields on living matter, macroscopic quantum coherence, and dark matter and energy

The effects of ELF em fields on vertebrate brain involving both physiology and behavior look like quantal appearing at multiples of basic frequency assignable to cyclotron transitions of biologically important ions such as Ca^{++} ion in endogenous magnetic field of $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ is the nominal value of Earth's magnetic field [23] The problem is that cyclotron energies are extremely low: more than ten orders of magnitude below thermal energies.

Question: Could Planck constant have nonstandard values: say $h_{eff} = n \times h$.

If this were the case, quantum scales would be scaled up. Energy $E = h_{eff}f$ associated with given frequency is scaled up. Could EEG consist of photons with $h_{eff} = n \times h$ such that the energies of dark EEG photons are above thermal energies. These photons can transform to ordinary photons perhaps identifiable as bio-photons in the energy range of visible and UV photons.

What these phases of matter with non-standard Planck constants could be? Why we have not observed them? We know that dark energy and dark matter exist. Could they correspond to $h_{eff} = n \times h$ phases? If so, dark matter could be in key role in living matter. Two mysteries would find a common explanation.

Question: Should one generalize quantum theory so that dark matter/energy would be assignable to hierarchy of $h_{eff} = n \times h$ phases?

1.3.2 Where could the dark matter reside?

Where could the dark matter reside?

1. The first hint comes from quite recent finding that the brain hemispheres of persons having no corpus callosum are in synchrony (see `http://tinyurl.com/3gjhtgb`). What synchronizes the brain hemispheres in this kind of situation? The hint comes from spontaneous synchronization of

clocks (penduli) involving generation of very weak periodic perturbation - "boss" - forcing the clocks in same phase. Is there a kind of "boss", which forces neurons to march in synchrony [58]?

2. Second hint comes from the observation that EEG correlates strongly with the contents of consciousness. Why? Information costs energy. Why to construct information not used for any purpose? Could it be that EEG communicates information about brain state to some entity? Could this entity be the "boss" in turn using EEG to control the brain. The wavelength associated with EEG frequency 7.8 Hz is circumference of Earth. Could this entity be of this size or even larger?

3. There is a further hint: the effects of ELF radiation were at cyclotron frequencies in endogenoues magnetic field with strength of .2 Gauss. For iron it corresponds to 10 Hz frequency for which wavelength is slightly larger than circumference of Earth. Could the "boss" be a magnetic field structure - magnetic body (MB) - assignable to the organism?

4. There is an objection against this idea. In Mawell's electrodynamics magnetic fields of different organisms interfere to a random background so that the informations from separate organisms would be lost. Standard space-time concept is not enough. Should the very notion of space-time be such that the magnetic field structures of different organisms behave like separate entities without interference between them. The phases of matter with different values of h_{eff} would in some sense live in different worlds - they would be dark relative to each other - but also interact with matter visible to us. Generalization of space-time concept seems to be necessary necessary. The guess is many-sheeted space.

Question: Do magnetic bodies carrying dark matter characterized by non-standard value of Planck constant carry serve as "bosses"? They should also effectively correspond to separate space-times.

1.3.3 How to create dark matter?

One eventually encounters the question how to test the theory. To achieve this one should be able to create dark matter by inducing phase transition of ordinary matter to dark matter or to do the opposite: ordinary matter would mysteriously disappear somewhere of pop up somewhere. This would serve as a signature for the dark matter. There are some hints.

1. Biosystems look like critical systems. Sensory systems have optimal sensitivity to small changes in environment. There is analogy with fundamental physics: in particle accelerators measurement instruments are critical systems to maximize the sensitivity and transform microscopic effects to macroscopic ones. Neural system is an excellent example of a control system in which small control signals give rise to large effects. Homeostasis can be understood in terms of positive and negative feedback keeping the system near criticality. Living systems are functional in rather narrow temperature range. There is also evidence for quantum criticality (QC) at molecular level [19].

2. The appearance of $h_{eff} = n \times h$ dark matter should lead to a generation of long range coherence and non-locality. On the other hand, long range fluctuations are the tell-tale signature of criticality. Could dark phases with $h_{eff} = n \times h$ be created at quantum criticality (QC)?

Question: IS QC is essential for having non-locality manifesting itself as long range correlations, dark matter, and $h_{eff} = n \times h$ phases.

1.4 Summing up

To sum up: these propagandistic arguments suggest the following picture.

1. Temporal non-locality requires that PEO is replaced ZEO. The arrow of time is not always the same. The relationship between experienced and geometric time must be understood: they are not same although they are strongly correlated.

2. The importance of shape - a non-local concept - in biology suggests identification of space-time as 4-D surface in some higher-D space-time.

3. EEG contains information about the contents of consciousness: EEG communicates information to some entity identified as magnetic body serving as intentional agent receiving sensory input and controlling biological body. The organism-environment duality would be replaced with trinity involving also MB.

4. Coherence in long scales reduces to quantum coherence for $\rightarrow h_{eff} = n \times h$ dark matter hierarchy and dark matter at magnetic bodies is the quintessence of living matter.

5. Criticality of living matter reduces to long range correlations implied by QC. Dark matter is created at QC and implies also non-locality.

The challenge is to realize this picture mathematically. TGD does this although I ended up with it with motivations coming from General Relativity and particle physics. In the sequel I discuss the mathematical formulation and its physical interpretation. I also discuss briefly various applications of this picture.

2 TGD and TGD inspired theory of consciousness

General theory of relativity (GRT) plagued by the problem that the notions of energy and momentum are not well-defined for curved space-time time. The proposal for overcoming the energy problem (made 1977, thesis came 1982) was that space-times are not abstract 4-D manifolds but representable as 4-D surfaces in certain 8-dimensional space-time $H = M^4 \times CP_2$, which is empty Minkowski space M^4 with points replaced with certain very small 4-D space CP_2 fixed uniquely from the condition that standard model symmetries and standard model fields can be geometrized. This choice of H is uniquely fixed both by twistorial considerations [54, 73] or by the condition that theory is consistent with standard model symmetries.

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

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

In what follows I will proceed from quantum TGD to classical TGD without starting from particle physics observations - it would be extremely boring to repeat same old arguments again and again and reader can find these arguments from [66].

2.1 Quantum TGD

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

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

The condition that the entire quantum theory is geometrized requires infinite-dimensional geometric structure instead of space-time and the "world of classical worlds" (WCW) identified roughly as the space of space-time surfaces is the natural identification [K3, 35].

1. The construction of quantum TGD leads to a generalization of the notion of super-space of Wheeler and to construction of infinite-dimensional geometry that I call "World of Classical Worlds" (WCW) having rough mathematical identification as space of 3-surfaces in H (ZEO dictates the identification in more detail). The mere mathematical existence of WCW geometry fixes it essentially uniquely - this is true already for the loop spaces of string model [2] - and therefore physics. A huge generalization of the symmetries of super-string models emerges giving hopes of understanding the theory.

   The geometrization of hermitian conjugation of quantum theory requires that WCW allows complex structure its metric is Kähler metric [35] and coded by Kähler function identified in terms of Kähler action for a preferred extremal: this gives direct connection with classical physics since induced Kähler form define classical U(1) field, for the U(1) factor of electroweak gauge group assignable with weak hyper-charge. Twistorial lift implies the presence of a volume term identifiable in terms of cosmological constant. It would bring also Planck length into the theory as the radius of twistor sphere [54].

2. Quantum states are identified as classical WCW spinor fields so that there is no need to perform quantization and state function reduction is the only genuinely quantal aspect of TGD [57, 69]. Spinor structure requires identification of gamma matrices anticommuting to WCW metric and if the metric is Kähler metric, the anti-commutation relations are completely analogous to those of fermionic oscillator operators and one can indeed express the gamma matrices as linear superpositions of fermionic oscillator operators at space-time surface. Second quantization at space-time level is a purely classical notion at WCW level and becomes geometrized in WCW context.

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

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

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

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

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

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

   This eventually led to the realization that partonic 2-surfaces and string world sheets should be enough for the formulation of WCW geometry and quantum TGD [31]. Classical fields in the interior of space-time surface would be needed only in quantum measurement theory, which demands classical physics in order to interpret the experiments. The outcome is SH stating that quantum physics should be coded by string world sheets and partonic 2-surfaces inside given causal diamond (CD). SH is very much analogous to the AdS/CFT correspondence but is much simpler: the simplicity is made possible by much larger group of conformal symmetries. 2-dimensionality of space-time regions carrying fermion field can be deduce also from the condition that electromagnetic charge is well-defined for spinor modes: this requires that W boson fields vanish and this implies in the generic case 2-D string world sheets. Number theoretic vision suggests the interpretation of string world sheets and partonic 2-surfaces as commutative or co-commutative sub-manifolds of the space-time having quaternionic (associative) tangent space as a 4-surface in the imbedding space with octonionic (non-associative) tangent space [52, 70].

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

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

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

The Kähler coupling strength α_K appearing in Kähler action is analogous to temperature. In its original form [35] QC stated that this coupling strength is analogous to critical temperature and therefore has discrete spectrum. This idea makes sense even if Kähler action is generalized to contain additional terms: all coupling constants would be analogous to critical thermodynamical parameters.

Indeed, the twistorial lift of TGD [54, 73] replacing space-time surfaces with their twistor spaces in 12-dimensional product of twistor spaces of M^4 and CP_2 indeed brings in cosmological constant Λ and Planck length as radius of the sphere S^2 serving as the fiber of twistor space. This lift makes sense only for $M^4 \times CP_2$ making this choice unique. If Planck length and cosmological constant emerge in this manner their spectrum would be fixed by QC condition. The negative pressure implying accelerated cosmic expansion can be also assigned to magnetic flux tubes with monopole flux so that the situation remains open.

The meaning of QC at the level of dynamics has become only gradually clearer. The development of several apparently independent ideas generated for about decade ago have led to the realization that QC [67] is behind all of them. Behind QC are in turn number theoretic vision and strong forms of general coordinate invariance (GCI) and holography (SGCI and SH).

1. The hierarchy of Planck constants labelling a hierarchy of dark phases of ordinary matter corresponds to a hierarchy of quantum criticalities assignable to a fractal hierarchy of sub-algebras of the super-symplectic algebra assignable to the boundary of causal diamond (CD) with points replaced with CP_2. The conformal weights are n-ples of those for the entire algebra, n corresponds to the value of effective Planck constant $h_{eff}/h = n$. These algebras are isomorphic to the full algebra and act as gauge conformal algebras so that a broken super-conformal invariance is in question. For $n > 1$ the hierarchy levels are interpreted in terms of dark matter. What is highly non-trivial that the conformal weights itself need not be integers or half integers as usually. The generators of algebra could have conformal weights which are proportional to zeros of zeta and poles of zeta so that the number of generating elements (finite for ordinary super-conformal algebras) would be infinite [32]. Physical states would however have real conformal weights which would be half integers (conformal confinement).

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

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

3. The hierarchy of algebraic extensions of rationals defines the values of the parameters characterizing the 2-surfaces, and one obtains a number theoretical realization of an evolutionary hierarchy. One can also algebraically continue the space-time surfaces to various number fields - reals and the algebraic extensions of p-adic number fields. Physics becomes adelic [70].

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

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

5. If twistorial lift is not performed, the only coupling constant of the theory is Kähler coupling constant $\alpha_K = g_K^2/4\pi\hbar$, which appears in the definition of the Kähler function K characterizing the geometry of WCW. In the most general case α_K has a spectrum of critical values and this conjecture seems at this moment the most reasonable one. It has indeed turned out that the discrete spectrum could have interpretation in terms of discretized coupling constant evolution for U(1) coupling constant of standard model. The identification of the spectrum in terms of zeros of so called fermionic zeta function expressible in terms of Riemann zeta is attractive [32]. The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed values of $\alpha_K = g_K^2/4\pi\hbar_{eff}$ should be analogous to critical temperatures and determined by QC requirement.

2.2 Classical TGD

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

2.2.1 Space-time surfaces as preferred extremals of Kähler action

Preferred extremal of Kähler action have remained for a long time one of the basic poorly defined notions of TGD. There are pressing motivations for understanding what "preferred" really means. For instance, the conformal invariance of string models naturally generalizes to 4-D invariance defined by quantum Yangian of quantum affine algebra (Kac-Moody type algebra) characterized by two complex coordinates and therefore explaining naturally the effective 2-dimensionality [54].

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

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

2.2.2 Many-sheeted space-time and topological field quantization

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

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

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

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

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

2.2.3 New ontology

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

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

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

3. A further modification of ontology is the replacement of the usual positive energy ontology (PEO) with what I call zero energy ontology (ZEO) already described. In ZEO quantum states are superpositions of quantum evolutions connecting the positive and negative energy parts of the states. Zero energy states are essentially 4-D and only the positive and negative energy parts are 3-D. Quantum jumps/state function reductions re-create the zero energy states with new ones and this allows to solve the basic paradox of ordinary quantum measurement theory due to the fact that non-determinism of state function reduction is in conflict with the determinism of unitary time evolution. One also ends up with identification of "self" as conscious entity: self corresponds to generalized Zeno effect: to a sequence of state function reduction to say positive (positive) energy part of zero energy state [30] [84]. Self dies when the first reduction to negative (positive) part occurs. Also the origin for the flow of experienced time can be understood.

2.2.4 Hierarchies

TGD Universe is characterized by various hierarchies. At space-time level there is a hierarchy of space-time sheets labelled by a hierarchy of p-adic length scales coming as primes near powers of two and probably generalizing to primes near powers of prime [64, 70]. In zero energy ontology (ZEO) and at imbedding space level there is a hierarchy of causal diamonds (CDs) labelled by their size scales coming as

integer multiples of CP_2 scales. The fractal hierarchy of symplectic sub-algebras leads to a generalization of quantum theory based on a hierarchy of Planck constants characterizing hierarchy of dark matters [33, 67], hierarchies of inclusions of hyper-finite factors [56], hierarchies of breakings of super-symplectic gauge symmetry [57, 69] associated with a hierarchy of quantum criticalities [67]. There is also a number theoretic hierarchy of algebraic extensions of rationals accompanied by those of p-adic number fields [70] allowing to see evolution as a gradual increase of the complexity for extensions of rationals assignable to the parameters characterizing string world sheets and partonic 2-surfaces. In TGD inspired theory of consciousness [38] self hierarchy emerges.

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

By SH implied by the SGCI the core of the mathematical description of quantum TGD reduces to that for 2-D systems associated with partonic 2-surfaces and string world sheets. Although space-time is 4-D, all that can be said mathematically about quantum physics can be reduced to these 2-D "space-time genes". 4-D space-time surfaces are however necessary for the classical description of TGD necessary to interpret quantum measurements in terms of frequencies and wavelengths classical space-time picture about particles. This reduction implies that the representations of charges of super-symplectic Yangian [54, 73] are in terms of fermionic strings connecting partonic 2-surfaces, which means enormous simplification of the theory. This representation also involves a generalization of AdS/CFT duality to TGD framework as manifestation of SGCI basically [31].

2.3 Number theoretical physics

Number theoretical physics involves several threads [70].

1. p-Adic physics as correlate for cognition, imagination, and intentionality [51] p-Adic physics was originally inspired by the challenge of understanding the mass scales of elementary particles but it soon turned that the interpretation in terms of mathematical correlates of cognition and imagination is very natural. This in turn forced the conclusion that cognition is probably present in all length scales, rather than only at the level of brain. The eventual outcome was a fusion of real and p-adic physics in terms of adelic physics.

2. Classical number fields emerge very naturally in TGD framework [52]. For instance, the conjecture is that space-time surfaces as preferred extremals of Kähler action are quaternionic sub-manifolds of imbedding space endowed with octonionic structure. Also quaternion analyticity [4, 3] as a generalization of complex analyticity central in string models is very attractive conjecture [54] in accordance with the original vision that 2-D analyticity in some sense generalizes to its 4-D variant.

3. Infinite primes [50] are constructed by a repeated second quantization of arithmetic quantum field theory and could be essential for understand of quantum TGD.

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

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

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

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

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

4. The fusion of real physics and various p-adic physics (identified as correlates for cognition, imagination, and intentionality) to single coherent whole leads to adelic physics [70]. Adeles associated with given extension of rationals are Cartesian product of real number field with all p-adic number fields extended by the extension of rationals. Besides algebraic extensions also the extension by any root of e is possible since it induces finite-dimensional p-adic extension. One obtains hierarchy of adeles and of corresponding adelic physics interpreted as an evolutionary hierarchy.

   An important restriction is that p-adic Hilbert spaces exist only if one restricts the p-adic numbers to an algebraic extension of rationals having interpretation as numbers in any number field. This is due to the fact that sum of the p-adic valued probabilities can vanish for general p-adic numbers so that the norm of state can vanish. One can say that the Hilbert space of states is universal and is in the algebraic intersection of reality and various p-adicities.

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

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

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

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

   The possibility of NE together with NMP [39] implies that the reduction does not always lead to an unentangled state but can generate NE. Living systems would be systems generating NE and biological evolution could be seen as a gradual generation of negentropic resources - I have called them Akashic Records. For rational probabilities entanglement negentropy equals to real entropy [81]. This might relate to the Jeremy Englands vision that high entropy is relevant for living matter.

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

2.3.2 The extension of real physics to adelic physics

In TGD framework cognition is described in terms of p-adic number fields and has led to a fusion of real and various p-adic physics to what I call adelic physics [70]. Real physics corresponds to sensory

experience and p-adic physics to cognition and imagination. Originally I talked about p-adic physics as physics of cognition and intentionality but I have have become ambivalent about intentionality: this issue remains unsettled.

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

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

2. The first guess was that this means at space-time level that imbedding space points with rational valued coordinates (or values in the extension of rationals) correspond to common points of real and p-adic space-time surfaces. This picture however leads to problems with both GCI and key symmetries of TGD. What are the preferred coordinates of space-time surface which would be in algebraic extension of rationals in the intersection? Should one restrict symmetry groups to their discrete subgroups?

3. A partial resolution of the problem came from the realization that the intersection of realities and p-adicities corresponds to space-time surfaces, whose representation is such that they make sense both in real and p-adic sense [70]. This requires that the WCW coordinates of these surfaces are invariant under various symmetries and general coordinate transformations of space-time belong to the extension of rationals in question. At the level of WCW the coordinates are highly unique on basis of symmetries and by GCI at space-time level. This also means discretization of the infinite-dimensional WCW and together with huge isometry group of WCW gives hopes about computatibility of TGD.

4. As often happens, also the original idea about points of given algebraic extension of rationals as common to real and p-adic space-time surfaces makes sense: one can say that these discrete points define cognitive representations in the real world. The point is that space-time surfaces can be identified as 4-surfaces in H and discretization is induced by that of H. At the first step, the pieces of hyperboloids inside CD and CP_2 can be replaced with their discrete variants making sense both in real and p-adic sense [83].

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

   The outcome is a precise mathematical formulation for the p-adic counterparts of space-time surfaces as preferred extremals of Kähler action. The p-adic variants of coset spaces can be seen as discretizations of real coset spaces with discrete points replaced by p-adic continua analogous to the monads of Leibniz [83]. This would make possible discretization without loosing differentiability central for field equations. One can define p-adic field equations inside these monads and strong SH makes sense in both real and p-adic sector.

   The same algebraic expressions would describe real and p-adic solutions of field equations locally when restricted to string world sheets and partonic 2-surfaces (maybe also their light-like orbits).

Inside monads real-p-adic correspondence would respect algebraic structures and symmetries. In the intersections symmetry groups would be replaced with discrete subgroups and continuity would be respected in the approximation provided by discretization and would confirm with the idea about finite measurement resolution.

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

2.3.3 p-Adic physics as physics of imagination

A further step in the progress came from the discovery of SH [31]. 2-dimensional surfaces (string world sheets and partonic 2-surfaces) are fundamental objects and 4-D physics is a kind of algebraic continuation from this intersection of reality and various p-adicities in both real and p-adic sectors of the adelic Universe. 4-D space-time surfaces are preferred extremals of Kähler action making them effectively 2-D in the sense that the 2-D surfaces serve as "space-time genes" . Also the quantum states assignable to the 2-D surfaces can be algebraically continued to the entire 4-D space-time.

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

2.3.4 Negentropic entanglement (NE)

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

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

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

TGD has been plagued by a longstanding interpretational problem: can one apply the notion of number theoretic entropy in the real context or not. If this is possible at all, under what conditions this is the case? How does one know that the entanglement probabilities are not transcendental as they would

be in generic case? There is also a second problem: p-adic Hilbert space is not a well-defined notion since the sum of p-adic probabilities defined as moduli squared for the coefficients of the superposition of orthonormal states can vanish and one obtains zero norm states.

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

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

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

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

   (a) For Option 1 the total entropy vanishes identically for *rational* probabilities and NMP would say nothing about the situation [81]. NMP would not prevent or favor state function reduction. It is not clear whether this situation corresponds to that in the physics of ordinary matter as opposite to that of living matter. For algebraic probabilities there would be a competition between real and p-adic sectors and p-adic sectors would win for algebraic extensions in the sense that p-adic entropy would be larger than real entropy.

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

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

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

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

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

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

TGD inspired theory of consciousness can be seen as a generalization of the quantum measurement theory by bringing observer as self. The basic vision is that quantum measurement theory must be generalized so that observer ceases to be an outsider and is described by the quantum physics. ZEO plays a key role in this generalization and makes highly non-trivial predictions. Raising quantum measurement to a universal physical phenomenon requires the identification of the density matrix of subsystem as a universal observable and introduction of Negentropy Maximization Principle (NMP) [39] as the fundamental variational principle of consciousness.

2.4.1 ZEO

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

1. In TGD framework the answer is Zero Energy Ontology (ZEO) [39]. The concept of quantum state is generalized. States are now analogs for physical events characterized by initial and final quantum state that is pairs of positive and negative energy states. The conserved quantum numbers of the members are opposite so that zero energy states can be created from vacuum. This is a radical generalization of the physicalist world of view but entirely consistent with conservation laws: there is no need to give laws of physics in order to have free will. Positive and negative energy parts of the zero energy states can be assigned to opposite light-like boundaries of causal diamonds (CDs), which are intersections of future and past directed light-cones multiplied by CP_2. CDs form a fractal scale hierarchy. They can be seen as imbedding space correlates for the 4-D perceptive fields of selves.

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

2.4.2 NMP as variational principle of consciousness

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

1. Negentropy Maximization Principle (NMP) [39] is the variational principle of consciousness in TGD framework reducing to quantum measurement theory in Zero Energy Ontology assuming adelic physics. Negentropy Maximization Principle or something akin to it should be consistent with the standard rules of quantum measurement theory and possibly generalize them. In particular, NMP should tell which observables are measured in given entangled situation. The density matrix defined by the entanglement is the unique candidate for the universal observable. All systems could be said to give rise to quantum measurements. NMP must decide how long the self "lives": self lives as long as repeated state function reductions at the same boundary give the maximal negentropy gain.

2. One must have a mathematical definition of negentropy [39]. When negentropic entanglement (NE) is possible and what is the measure for the negentropy? Shannon entropy is the natural starting point and p-adic generalization of Shannon entropy by replacing the logarithms of probabilities with the logarithms of their p-adic norms might fit the bill. It is well defined for algebraic entanglement probabilities belonging to the algebraic extension of rationals defining also the extensions of varius various p-adic number fields) [81].

   Adelicity holds true in the sense that the sum of real and p-adic information measures (finite number of primes contribute) over all primes vanishes for rational entanglement probabilities. This is not the case for the algebraic extensions of adeles induced by those of rationals [81].

   It is not quite clear whether NMP applies to the sum of p-adic entropies or to the sum of real and p-adic entropies providing alternative definitions of information. Both options conform with the fact that large entropy seems to be prerequisite for life as proposed Jeremy England [17, 78].

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

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

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

There is an obvious analogy with the Integrate Information Theory (IIT) of Tononi and Koch. The quantity Φ postulated by Tononi and Koch [29] resembles negentropy in TGD [86]. The basic objection against IIT is that the notion of conscious information is circular being based on entropy as fundamental notion. Information is defined as reduction of entropy when conscious entity learns what the state of system is. The notion of conscious information cannot involve this kind of dependence. In TGD framework negentropy for entanglement does not involve this kind of assumption since conscious information represents abstraction or rule with the superposed state pairs (a_i, b_i) representing the instances of a rule (A, B) and A and B representing concepts.

2.4.3 The notion of self

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

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

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

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

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

4. Self can also make moral choices since NMP in its weak form leaves us freedom to make also bad choices or especially negentropic choices (for details see [39]). Possible are also choices, which do not yield optimal negentropy gain. By allowing sin NMP also makes possible really big negentropy gains: NMP would be like venture capitalist in this sense. In statistical sense there is however an evolution as increase of the negentropic sources of the Universe. Crime is part of being alive: living creatures are fighting desperately for NE and a clever but inmoral manner to gain it is to eat other living beings.

5. One big news is that selves form a hierarchy (CDs within CDs) and sub-selves are identified as mental images. In TGD framework it is also possible for sub-selves of two unentangled selves to entangle negentropically. This corresponds to sharing of mental images and means that our conscious experience is not completely private. The pool of shared mental images might in fact make possible communication and social structures. Sharing of mental images is possible only in many-sheeted space-time forcing to generalize the standard view about subsystem.