TGD inspired Quantum Theory of Consciousness and of Bio-systems: an Overall View

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Contents

Abstract

The purpose of this chapter is to represent a bird eye's of view about the basic ideas of TGD inspired consciousness and its applications to living matter. The notion of many-sheeted space-time, dark matter hierarchy with levels by the values of dynamical quantized Planck constant, and the resulting basic vision about bio-systems as macroscopic quantum systems are summarized. The basic ideas and concepts of TGD inspired theory of consciousness are reviewed. Discussed are also the recent views about how local p-adic physics codes for the long range correlations of the real physics as p-adic fractality and how p-adic space-time sheets provide correlates for cognition and intentionality.

1 Introduction

In this chapter I will discuss TGD based view about time and space-time. The discussion of the many-sheeted space-time concept explaining the basic notions once again is included because I feel that this is in order since the understanding of "topological light rays" (massless extremals, briefly MEs), and of magnetic and electric flux quanta has developed vigorously since the articles published in the last issue of JNLRMI [16]. I have not even attempted to include all essential aspects since this would simply lead both me and the reader to despair. I consider those aspect that I feel especially relevant just now. To be honest, the act of writing the article generated a lot of new insight s and ideas so that the boring duty to summarize something already done transformed once again to an active process of thinking and identifying weak points in the existing scenario and trying to see the idea landscape from a more general perspective. The 8 online books [10, 8, 9, 13, 11, 12, 14, 15] at my home page provide a comprehensive unavoidably out of date summary TGD inspired theory of consciousness.

A brief summary of what might be called basic principles is in order to facilitate the reader to assimilate the basic tools and rules of intuitive thinking involved.

1.1 Quantum-classical correspondence

The fundamental metalevel guiding principle is quantum-classical correspondence (classical physics is an exact part of quantum TGD). The principle states that all quantum aspects of the theory, which means also various aspects of consciousness such as volition, cognition, and intentionality, should have space-time correlates. Real space-time sheets provide kind of symbolic representations whereas p-adic space-time sheets provide correlates for cognition and intentions. All that we can symbolically communicate about conscious experience relies on quantal space-time engineering to build these representations.

1.2 Classical physics as exact part of quantum theory

Classical physics corresponds to the dynamics of space-time surfaces determined by the absolute minimization of so called Kähler action. This dynamics have several unconventional features basically due to the possibility to interpret the Kähler action as a Maxwell action expressible in terms of the induced metric defining classical gravitational field and induced Kähler form defining a non-linear Maxwell field not as such identifiable as electromagnetic field however.

1.2.1 Classical weak and color fields as signature for a fractal hierarchy of copies standard model physics

The geometrization of classical fields means that various classical fields are expressible in terms of imbedding space-coordinates and are thus not primary dynamical variables. This predicts the

presence of long range Z^0 and color (gluon) fields not possible in standard physics context. It took 26 years to end up with a convincing interpretation for this puzzling prediction.

What seems to be the correct interpretation is in terms of an infinite fractal hierarchy of copies of standard models physics with appropriately scaled down mass spectra for quarks, leptons, and gauge bosons. Both p-adic length scales and the values of Planck constant predicted by TGD [C6] label various physics in this hierarchy. Also other quantum numbers are predicted as labels. This means that universe would be analogous to an inverted Mandelbrot fractal with each bird's eye of view revealing new long length scale structures serving also as correlates for higher levels of self hierarchy.

Exotic dark weak forces and their dark variants are consistent with the experimental widths for ordinary weak gauge bosons since the particles belonging to different levels of the hierarchy do not have direct couplings at Feynman diagram level although they have indirect classical interactions and also the de-coherence reducing the value of $\hbar$ is possible. Classical long ranged weak fields play a key role in quantum control and communications in living matter [M3, L4]. Long ranged classical color force in turn is the backbone in the model of color vision [K3]: colors correspond to the increments of color quantum numbers in this model. The increments of weak isospin in turn could define the basic color like quale associated with hearing (black-white $\leftrightarrow$ to silence-sound [K3, M5, M6]).

1.2.2 Topological field quantization and the notion of many-sheeted space-time

The compactness of CP_2 implies the notions of many-sheeted space-time and field quantization. Topological field quantization means that various classical field configurations decompose into topological field quanta. One can see space-time as a gigantic Feynman diagram with lines thickened to 4-surfaces. Absolute minimization of Kähler action implies that only selected field configurations analogous to Bohr's orbits are realized physically so that quantum-classical correspondence becomes very predictive. An interpretation as a 4-D quantum hologram is a further very useful picture [K2] but will not be discussed in this chapter in any detail.

Topological field quantization implies that the field patterns associated with material objects form extremely complex topological structures which can be said to belong to the material objects. The notion of field body, in particular magnetic body, typically much larger than the material system, differentiates between TGD and Maxwell's electrodynamics, and has turned out to be of fundamental importance in the TGD inspired theory of consciousness. One can say that field body provides an abstract representation of the material body.

One implication of many-sheetedness is the possibility of macroscopic quantum coherence. By quantum classical correspondence large space-time sheets as quantum coherence regions are macroscopic quantum systems and therefore ideal sites of the quantum control in living matter.

1. The original argument was that each space-time sheet carrying matter has a temperature determined by its size and the mass of the particles residing at it via de Broglie wave length $\lambda_{dB} = \sqrt{2mE}$ assumed to define the p-adic length scale by the condition $L(k) < \lambda_{dB} < L(k_>)$. This would give very low temperatures when the size of the space-time sheet becomes large enough. The original belief indeed was that the large space-time sheets can be very cold because they are not in thermal equilibrium with the smaller space-time sheets at higher temperature.

2. The assumption about thermal isolation is not needed if one accepts the possibility that Planck constant is dynamical and quantized and that dark matter corresponds to a hierarchy of phases characterized by increasing values of Planck constant [C6, J6]. From $E = hf$ relationship it is clear that arbitrarily low frequency dark photons (say EEG photons) can have energies above thermal energy which would explain the correlation of EEG with consciousness. This vision allows to formulate more precisely the basic notions of TGD inspired

theory of consciousness and leads to a model of living matter giving precise quantitative predictions. Also the ability of this vision to generate new insights to quantum biology provides strong support for it [M3].

Many-sheeted space-time predicts also fundamental mechanisms of metabolism based on the dropping of particles between space-time sheets with an ensuing liberation of the quantized zero point kinetic energy. Also the notion of many-sheeted laser follows naturally and population inverted many-sheeted lasers serve as storages of metabolic energy [K6].

Space-time sheets topologically condense to larger space-time sheets by wormhole contacts which have Euclidian signature of metric. This implies causal horizon at which the signature of the induced metric changes from Minkowskian to Euclidian. This forces to modify the notion of subsystem. What is new is that two systems represented by space-time sheets can be unentangled although their subsystems bound state entangle with the mediation of the join along boundaries bonds connecting the boundaries of sub-system space-time sheets. This is not allowed by the notion of subsystem in ordinary quantum mechanics. This notion in turn implies the central concept of fusion and sharing of mental images by entanglement.

1.2.3 The possibility of negative energies

A further prediction derives from the fact that space-time is 4-surface rather than an abstract manifold. Energy momentum tensor of general relativity is replaced by a collection of conserved energy and momentum currents, which are 4-vector fields. This makes the notions of energy and momentum precisely defined but also implies that the sign of energy and momentum depend on the time-orientation of the space-time sheet. Negative energies become therefore possible somewhat like in the lines of a Feynman diagram. Negative energy topological light rays have phase conjugate laser waves [20] as the most plausible standard physics counterparts, and play a fundamental role in quantum metabolism as a kind of quantum credit card [K6]. They generate also time like entanglement which corresponds to a formation of new kind of bound states.

Negative energies might be possible even for ordinary particles and could mean dramatic deviation from the standard quantum theory. The roles of annihilation and creation operators have changed for negative energy space-time sheets. This would mean that operator combinations involving both annihilation and creation operators would generate states involving positive and negative energy space-time sheets. One can even imagine that a intentional action could create states with vanishing net quantum numbers and that positive and negative energy particles could be separated from each other.

1.2.4 TGD Universe is quantum spin glass

Since Kähler action is Maxwell action with Maxwell field and induced metric expressed in terms of $M^4_+ \times CP_2$ coordinates, the gauge invariance of Maxwell action as as a symmetry of the vacuum extremals (this implies is a gigantic vacuum degeneracy) but not of non-vacuum extremals. Gauge symmetry related space-time surfaces are not physically equivalent and gauge degeneracy transforms to a huge spin glass degeneracy. Spin glass degeneracy provides a universal mechanism of macro-temporal quantum coherence and predicts degrees of freedom called zero modes not possible in quantum field theories describing particles as point-like objects. Zero modes are identifiable as effectively classical variables characterizing the size and shape of the 3-surface as well as the induced Kähler field.

1.2.5 Classical and p-adic non-determinism

The vacuum degeneracy of Kähler action implies classical non-determinism, which means that space-like 3-surface is not enough to fix the space-time surface associated with it uniquely as an

absolute minimum of action, and one must generalize the notion of 3-surface by allowing sequences of 3-surfaces with time like separations to achieve determinism in a generalized sense. These "association sequences" can be seen as symbolic representations for the sequences of quantum jumps defining selves and thus for contents of consciousness. Not only speech and written language define symbolic representations but all real space-time sheets of the space-time surfaces can be seen in a very general sense as symbolic representations of not only quantum states but also of quantum jump sequences. An important implication of the non-determinism is the possibility to have conscious experiences with contents localized with respect to geometric time. Without this non-determinism conscious experience would have no correlates localized at space-time surface, and there would be no psychological time.

p-Adic non-determinism follows from inherent non-determinism of p-adic differential equations for any action principle and is due to the fact that integration constants, which by definition are functions with vanishing derivatives, are not constants but functions of the pinary cutoffs x_N defined as $x = \sum_k x_k p^k \to x_N = \sum_{k<N} x_k p^k$ of the arguments of the function. In p-adic topology one can therefore fix the behavior of the space-time surface at discrete set of space-time points *above* some length scale defined by p-adic concept of nearness by fixing the integration constants. In the real context this corresponds to the fixing the behavior *below* some time/length scales since points p-adically near to each other are in real sense faraway. This is a natural correlate for the possibility to plan the behavior and p-adic non-determinism is assumed to be a classical correlate for the non-determinism of intentionality, and perhaps also imagination and cognition.

These two non-determinisms allow to understand the self-referentiality of consciousness at a very general level. In a given quantum jump a space-time surface can be created with the property that it represents symbolically or cognitively something about the contents of consciousness before the quantum jump. Thus it becomes possible to become conscious about being conscious of something. This is very much like mathematician expressing her thoughts as symbol sequences which provides feedback to go the next abstraction level.

Classical and p-adic non-determinisms force also the generalization of the notion of entanglement. Time-like entanglement, crucial for understanding long term memory and precognition becomes possible. The notion of many-sheeted space-time forces also to modify the notion of subsystem, which implies that unentangled systems can have entangled subsystems. One can partially understand this in terms of length scale dependent notion of entanglement (the entanglement of subsystems is not seen in the length scale resolution defined by the size of unentangled systems) but only partially. The formation of join along boundaries bonds between subsystem space-time sheets and the fact that topologically condensed space-time sheets are separated by "elementary particle horizons" from larger space-time sheets, provide the deeper topological motivation for the generalization of subsystem concept.

1.2.6 p-Adic fractality of life and consciousness

p-Adic fractality of biology and consciousness has become an increasingly important guide line in the construction of the theory. This notion allows to relate phenomena occurring in the molecular level to phenomena like remote viewing and psychokinesis and it leads also to the view that topological field quanta of various fields of astrophysical size are crucial for the functioning of bio-systems. If one accepts p-adic fractality, the theory can be tested in unexpected manners, in particular in molecular and cellular length scales where the systems are much simpler. Sensory perception, long term memory, remote mental interactions, metabolism: all these phenomena rely on the same basic mechanisms. p-Adic length scale hypothesis allows to quantify the hypothesis with testable quantitative predictions.

1.3 Some basic ideas of TGD inspired theory of consciousness and quantum biology

The following ideas of TGD inspired theory of consciousness and of quantum biology are the most relevant ones for what will follow.

1. "Everything is conscious and consciousness can be only lost" is the briefest manner to summarize TGD inspired theory of consciousness. Quantum jump as moment of consciousness and the notion of self are key concepts of the theory. Self is a system able to avoid bound state entanglement with environment and can be formally seen as an ensemble of quantum jumps. The contents of consciousness of self are defined by the averaged increments of quantum numbers and zero modes (sensory and geometric qualia). Moments of consciousness can be said to be the counterparts of elementary particles and selves the counterparts of many-particle states, both bound and free. The selves formed by macro-temporal quantum coherence are in turn the counterparts of atoms, molecules and larger structures. Macro-temporal quantum coherence effectively binds a sequence of quantum jumps to a single quantum jump as far as conscious experience is considered. The idea that conscious experience is about changes amplified to macroscopic quantum phase transitions, is the key philosophical guideline in the construction of various models, such as the model of qualia, the capacitor model of sensory receptor, the model of cognitive representations, and declarative memories.

2. Macro-temporal quantum coherence is a second consequence of the spin glass degeneracy [K2]. It is essentially due to the formation of bound states and has as a topological correlate the formation of join along boundaries bonds connecting the boundaries of the component systems. During macro-temporal coherence quantum jumps integrate effectively to single long-lasting quantum jump and one can say that system is in a state of oneness, eternal now, outside time. Macro-temporal quantum coherence makes possible stable non-entropic mental images. Negative energy MEs are one particular mechanism making possible macro-temporal quantum coherence via the formation of bound states, and remote metabolism and sharing of mental images are other facets of this mechanism. The real understanding of the origin of macroscopic quantum coherence requires the generalization of quantum theory allowing dynamical and quantized Planck constant [J6, M3].

3. p-Adic physics as physics of intentionality and possily also of cognition is a further key idea of TGD inspired theory of consciousness. p-Adic space-time sheets as correlates for intentions and p-adic-to-real transformations of them as correlates for the transformation of intentions to actions allow deeper understanding of also psychological time as a front of p-adic-to-real transition propagating to the direction of the geometric future. Negative energy MEs are absolutely essential for the understanding of how precisely targeted intentionality is realized.

2 Many-sheeted space-time, magnetic flux quanta, electrets and MEs

TGD inspired theory of consciousness and of living matter relies on space-time sheets carrying ordinary matter, topological light rays (massless extremals, MEs), and magnetic and electric flux quanta. There are some new results which motivate a separate discussion of them.

2.1 Dynamical quantized Planck constant and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that

Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

2.1.1 Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [D6].

2.1.2 Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of biochemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

2.2 p-Adic length scale hypothesis and the connection between thermal de Broglie wave length and size of the space-time sheet

Also real space-time sheets are assumed to be characterized by p-adic prime p and assumed to have a size determined by primary p-adic length scale L_p or possibly n-ary p-adic length scale $L_p(n)$. More generally, each space-time dimension could correspond to its own p-adic length scale and even several p-adic primes could be associated with single dimension.

The possibility to assign a p-adic prime to the real space-time sheets is required by the success of the elementary particle mass calculations and various applications of the p-adic length scale hypothesis. Rationals are common to reals and all p-adic number fields. The p-adic-to-real transition transforming intentions to actions is made possible by a large number of common rational points between p-adic and real space-time surfaces, which supports the view that real space-time sheets obeys effective p-adic topology as an approximate topology in some resolution and below some length scale. p-Adic prime thus characterizes the classical non-determinism of the Kähler action.

Parallel space-time sheets with distance about 10^4 Planck lengths form a hierarchy. Each material object (...,atom, molecule, ..., cell,...) corresponds to this kind of space-time sheet. The p-adic primes $p \simeq 2^k$, k prime or power of prime, characterize the size scales of the space-time

sheets in the hierarchy. The p-adic length scale $L(k)$ can be expressed in terms of cell membrane thickness as

$$L(k) = 2^{(k-151)/2} \times L(151) \ , \tag{1}$$

$L(151) \simeq 10$ nm. These are so called primary p-adic length scales but there are also n-ary p-adic length scales related by a scaling of power of $\sqrt{p}$ to the primary p-adic length scale. Quite recent model for photosynthesis [K6] gives additional support for the importance of also n-ary p-adic length scales so that the relevant p-adic length scales would come as half-octaves in a good approximation but prime and power of prime values of k would be especially important.

2.3 Topological light rays (massless extremals, MEs)

I have described MEs, or "topological light rays", in previous articles of JNLRMI [18] and in [J4, J7], and describe here only very briefly the basic characteristics of MEs and concentrate on new idea about their possible role for consciousness and life.

2.3.1 What MEs are?

MEs can be regarded as topological field quanta of classical radiation fields [J4, J7]. They are typically tubular space-time sheets inside which radiation fields propagate with light velocity in single direction without dispersion. The simplest case corresponds to a straight cylindrical ME but also curved MEs, kind of curved light rays, are possible. The initial values for a given moment of time are arbitrary by light likeness. Therefore MEs are ideal for precisely targeted communications. What distinguishes MEs from Maxwellian radiation fields in empty space is that light like vacuum 4-current is possible: ordinary Maxwell's equations would state that this current vanishes. Quite generally, purely geometric vacuum charge densities and 3-currents are purely TGD based prediction and could be seen as a classical correlate of the vacuum polarization predicted by quantum field theories.

MEs are fractal structures containing MEs within MEs. The so called scaling law of homeopathy predicts that the high frequency MEs inside low frequency MEs are in a ratio having discrete values [K5]. One can indeed justify this relationship. As ions drop from smaller space-time sheets to magnetic flux tubes, zero point kinetic energy is liberated as high frequency MEs, and the ions dropped to magnetic flux quanta generate cyclotron radiation, and the ratio of the fundamental frequencies is constant not depending on particle mass and being determined solely by p-adic length scale hypothesis. The model for the radio waves induced by the irradiation of DNA by laser light [25] gives support for this picture [K2].

2.3.2 Two basic types of MEs

MEs have 2-dimensional CP_2 projection which means that electro-weak holonomy group is Abelian (color holonomy is always Abelian which suggests that physical states in TGD Universe correspond to states of color multiplets with vanishing color hypercharge and isospin rather than color singlets). If CP_2 projection belongs to a homologically non-trivial geodesic sphere, only em and Z^0 fields and Abelian color gauge fields are present. In the homologically trivial case only classical W fields are non-vanishing.

1. Neutral MEs can be assigned to various kinds of communications from biological body to the magnetic body and fractal hierarchy of EEGs and ZEGs represent the basic example in this respect [M3].

2. Dark W MEs serving as correlate for dark W exchanges induce an exotic ionization of atomic nuclei [F8, F9, M3]. This induces charge entanglement between magnetic body and biological body generating dark plasma oscillation patterns inducing nerve pulse patterns and ion waves at the space-time sheets occupied by the ordinary matter. The mechanism is based on many-sheeted Faraday law inducing electromagnetic fields at ordinary space-time sheet in turn giving rise to ohmic currents. State function reduction selects one of the exotically ionized configurations. This mechanism is the most plausible candidate for how magnetic body as an intentional agent controls biological body.

2.3.3 Negative energy MEs

MEs can have either positive or negative energy. The understanding of negative energy MEs has increased considerably. Phase conjugate laser waves [20] are the most plausible standard physics counterparts of negative energy MEs since they can be interpreted as time reversed laser beams and do not possess direct Maxwellian analog. By quantum-classical correspondence one can interpret the frequencies associated with negative energy MEs as energies. One can also assume that the Bose-Einstein condensed photons associated with negative energy MEs and with the coherent light generated by the light like vacuum current have negative energies.

For frequencies which are above thermal energy there is no system which could interact with negative energy MEs or absorb negative energy photons. Therefore negative energy MEs and corresponding photons should propagate through matter practically without any interaction. Feinberg has demonstrated that phase conjugate laser beams behave similarly: for instance, one can see through chickens using these laser beams [21]. This means that negative energy MEs do not respect Faraday cages and thus represent an attractive candidate for the hypothetical Psi field. Note that MEs are not a mere classical correlate for photons, as is clear from the fact that in the case of Z^0 MEs there are no Z^0 photons.

Negative energy MEs have many applications.

1. Negative energy MEs ideal for generating time like entanglement. Since negative energies are involved, this entanglement can be seen as a correlate for the bound state entanglement leading to a macro-temporal quantum coherence. Negative energy MEs make thus possible telepathic sharing of mental images. Negative energy MEs are involved with both sensory perception, long term memory, and motor action.

2. Negative energy MEs are ideal for a precisely targeted realization of intentions. p-Adic ME having a large number of common rational points with negative energy ME is generated and transformed to a real ME in quantum jump. The system receives positive energy and momentum as a recoil effect and the transition is not masked by ordinary spontaneously occurring quantum transitions since the energy of the system increases. One can say that negative energy ME represents the desires communicated to the geometric past and inducing as a reaction the desired action realized as say neuronal activity and generation of positive energy MEs.

3. The generation of negative energy MEs is also in a key role in remote metabolism and MEs serve as quantum credit cards implying an extreme flexibility of the metabolism. During the writing of this article one new and important aspect of remote metabolism became obvious. If the system receiving negative energy MEs is a population inverted laser or its many-sheeted counterpart, then quite a small field intensity associated with negative energy MEs (intensity of negative energy photons) can lead to the amplification of the time reflected positive energy signal. The reason is that the rate for the induced emission is proportional to the number of particles dropped to the ground state from the excited state. Therefore even negative energy

bio-photons might serve as quantum controllers of metabolism and induce much more intense beams of positive energy photons, say when interacting with mitochondria.

2.4 Magnetic flux quanta and electrets

Magnetic flux tubes and electrets are extremals of Kähler action dual to each other. Also layer like magnetic flux quanta and their electric counterparts are possible. The magnetic/electric field is in a good approximation of constant magnitude but has varying direction.

2.4.1 Magnetic fields and life

The magnetic field associated with any material system is topologically quantized, and one can speak about magnetic body. An attractive idea is that the relationship of the magnetic body to the material system is to some degree that of the manual to an electronic instrument. Magnetic body would thus allow to realize both sensory and abstract symbolic representations about the material body. Magnetic body would in this case serve as a kind of computer screen at which the data items processes in say brain are communicated either classically (positive energy MEs) or by sharing of mental images (negative energy MEs).

Magnetic body is also an active intentional agent: motor actions are controlled from magnetic body and proceed as cascade like processes from long to short length and time scales as quantum communications of desires at various levels of hierarchy of magnetic bodies. Communication occurs backwards in geometric time by negative energy MEs. Motor action as a response to these desires occurs by classical communications by positive energy MEs and as neural activities. This explains the coherence and synchrony of motor actions difficult to understand in neuroscience framework. The sizes of flux tubes are astrophysical: for instance, EEG frequency of 7.8 Hz corresponds to a wave length defined by Earth's circumference. The non-locality in the length scale of magnetosphere, and even in length scales up to light life, is forced by Uncertainty Principle alone, if taken seriously in macroscopic length scales.

The leakage of supra currents of ions and their Cooper pairs from magnetic flux tubes of the Earth's magnetic field to smaller space-time sheets and their dropping back involving liberation of the zero point kinetic energy defines one particular metabolic "Karma's cycle". The dropping of protons from $k = 137$ atomic space-time sheet involved with the utilization of ATP molecules is only a special instance of the general mechanism involving an entire hierarchy of zero point kinetic energies defining universal metabolic currencies. This leads to the idea that the topologically quantized magnetic field of Earth defines the analog of central nervous system and blood circulation present already during the pre-biotic evolution and making possible primitive metabolism. This has far reaching implications for the understanding of how pre-biotic evolution led to living matter as we understand it [L4].

For instance, it has recently become clear that the dropping of atoms and molecules from $k = 131$ space-time sheets creates photons at visible and near infrared wave lengths. The hot $k = 131$ space-time sheets (with temperatures above 1000 K) could have served as a source of metabolic energy for life-forms at cool $k = 137$ sheets. Photosynthesis could have developed in the circumstances where solar radiation was replaced with these photons. The correct prediction is that chlorophylls should be especially sensitive to these wave lengths. In particular, it is predicted that also IR wave lengths 700-1000 nm should have been utilized. There indeed are bacteria using only this portion of solar radiation. This leads to a scenario making sense only in TGD universe. Pre-biotic life could have developed at the cool space-time sheets in the hot interior of Earth below crust, where $k = 131$ space-time sheets are possible and this life could still be there [L4]. Also the life as we know it, could involve hot spots generated by the cavitation of water inside cell. The classical repulsive Z^0 force causes a strong acceleration during final stages of bubble collapse creating high temperatures, and could explain also sono-luminescence [22] as suggested in [F9].

Magnetic Mother Gaia could also form sensory and other representations receiving input from several brains via negative energy EEG MEs entangling magnetosphere with brains. The multi-brained magnetospheric selves could be responsible for the third person aspect of consciousness and for the evolution of social structures. Some aspects of remote viewing very difficult to understand if remote viewing involves only the target and viewer [26], the successful healing by prayer and meditation groups [27], and the experiments of Mark Germine [28] support the view that multi-brained possibly magnetospheric selves are involved. Magnetic flux tubes could function as wave guides for MEs and this aspect is crucial in the model of long term memory.

2.4.2 Electrets and bio-systems

Bio-systems are known to be full of electrets and liquid crystals [23]. Perhaps the most fundamental electret structure is cell membrane. In particular, the water inside cells tends to be in gel phase which is liquid crystal phase. There are many good reasons for why water should be in ordered phase. One very fundamental reason is that bio-polymers are stable in liquid crystal/ordered water phase since there are no free water molecules available for the depolymerization by hydration. In fact, only a couple of years ago it was experimentally discovered that bio-polymers can be stabilized around ice.

The capacitor model for sensory receptor is one very important application of the electret concept (see the article "Quantum model of sensory receptor" in [17] and [K3]). Sensory qualia result in the flow of particles with given quantum numbers from the plate to another one in quantum discharge. This kind of amplification of quantum number *resp.* zero mode increments would give rise to both geometric *resp.* non-geometric qualia [K3].

Also micro-tubuli are electrets. Sol-gel transition, as any phase transition, is an good candidate for the representation of a conscious bit and controlled local sol-gel transitions between ordinary and liquid crystal water could be a basic control tool making possible cellular locomotion, changes of protein conformations, etc... The tubulin dimers of micro-tubuli could induce sol-gel transformations by generating negative energy MEs, and micro-tubular surface could provide bit maps of their environment somewhat like sensory areas of brain provide maps of body. If gel→sol transition around tubulin inducing conformational change induces sol→gel transformation in some point of environment as would be the case for the seesaw mechanism to be discussed below, a one-one correspondence would result. By this one-one correspondence micro-tubules would automatically generate kind of conscious log files about the control activities which could have evolved to micro-tubular declarative memory representations about what happens inside cell [K6].

3 TGD inspired theory of consciousness very briefly

In the following the basic concepts and ideas of TGD inspired theory of consciousness are briefly summarized.

3.1 Quantum jumps between quantum histories as moments of consciousness

The individual quantum jump between quantum histories has a complex anatomy which has become obvious only gradually. Quantum jump consists of the unitary, informational "time evolution"

$$\Psi_i \to U\Psi_i$$

of the initial quantum history Ψ_i described by the unitary operator U (essentially S-matrix), followed by the step

$$U\Psi_i \rightarrow \Psi_{f_0} \quad ,$$

in which a localization in zero modes occurs. This step is the counterpart of the state function reduction process and gives rise to the ordinary quantum measurement with zero modes playing the role of classical variables.

This step is followed by a sequence of self measurements

$$\Psi_{f_0} \rightarrow \Psi_{f_1} \rightarrow ....\Psi_f$$

leading to a state Ψ_f in which only bound state entanglement remains. This process is the counterpart of the state preparation. In a given self measurement sub-system decomposes into two unentangled parts and the decomposition is fixed by the requirement that the reduction of the entanglement entropy is maximal (Negentropy Maximization Principle) and the density matrix serves as a universal observable in the self measurement.

It should be emphasized that the operator U, or equivalently S-matrix, is only the formal counterpart of the Schrödinger time evolution lasting infinite time: there is no actual Schrödinger equation involved and U has nothing to do with geometric time development[1]. U codes all the statistical predictions of quantum TGD and is the counterpart of S-matrix of quantum field theories.

Subjective time development understood as a sequence of quantum jumps occurs outside the realm of the geometric space-time. It could be regarded as a non-deterministic hopping in the space of the configuration space spinor fields. Individual quantum jump is however fundamentally irreducible in the sense that one cannot model it by any dynamical time development. The identification of quantum jump as a moment of consciousness defines what might be called microscopic theory of consciousness. The subjective time development presumably obeys some variational principle consistent with the quantum measurement theory, in particular, with its non-determinism[2]. This principle dictates which systems for given initial quantum history can perform quantum jumps and have moments of consciousness. This variational principle will be discussed in section [2.2.2].

3.1.1 Standard quantum measurement theory

The assumption that a localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies standard quantum measurement theory as the following arguments demonstrate.

1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory.

2. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero

[1]From TGD point of view the identification of the geometric time and the time coordinate appearing in the general Schrödinger equation of quantum field theories quantized using Hamiltonian formalism is wrong. Schrödinger equation is not even needed. The identification of the time coordinate of the Dirac equation as a geometric time however makes sense from TGD point of view.

[2]This means that the variational principle in question must be more akin to the second law of thermodynamics rather than to the ordinary variational principles of physics.

modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

3. Unitarity is consistent with the localization in zero modes if the unitary time evolution operator U acts effectively as a flow in zero mode degrees. This means that in some incoming state basis $|n, z\rangle$, where z refers to zero modes, the outgoing states are of form $S^{\dagger}_{nm}|m, z_1(z, n)\rangle$. The effective flow property means a 1-1 mapping of the outgoing quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field). The final state is an eigenstate of the density matrix for the measured system identified as quantum fluctuating degrees of freedom and zero mode degrees of freedom identified as measuring system.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to basic quantum theory. This reduction involves crucially the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. The reduction is a triumph for quantum TGD and favours TGD against string models.

3.1.2 Also self measurements are possible

TGD allows also second type of quantum measurement following ordinary quantum measurement reducing entanglement in quantum fluctuating degrees of freedom for some sub-system-complement pair inside self which corresponds to a state localized in zero modes. This measurement can be regarded as a self measurement and there is entire cascade of them reducing the state to a completely classical product state. The process is obviously the counterpart of the phenomenological state preparation process in quantum physics. The only universal observable is the *density matrix* of the sub-system, which should be thus measured in the quantum jump. Negentropy Maximization Principle (NMP) governs the dynamics of self measurement and states that the the density matrix of a sub-system of self for which the reduction of entanglement entropy is maximal, is measured in self measurement. In the real context self measurement means a reduction of the entanglement and provides a mechanism of self-repair: NMP [H2] says that the biggest hole in the leaking boat is filled first. In p-adic context NMP becomes the basic dynamical principle of cognition.

It is however far from obvious what the notion of quantum measurement means when quantum states are quantum histories. For instance, the precise definition of the sub-system concept involves nontrivial delicacies caused by the classical non-determinism of Kähler action. In absence of this non-determinism, all self measurements could be assigned to the boundary of the future light cone (big bang) in accordance with the quantum holography principle. The fact that the lightlike boundaries of (MEs) allow superconformal and supercanonical symmetries crucial for construction of quantum TGD and act as quantum holograms, leads to the hypothesis that non-determinism of Kähler action induces a fractal hierarchy of MEs in inside MEs and to the identification of the geometric correlates of selves as lightlike boundaries of MEs. MEs can have also finite time duration (virtual MEs) and define also what might be called mindlike space-time sheets.

State preparations induce a tendency opposite to the second law of thermodynamics which follows from the non-determinism of Kähler action implying the generation of MEs inside MEs inside future lightcone. This in turn means that one cannot predict the future from the knowledge of the quantum state at the boundary of the future lightcone using general coordinate invariance as the most stringent form of quantum holography would predict.

3.1.3 Quantum jump as quantum computation like process

The Universe according to TGD is a quantum computer in an extremely general sense of the word. Every quantum jump involves unitary informational "time development" U (quantum computation) and state function reduction involving a localization in the zero modes (halting of the computation) and a sequence of self measurements giving rise to state preparation. It is neither possible nor necessary to assign Schrödinger equation with U. U is however completely analogous to the time evolution operator $U(-t,t)$, $t \to \infty$, defining the S-matrix in quantum field theories. It is important to notice that also in quantum field theories one is interested only in the S-matrix so that new interpretation brings in nothing new at practical level.

There are thus three time developments in TGD:

1. The geometric time development of the space-time surface determined by the absolute minimization of the Kähler action, which also via general coordinate invariance defines in what sense quantum histories are histories;

2. the informational "time development" U analogous to quantum computation (hence the attribute 'informational') represented by S-matrix;

3. the subjective time development by quantum jumps taking outside the realm of the space-time.

These three notions of time development fuse to single "holy trinity" of informational, subjective and geometric time evolutions. This "holy trinity" of time evolutions corresponds to the "holy trinity" of

1. matter in the sense of res extensa identified as 3-surfaces,

2. ideas/objective realities (logos= cosmos) identified as quantum histories (physics= mathematics)[3].

3. and the world of subjective experiences defined by the quantum jump sequences for selves (mathematician exists subjectively in the quantum jumps between mathematical ideas).

Tri-partism allows to overcome the basic difficulties of the monistic and dualistic world pictures. In particular, the theory-reality dualism disappears.

It should be emphasized that in this framework the standard physics identification of the time parameter of Schrödinger evolution with geometric time is wrong. The big problem, to be discussed later, is how the value of geometric time associated with the contents of conscious experience is determined.

3.1.4 How the world of conscious experience can look classical?

If quantum histories (/states) are quantum superpositions over a huge number of classical space-time surfaces, it is very difficult to understand how the world of conscious experience manages to look classical. The solution of the problem comes out from the requirement that quantum jumps in a well defined sense reduce to quantum measurements performed in a space-time with a fixed macroscopic geometry as in quantum field theory. The macroscopic aspects of the space-time surface are determined completely by the zero modes of the configuration space characterizing the induced Kähler field and geometric size and shape of the four-surface totally. Thus, if each quantum measurement involves a localization in zero modes, then the classicality of the universe of

[3]Quantum histories can be regarded as superpositions of Boolean statements represented by many fermion Fock states (fermion number=1↔true, fermion number =0↔ false), hence logos=cosmos identification.

subjective experience is achieved automatically, and as noticed, standard quantum measurement theory follows from quantum TGD proper. In p-adic space-time degrees of freedom complete localization must occur in every quantum jump for purely mathematical reasons, and the interpretation is that intentionality and cognition are completely classical.

During macrotemporal quantum coherence due to the formation of bound state half of the zero modes of two space-time sheets connected by join along boundaries bonds become macroscopic quantum fluctuating degrees of freedom, and in these states consciously experienced world looks non-classical. These states correspond to states of "one-ness" at the level of conscious experience.

There are counter arguments against complete localization. First of all, one can imagine that the reduction could occur to a sub-space of zero modes consisting of a discrete points. Rational bound state entanglement in discrete sub-spaces of zero modes would be stable against state function reduction. Even more generally, the existence of symplectic structure in zero modes allows to consider a hierarchy of 2n-dimensional sub-manifolds in the space of zero modes with volume element defined by the n:th power of the symplectic form. State function reduction could occur to this kind of sub-manifold since at least the transition amplitude would be well-defined. Preferred sub-manifolds of this kind are sub-manifolds closed with respect to the action of $SO(3) \times SU(3)$ isometries such that only the coordinates associated with a finite number of super-canonical generators are non-constant.

3.2 Quantum self

In the following the notion of self is introduced. To avoid confusions it must be emphasised that the notion of self is completely general and by no means restricted to brain. Brain consciousness is in this framework only a special form of consciousness.

3.2.1 The notions of self and subjective memory

The simplest hypothesis is that the contents of consciousness are determined by single quantum jump. There are several objections to this view.

1. The idea about self as a continuous stream of consciousness is very attractive and it seems difficult to believe that our consciousness could be actually a sequence of moments of consciousness with gaps between.

2. Furthermore, if the contents of consciousness are determined completely by the initial and final states of single quantum jump, we cannot have any memories about our previous conscious experiences. Hence subjective memories should be only pseudo memories perhaps resulting from the simulations of the subjective past.

It took quite a long time to realize the real strength of these objections and to discover that a proper quantum definition of the concept of self provides a manner to overcome these obstacles.

1. Entanglement is one of the basic non-classical notions of quantum theory. Un-entangled sub-system, as opposed to an entangled one, behaves as its own sub-universe and can be regarded as a pure quantum state. The natural guess is that self should be identified as a sub-system able to remain unentangled in subsequent quantum jumps. The self lasting only single quantum jump can be also regarded formally as self. This kind of a definition looks intuitively very satisfactory since me-external world separation is a basic characteristic of consciousness. The problem is to formulate precisely what are the characteristics of sub-system defining self, which must remain invariant in quantum jump. It seems that the p-adic prime characterizing the system might be the basic and perhaps only invariant of this kind.

2. The absence of entanglement between space-time regions belonging to different number fields (real and p-adic) would automatically imply the decomposition of the space-time surface to regions identifiable as selves. The entanglement between real and p-adic space-time regions is however possible if entanglement coefficients for orthonormalized state basis are algebraic numbers [H2], and has an interpretation as giving rise to a correlation between cognitive quantum states and the states of the material system. For a negative entanglement entropy the reduction of the entanglement would be in a conflict with NMP: hence a cognitive bound state is in question. This means a period of macrotemporal cognitive quantum coherence during which a sequence of quantum jumps is effectively fused to a single quantum jump. The state decays in what might be called a cognitive measurement. Cognitive bound state entanglement is possible only in configuration space spin degrees of freedom, that is in basically fermionic degrees of freedom (elementary bosons can be regarded as antifermion-fermion bound states).

3. The hypothesis that the experiences of self associated with the quantum jumps occurred after the "wake-up" (the quantum jump during which U made sub-system unentangled or created unentangled sub-system) sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore the self becomes an extended object with respect to the subjective time and has a well defined "personal history". Subjective memory has a natural identification as a short term memory with a duration of order second.

4. If the temporal binding of experiences involves some kind of averaging, that is, if quantum statistical determinism generalizes to the level of the subjective experience, the total experience defined by the heap of the experiences associated with individual quantum jumps is reliable.

5. Self can have sub-selves: this corresponds geometrically to a space-time sheet having smaller space-time sheets glued to it. An irreducible self is defined as a self having no sub-selves. Reducible and irreducible selves give rise to two modes of consciousness identifiable as ordinary and "whole-body" consciousness.

6. The sub-selves of two selves can entangle if one allows the definition of sub-system concept based on p-adic length scale cutoff. Essentially this means that because of the p-adic length scale cutoff, the entanglement of sub-systems is not 'seen' at the level of systems so that they can remain unentangled. p-Adic length scale cutoff is natural since the wormhole contacts associated with topologically condensed space-time sheets are surrounded by 'elementary particle horizons' analogous to blackhole horizons. Therefore the larger space-time sheet 'sees' about topologically condensed space-time sheet only some quantum numbers like mass, spin and charge. The entanglement of sub-systems makes possible fusion and sharing of mental images crucial for quantum communications. For instance, receiver can understand the message by sharing the mental image of the sender representing the understanding of the message.

7. Sub-system can wake-up (become conscious self) in several manners. The phase transitions $R \leftrightarrow R_p$ inside real/p-adic self generate new p-adic/real sub-selves. In fact, real–p-adic phase transitions correspond to the transformation of sensory input into cognition and thought into action. Also the transitions $R_{p_1} \to R_{p_2}$ inside p_1-adic self generate new p_2-adic sub-selves.

3.2.2 Negentropy Maximization Principle

As already explained, TGD reduces the state function reduction of the standard quantum measurement theory to the localization in zero modes. Besides this, it is postulated that the localization

in zero modes is followed by a cascade of self measurements giving rise to an unentangled product state and thus state preparation. NMP governs the dynamics of self measurement.

1. NMP applies to each un-entangled sub-system resulting in self measurement cascase separately, and is therefore in a well-defined sense a local principle. Every un-entangled subsystem X in Ψ_{f_0} participates in quantum jump $\Psi_{f_0} \to \Psi_{f_1}$, which means that the density matrix for some sub-system of X is quantum measured.

2. A quantum jump for a given unentangled sub-system X corresponds to a measurement of the density matrix for some sub-system Y of X. In this measurement sub-system Y goes to an eigenstate of the density matrix and Y becomes unentangled. Same happens to the complement of Y inside X. The amount of entanglement is measured by entanglement entropy S and S vanishes for the final state of the quantum jump. Thus S can be regarded as negentropy gain having interpretation as some kind of conscious information, or rather, reduction of dis-information. The conscious experience must be assigned with X. One cannot associate it with the measured sub-system or its complement inside$X$ since they are in completely symmetric position since diagonalized density matrices are identical. Hence there is no manner to tell which is the measured system and which the measuring subsystem. Thus one must define self measurement as a measurement creating an unentangled sub-system-complement pair inside X and identify X as the conscious measurer.

3. NMP states that the entanglement entropy reduction associated with the conscious experience of the sub-system X is maximal. Interpreting entanglement negentropy gain as conscious information, on can say that we live in (or create) the best possible world. Only the quantum jumps giving rise to maximum information content of conscious experience occur. It must be noticed however that one can assign several types of information measures with conscious experience. This requirement fixes the quantum measured sub-system Y of given self uniquely unless there are several sub-systems giving rise to same maximum negentropy gain: in this case any of the quantum jumps occurs with same probability.

The precise formulation of NMP involves delicate issues. In the purely real standard physics context NMP need not make sense since in the generic case the entire universe could be the only un-entangled system after state function reduction and entanglement entropies for candidate sub-systems would be infinite. In TGD space-time decomposing into both real and p-adic space-time sheets, an elegant formulation of NMP with sensical predictions is possible, since universe decomposes to sub-selves possessing finite entanglement entropies. NMP reduces to a local principle applying separately to each unentangled system.

In p-adic context entanglement negentropy gain is defined as the real counterpart of the p-adic negentropy gain with p-adic prime p characterizing the sub-system in question. The definition of the negentropy concept in p-adic framework involves quite interesting delicacies. For instance, entanglement with a vanishing entanglement entropy is possible [H3, H5]. One must also define the concept of sub-system very carefully since quantum states are identified as quantum histories in TGD framework and here MEs turn out to be crucial element because their lightlike boundaries have quantum hologram property meaning the reduction the physics inside ME to conformally invariant physics at the boundary of ME. It has been already mentioned that number theoretic entanglement entropies emerge naturally in case of real-p-adic entanglement and can be negative.

3.2.3 Summation hypothesis and binding of experiences

The self X behaves essentially as a separate sub-Universe. Also the sub-selves of X_i of X have their own experiences. The question is: how the experience of X and experiences of X_i are related? The following basic hypothesis provides a possible answer to this question.

1. X experiences the sub-selves X_i as separate mental images superposed to the pure self experience of X: this is natural since sub-selves are unentangled and hence behave like separate sub-Universes.

2. The experiences of self X about the experiences of its sub-selves X_i are abstractions. Sub-self X_i experiences its sub-selves X_{ij} as separate mental images. X however experiences them as a single mental image representing what it is to be a sub-self of X_i, that is the average $\langle X_{ij} \rangle$ of the mental images X_{ij}. Thus the mental images of sub-sub-...selves of X are smoothed out to an average mental image and become effectively unconcious to X. Averaging hypothesis generalizes quantum statistical determinism to the level of subjective experience and is analogous to the hypothesis about averaging related to temporal binding.

Temporal binding with averaging implies that the experiences of the individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles. The inability to perceive the flickering of light when the frequency of the flickering is larger than about one Hz is consistent with the hypothesis that subjective sensory memory has duration of order .1 seconds and that temporal averaging indeed occurs. Time averaging could involve weighting such that the conscious experiences associated with the last quantum jumps have the largest weight. This would allow our self to have duration much longer than .1 seconds. For instance, the duration of the ordinary wake-up period could determine the duration of our self. The duration could be even longer: sleep could actually involve awareness and the lack of the sensory memories from sleep period could create the illusion about sleep as an unconscious state.

Summation hypothesis and temporal binding imply a hierarchy of conscious experiences with increasingly richer contents and at the top of the hierarchy is the entire universe, God, enjoying eternal self-consciousness since it cannot entangle with with any larger system. Also we are mental images of some higher level self. This hierarchy obviously has far-reaching consequences.

3.2.4 Binding of the experiencers by entanglement

The binding of experiencers is also possible. The binding of selves by quantum entanglement however means they lose their consciousness. This process naturally corresponds to the formation of wholes from their parts at the level of conscious experiences. The formation of a mental image (sub-self) representing word from the mental images representing letters is example of this process. Also the fusion of the left and right visual fields to a single visual field could occur via the entanglement of the corresponding sub-selves. Note however that right–left entanglement might occur already at neuronal level. Entanglement mechanism provides also a possible mechanism of "enlightment" experiences envolving extension of self [H3, H5]. Quantum entanglement could make possible communication between selves belonging to different levels of the self hierarchy.

3.2.5 Binding and quantum metabolism as different sides of the same coin

Quantum jump involves also a state preparation process and only bound state entanglement is stable against the state preparation. Hence the fusion of the mental images implicates the formation of a bound state. This process is expected to involve a liberation of the binding energy as a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and binding are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enchanced oxidative metabolism [24]. A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

3.2.6 How to understand evolution and self-organization?

One could argue that since the quantum jump is random (not actually since selection between the eigenstates of the density matrix occurs), quantum jump as a moment of consciousness identification cannot explain evolution. In standard physics it is difficult to circumvent this objection. Even worse, heat death seems to be the ultimate fate of the universe according to standard physics.

The fact that quantum jump involves localization in zero modes and thus localization into a definite sector D_P of configuration space labelled by infinite prime P, implies evolution as a statistical increase of P. Since infinite primes are in well-defined sense composites of finite primes, this in turn implies that the finite p-adic prime associated with a given sub-system tends to increase and that new space-time sheets labelled by finite primes emerge during the time evolution by quantum jumps.

This means that the concept of nearness defining the effective topology becomes gradually more refined, the complexity of the universe increases, and the maximal information contents of the conscious experience increase in the long run (like $p \times log(p)$ or at least as $log(p)$ as a function of p-adic prime characterizing the system). This is nothing but evolution. NMP, which states that entanglement negentropy gain maximal for allowed quantum jumps, enhances this tendency.

Quantum jumps between quantum histories make also possible genuine quantum self-organization. The concept of self-organization gets quite new additional meaning in TGD framework. Self-organization means also evolution of self-hierarchies (MEs inside MEs inside...). Self-organization by quantum jumps can be regarded as a hopping in the zero modes characterizing the macroscopic aspects of the space-time surface. Each self is a dissipative system which ends up to some asymptotic self-organization pattern in the presence of the external energy feed (or even without it). Dissipation is the ultimate Darwinian selector picking up the winning selves as favoured self organization patterns. Since sub-selves correspond to mental images, the immediate implication is that also memes are subject to similar selection. For instance, the formation of long term memories and habits could be understood as a formation of surviving sub-selves.

The proposed realization of the quantum criticality, besides making macroscopic quantum systems possible, in a well-defined sense maximizes the intelligence and complexity of the universe [H7]. TGD universe is quantum spin glass and this adds additional aspect to the self-organization process. For instance, the energy landscape of the spin glass is fractal like structure containing valleys inside valleys and provides an ideal dynamical memory mechanism.

3.2.7 How to understand morally responsible free will?

One could argue that the randomness of the quantum jump means that moral choices are impossible. The essence of volition is intentionality. p-Adic space-time sheets are excellent candidates for the correlates of intentions because of the inherent non-determinism of the p-adic differential equations. p-adic-to-real transformation of a p-adic space-time sheet in quantum jump is the geometric correlate for the transformation of intention to action. At configuration space level one cannot assign any (at least p-adic probabilities to p-adic localizations so that randomness is not in question. System can therefore intend, that is perform a particular localization in p-adic degrees of freedom very many times.

p-Adic evolution defines the fundamental value of the quantum ethics. The selections which tend to increase the value of the p-adic prime represent good deeds since they mean evolution. The values of this ethics are not in the physical world but in the quantum jumps defining the subjective reality.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* space-time region, rather than only time=constant snapshot, and gives rise to a "prophecy", a prediction for the future and past, which would be reliable if the world were completely classical). As a matter fact, it is p-adic space-time sheets

which correspond to intentions and plans and act of volition transforms p-adic space-time sheet to a real one. Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps. Thus selves are genuine moral agents if they can experience directly that increase of p is good and decrease of p is bad.

3.3 Space-time correlates of matter and mind

3.3.1 Mindlike and material space-time sheets

In TGD space-time surfaces decompose into real and p-adic regions. p-Adic regions are identified as cognitive representations for real regions. The basic motivation for this identification is the inherent non-determinism of the p-adic field equations making possible imagination and simulation.

The classical non-determinism of Kähler action makes possible also real space-time sheets of finite temporal duration. These space-time sheets are identified as mindlike space-time sheets serving as geometric correlates of sensory experience. Thus matter-mind duality is realized geometrically although space-time as such is not conscious. The notion of mindlike space-time sheets (referred to as cognitive space-time sheets in earlier writings) has turned out to be crucial for the understanding of cognition and sensory experience.

Mindlike space-time sheets provide a simulation of geometric history and explain the intentional aspects of consciousness (planning, expectations, desires,...), the localization of contents to finite time interval, and give rise to what might be called "geometric memory". Each quantum jump involves naturally comparison of the expected time development provided by "geometric memory" and the actual subjective time development stored in subjective memory. This comparison should give rise to those emotions involving comparison of some kind.

One can understand the arrow of psychological time very simply. The center of mass time coordinate for a given mindlike space-time sheet is zero mode so that each quantum jump involves localization to a superposition of space-time surfaces for which the values of the psychological time for all mindlike space-time sheets involved are identical. Since there is much more room in the future of a given point of the future lightcone than in its past, mindlike space-time sheets are expected to gradually drift in the direction of future so that the arrow of psychological time results.

3.3.2 p-Adic–real phase transitions as a transformation of thought to action and of sensory input to cognition

Basic hypothesis is that sensory experiences resp. thoughts have real resp. p-adic space-time sheets as their geometric correlates. A fundamental model for the transformation of thought into action is as a p-adic-to-real phase transition for the topology of a mindlike space-time sheet induced by quantum jump. TGD as a generalized number theory vision suggests that this kind of phase transition can be induced by a variation of the parameters in the polynomial $P(p, q)$ of two quaternionic imbedding space coordinates defining the space-time surface changing a p-adic root to a real one or viceversa. The reverse of this phase transition corresponds to the transformation of sensory experiences to cognition.

In principle it is enough that very simple and possibly standardized p-adic–real transformations occur at some level, say neuronal level or at the level of topological field quanta of em field ("massless extremals"). The reason is that simple transformations can serve as symbols inducing macrocopic action in an initial value sensitive system (single push of button can induce nuclear war). The commands given using written or spoken language are typical examples of the emergence of this kind symbol function.

3.4 Dynamical quantized Planck constant,dark matter hierarchy, and consciousness

Dark matter hierarchy has far reaching implications for TGD inspired theory of consciousness since it makes possible the realization of macroscopic and macro-temporal coherence. It also allows to make more precise the idea about hierarchy of quantum jumps with increasing durations with respect to the geometric time.

3.4.1 p-Adic and dark matter hierarchies and hierarchy of moments of consciousness

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

1. Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

2. The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta with field magnitude near to that for Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [M3].

For years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value .3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest a general formula for the allowed values of λ [C7] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [C6]. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \to h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L(k) \to nL(k)$ and $B \to B/n$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 25$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model

for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [E9].

The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

3.4.2 Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

3.4.3 Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$. Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. The quantum parallel dissipation at the lower levels would give rise to the experience of flow of time. For instance, hadron as a macro-temporal quantum system in the characteristic time scale of hadron is a dissipating system at quark and gluon level corresponding to shorter p-adic time scales. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would

experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

3.4.4 The time span of long term memories as signature for the level of dark matter hierarchy

The simplest dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4\ CP_2$ times so that $2^{127}-1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k=127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness [L1]. A more refined guess is that $\tau_p = \sqrt{p}\tau$ gives the dependence of the duration of quantum jump on p-adic prime p. By multi-p-fractality predicted by TGD and explaining p-adic length scale hypothesis, one expects that at least $p=2$-adic level is also always present. For the higher levels of dark matter hierarchy τ_p is scaled up by $\hbar/\hbar_0$. One can understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ [L2].

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k=4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [M3]. $k=7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k=7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k=5$ would correspond to time scale of short term memories measured in minutes and $k=6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [L2, M3]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

3.5 About the arrow of psychological time and notion of self: once again!

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic. I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation [O4] has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

3.5.1 Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

   i) Why this drifting?

   ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

   iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

There are also other models but these two are the ones which come into my mind first.

3.5.2 The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - began to look very elegant during last night. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. The simplest assumption is that evolution in a reasonable approximation means shifting of the field patterns backwards in geometric time by some amount per quantum jump. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the perceiver space-time sheet and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a

model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-atronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

3.5.3 Can one choose between the two variants for the notion of self?

I have considered two different notions of "self" and it is interesting to see whether this picture might allow to choose between them.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labelled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the notion of self hierarchy to that of fractal quantum jump in the sense of dark matter hierarchy but there is an objection. Does this concept really make sense? Fractality is a geometric notion and subjective time does not reduce to the geometry. It is also not quite clear whether the reasonable looking idea about the role of entanglement can be kept.

The older variant of self looks more attractive if one accepts the new model for the arrow of psychological time.

1. Entire Universe performs the quantum jump and there is an infinite fractal hierarchy of scales associated with quantum jump and state function reduction/state preparation part of quantum jump proceeds as a sequence from long to short scales. One cannot assign any finite geometric duration to a given step in this sequence since the geometric duration assignable

to the entire quantum jump would in this case be automatically infinite. In this framework our life cycle would most naturally correspond to a sequence of quantum jumps.

2. The simplest guess for the interval of geometric time assignable to single quantum jump is as CP_2 time. p-Adic time scales define alternative and perhaps more attractive identification. The larger the value of p-adic prime p, the faster the psychological time would flow and faster the experienced rate of evolution would be. Also the hierarchy of Planck constants suggests a hierarchy of these times and the concentration of attention to to dark matter levels would make the flow of psychological time much faster. The model of tqc suggests that each period of EEG rhythm corresponds to single quantum jump for corresponding "me" in un-entangled self-state.

3. The ability to avoid entanglement with environment would be essential for the original notion of self. One can of however ask whether the assumption about the loss of consciousness in entanglement - that is during sleep - is really necessary. One could however argue that if consciousness is really lost during sleep, we could not have the deep conviction that we existed yesterday. Furthermore, during topological quantum computation entanglement is absent and thus this state should correspond to conscious experience. Night time is however the best time for tqc since sensory input and motor action do not take metabolic resources and we certainly do problem solving during sleep. Thus we should be conscious at some level during sleep and perform quite a long tqc. Perhaps we are!

Could it be that we do not remember anything about the period of sleep because our attention is directed elsewhere and memory recall uses only copies of "me" assignable to brain manufacturing standardized mental images? Perhaps the communication link to the mental images during sleep experienced at dark levels of existence is lacking or sensory input and motor activities of busy westeners do not allow to use metabolic energy to build up this kind of communications. Hence one can seriously ask, whether self is actually eternal with respect to the subjective time and whether entangling with some system means only diving into the ocean of consciousness as someone has expressed it. We would be Gods as also quantum classical correspondence in the reverse direction requires (p-adic cognitive space-time sheets have literally infinite size in both temporal and spatial directions). This would be the most optimistic view that one can imagine.

This arguments look nice but more arguments are needed to exclude the model of self as single quantum jump.

3.5.4 What after biological death?

Could the new option allow to speculate about the course of events at the moment of death? Certainly this particular sensory "me" would effectively meet the geometro-temporal boundary of the biological body: sensory input would cease and there would be no biological body to use anymore. "Me" might lose its consciousness (if it can!). "Me" has also other mental images than sensory ones and these could begin to dominate the consciousness and "me" could direct its attention to space-time sheets corresponding to much longer time scale, perhaps even to that of life cycle, giving a summary about the life.

What after that? The Tibetan Book of Dead gives some inspiration. A western "me" might hope (and even try use its intentional powers to guarantee) that quantum Turing tape brings in a living organism, be it human or cat or dog or at least some little bug. If this "me" is lucky, it could direct its attention to it and become one of the very many sensory "me's" populating this particular 4-D biological body. There would be room for a newcomer unlike in the alternative models. A "me" with Eastern/New-Ageish traits could however direct its attention permanently to the dark space-time sheets and achieve what might she might call enlightment.

4 Local p-adic physics and the p-adic fractality of the real physics and p-adic-to-real transition as a space-time correlate for the transformation of intention to action

This section provides the recent view about transformation of intentions to actions and the presence of this a motivation for its presence of p-adic cognitive neutrino pair. The interpretation of the p-adic as physics of cognition and the vision about reduction of physics to rational physics continuable algebraically to various extensions of rationals and p-adic number fields is an attractive general framework allowing to understand how p-adic fractality could emerge in real physics. In this section it will be found that this vision provides a concrete tool in principle allowing to construct global solutions of field equations by reducing long length scale real physics to short length scale p-adic physics. Also p-adic length scale hypothesis can be understood and the notion of multi-p p-fractality can be formulated in precise sense in this framework. This vision leads also to a concrete quantum model for how intentions are transformed to actions and the S-matrix for the process has the same general form as the ordinary S-matrix.

4.1 p-Adic physics and the construction of solutions of field equations

The number theoretic vision about physics relies on the idea that physics or, rather what we can know about it, is basically rational number based. One interpretation would be that space-time surfaces, the induced spinors at space-time surfaces, configuration space spinor fields, S-matrix, etc..., can be obtained by algebraically continuing their values in a discrete subset of rational variant of the geometric structure considered to appropriate completion of rationals (real or p-adic). The existence of the algebraic continuation poses very strong additional constraints on physics but has not provided any practical means to solve quantum TGD.

In the following it is however demonstrated that this view leads to a very powerful iterative method of constructing global solutions of classical field equations from local data and at the same time gives justification for the notion of p-adic fractality, which has provided very successful approach not only to elementary particle physics but also physics at longer scales. The basic idea is that mere p-adic continuity and smoothness imply fractal long range correlations between rational points which are very close p-adically but far from each other in the real sense and vice versa.

4.1.1 The emergence of a rational cutoff

For a given p-adic continuation only a subset of rational points is acceptable since the simultaneous requirements of real and p-adic continuity can be satisfied only if one introduces ultraviolet cutoff length scale. This means that the distances between subset of rational points fixing the dynamics of the quantities involved are above some cutoff length scale, which is expected to depend on the p-adic number field R_p as well as a particular solution of field equations. The continued quantities coincide only in this subset of rationals but not in shorter length scales.

The presence of the rational cutoff implies that the dynamics at short scales becomes effectively discrete. Reality is however not discrete: discreteness and rationality only characterize the inherent limitations of our knowledge about reality. This conforms with the fact that our numerical calculations are always discrete and involve finite set of points.

The intersection points of various p-adic continuations with real space-time surface should code for all actual information that a particular p-adic physics can give about real physics in classical sense. There are reasons to believe that real space-time sheets are in the general case characterized by integers n decomposing into products of powers of primes p_i. One can expect that for p_i-adic continuations the sets of intersection points are especially large and that these p-adic space-time surfaces can be said to provide a good discrete cognitive mimicry of the real space-time surface.

Adelic formula represents real number as product of inverse of its p-adic norms. This raises the hope that taken together these intersections could allow to determine the real surface and thus classical physics to a high degree. This idea generalizes to quantum context too.

The actual construction of the algebraic continuation from a subset of rational points is of course something which cannot be done in practice and this is not even necessary since much more elegant approach is possible.

4.1.2 Hierarchy of algebraic physics

One of the basic hypothesis of quantum TGD is that it is possible to define exponent of Kähler action in terms of fermionic determinants associated with the modified Dirac operator derivable from a Dirac action related super-symmetrically to the Kähler action.

If this is true, a very elegant manner to define hierarchy of physics in various algebraic extensions of rational numbers and p-adic numbers becomes possible. The observation is that the continuation to various p-adic numbers fields and their extensions for the fermionic determinant can be simply done by allowing only the eigenvalues which belong to the extension of rationals involved and solve field equations for the resulting Kähler function. Hence a hierarchy of fermionic determinants results. The value of the dynamical Planck constant characterizes in this approach the scale factor of the M^4 metric in various number theoretical variants of the imbedding space $H = M^4 \times CP_2$ glued together along subsets of rational points of H. The values of $\hbar$ are determined from the requirement of quantum criticality [C6] meaning that Kähler coupling strength is analogous to critical temperature.

In this approach there is no need to restrict the imbedding space points to the algebraic extension of rationals and to try to formulate the counterparts of field equations in these discrete imbedding spaces.

4.1.3 p-Adic short range physics codes for long range real physics and vice versa

One should be able to construct global solutions of field equations numerically or by engineering them from the large repertoire of known exact solutions [D1]. This challenge looks formidable since the field equations are extremely non-linear and the failure of the strict non-determinism seems to make even in principle the construction of global solutions impossible as a boundary value problem or initial value problem.

The hope is that short distance physics might somehow code for long distance physics. If this kind of coding is possible at all, p-adicity should be crucial for achieving it. This suggests that one must articulate the question more precisely by characterizing what we mean with the phrases "short distance" and "long distance". The notion of short distance in p-adic physics is completely different from that in real physics, where rationals very close to each other can be arbitrary far away in the real sense, and vice versa. Could it be that in the statement "Short length scale physics codes for long length scale physics" the attribute "short"/"long" could refer to p-adic/real norm, real/p-adic norm, or both depending on the situation?

The point is that rational imbedding space points very near to each other in the real sense are in general at arbitrarily large distances in p-adic sense and vice versa. This observation leads to an elegant method of constructing solutions of field equations.

1. Select a rational point of the imbedding space and solve field equations in the real sense in an arbitrary small neighborhood U of this point. This can be done with an arbitrary accuracy by choosing U to be sufficiently small. It is possible to solve the linearized field equations or use a piece of an exact solution going through the point in question.

2. Select a subset of rational points in U and interpret them as points of p-adic imbedding space and space-time surface. In the p-adic sense these points are in general at arbitrary

large distances from each and real continuity and smoothness alone imply p-adic long range correlations. Solve now p-adic field equations in p-adically small neighborhoods of these points. Again the accuracy can be arbitrarily high if the neighborhoods are choose small enough. The use of exact solutions of course allows to overcome the numerical restrictions.

3. Restrict the solutions in these small p-adic neighborhoods to rational points and interpret these points as real points having arbitrarily large distances. p-Adic smoothness and continuity alone imply fractal long range correlations between rational points which are arbitrary distant in the real sense. Return to 1) and continue the loop indefinitely.

In this manner one obtains even in numerical approach more and more small neighborhoods representing almost exact p-adic and real solutions and the process can be continued indefinitely.

Some comments about the construction are in order.

1. Essentially two different field equations are in question: real field equations fix the local behavior of the real solutions and p-adic field equations fix the long range behavior of real solutions. Real/p-adic global behavior is transformed to local p-adic/real behavior. This might be the deepest reason why for the hierarchy of p-adic physics.

2. The failure of the strict determinism for the dynamics dictated by Kähler action and p-adic non-determinism due to the existence of p-adic pseudo constants give good hopes that the construction indeed makes it possible to glue together the (not necessarily) small pieces of space-time surfaces inside which solutions are very precise or exact.

3. Although the full solution might be impossible to achieve, the predicted long range correlations implied by the p-adic fractality at the real space-time surface are a testable prediction for which p-adic mass calculations and applications of TGD to biology provide support.

4. It is also possible to generalize the procedure by changing the value of p at some rational points and in this manner construct real space-time sheets characterized by different p-adic primes.

5. One can consider also the possibility that several p-adic solutions are constructed at given rational point and the rational points associated with p-adic space-time sheets labelled by $p_1, ..., p_n$ belong to the real surface. This would mean that real surface would be multi-p p-adic fractal.

I have earlier suggested that even elementary particles are indeed characterized by integers and that only particles for which the integers have common prime factors interact by exchanging particles characterized by common prime factors. In particular, the primes $p = 2, 3, ..., 23$ would be common to the known elementary particles and appear in the expression of the gravitational constant. Multi-p p-fractality leads also to an explanation for the weakness of the gravitational constant. The construction recipe for the solutions would give a concrete meaning for these heuristic proposals.

This approach is not restricted to space-time dynamics but is expected to apply also at the level of say S-matrix and all mathematical object having physical relevance. For instance, p-adic four-momenta appear as parameters of S-matrix elements. p-Adic four-momenta very near to each other p-adically restricted to rational momenta define real momenta which are not close to each other and the mere p-adic continuity and smoothness imply fractal long range correlations in the real momentum space and vice versa.

4.1.4 p-Adic length scale hypothesis

Approximate p_1-adicity implies also approximate p_2-adicity of the space-time surface for primes $p \simeq p_1^k$. p-Adic length scale hypothesis indeed states that primes $p \simeq 2^k$ are favored and this might be due to simultaneous $p \simeq 2^k$- and 2-adicity. The long range fractal correlations in real space-time implied by 2-adicity would indeed resemble those implied by $p \simeq 2^k$ and both $p \simeq 2^k$-adic and 2-adic space-time sheets have larger number of common points with the real space-time sheet.

If the scaling factor λ of $\hbar$ appearing in the dark matter hierarchy is in good approximation $\lambda = 2^{11}$ also dark matter hierarchy comes into play in a resonant manner and dark space-time sheets at various levels of the hierarchy tend to have many intersection points with each other.

There is however a problem involved with the understanding of the origin of the p-adic length scale hypothesis if the correspondence via common rationals is assumed.

1. The mass calculations based on p-adic thermodynamics for Virasoro generator L_0 predict that mass squared is proportional to $1/p$ and Uncertainty Principle implies that L_p is proportional to $\sqrt{p}$ rather than p, which looks more natural if common rationals define the correspondence between real and p-adic physics.

2. It would seem that length $d_p \simeq pR$, R or order CP_2 length, in the induced space-time metric must correspond to a length $L_p \simeq \sqrt{p}R$ in M^4. This could be understood if space-like geodesic lines at real space-time sheet obeying effective p-adic topology are like orbits of a particle performing Brownian motion so that the space-like geodesic connecting points with M^4 distance r_{M^4} has a length $r_{X^4} \propto r_{M^4}^2$. Geodesic random walk with randomness associated with the motion in CP_2 degrees of freedom could be in question. The effective p-adic topology indeed induces a strong local wiggling in CP_2 degrees of freedom so that r_{X^4} increases and can depend non-linearly on r_{M^4}.

3. If the size of the space-time sheet associated with the particle has size $d_p \sim pR$ in the induced metric, the corresponding M^4 size would be about $L_p \propto \sqrt{p}R$ and p-adic length scale hypothesis results.

4. The strongly non-perturbative and chaotic behavior $r_{X^4} \propto r_{M^4}^2$ is assumed to continue only up to L_p. At longer length scales the space-time distance d_p associated with L_p becomes the unit of space-time distance and geodesic distance r_{X^4} is in a good approximation given by

$$r_{X^4} = \frac{r_{M^4}}{L_p} d_p \propto \sqrt{p} \times r_{M^4} \quad , \tag{2}$$

   and is thus linear in M^4 distance r_{M^4}.

4.1.5 Does cognition automatically solve real field equations in long length scales?

In TGD inspired theory of consciousness p-adic space-time sheets are identified as space-time correlates of cognition. Therefore our thoughts would have literally infinite size in the real topology if p-adics and reals correspond to each other via common rationals (also other correspondence based on the separate canonical identification of integers m and n in $q = m/n$ with p-adic numbers).

The cognitive solution of field equations in very small p-adic region would solve field equations in real sense in a discrete point set in very long real length scales. This would allow to understand why the notions of Universe and infinity are a natural part of our conscious experience although our sensory input is about an infinitesimally small region in the scale of universe.

The idea about Universe performing mimicry at all possible levels is one of the basic ideas of TGD inspired theory of consciousness. Universe could indeed understand and represent the long

length scale real dynamics using local p-adic physics. The challenge would be to make quantum jumps generating p-adic surfaces having large number of common points with the real space-time surface. We are used to call this activity theorizing and the progress of science towards smaller real length scales means progress towards longer length scales in p-adic sense. Also real physics can represent p-adic physics: written language and computer represent examples of this mimicry.

4.2 A more detailed view about how local p-adic physics codes for p-adic fractal long range correlations of the real physics

The vision just described gives only a rough heuristic view about how the local p-adic physics could code for the p-adic fractality of long range real physics. There are highly non-trivial details related to the treatment of M^4 and CP_2 coordinates and to the mapping of p-adic H-coordinates to their real counterparts and vice versa.

4.2.1 How real and p-adic space-time regions are glued together?

The first task is to visualize how real and p-adic space-time regions relate to each other. It is convenient to start with the extension of real axis to contain also p-adic points. For finite rationals $q = m/n$, m and n have finite power expansions in powers of p and one can always write $q = p^k \times r/s$ such that r and s are not divisible by p and thus have pinary expansion of in powers of p as $x = x_0 + \sum_1^N x_n p^n$, $x_i \in \{0, p\}$, $x_0 \neq 0$.

One can always express p-adic number as $x = p^n y$ where y has p-adic norm 1 and has expansion in non-negative powers of p. When x is rational but not integer the expansion contains infinite number of terms but is periodic. If the expansion is infinite and non-periodic, one can speak about *strictly p-adic* number having infinite value as a real number.

In the same manner real number x can be written as $x = p^n y$, where y is either rational or has infinite non-periodic expansion $y = r_0 + \sum_{n>0} r_n p^{-n}$ in negative powers of p. As a p-adic number y is infinite. In this case one can speak about strictly real numbers.

This gives a visual idea about what the solution of field equations locally in various number fields could mean and how these solutions are glued together along common rationals. In the following I shall be somewhat sloppy and treat the rational points of the imbedding space as if they were points of real axis in order to avoid clumsy formulas.

1. The p-adic variants of field equations can be solved in the strictly p-adic realm and by p-adic smoothness these solutions are well defined also in as subset of rational points. The strictly p-adic points in a neighborhood of a given rational point correspond as real points to infinitely distant points of M^4. The possibility of p-adic pseudo constants means that for rational points of M^4 having sufficiently large p-adic norm, the values of CP_2 coordinates or induced spinor fields can be chosen more or less freely.

2. One can solve the p-adic field equations in any p-adic neighborhood $U_n(q) = \{x = q + p^n y\}$ of a rational point q of M^4, where y has a unit p-adic norm and select the values of fields at different points q_1 and q_2 freely as long as the spheres $U_n(q_1)$ and $U_n(q_2)$ are disjoint (these spheres are either identical or disjoint by p-adic ultra-metricity).

   The points in the p-adic continuum part of these solutions are at an infinite distance from q in M^4. The points which are well-defined in real sense form a discrete subset of rational points of M^4. The p-adic space-time surface constructed in this manner defines a discrete fractal hierarchy of rational space-time points besides the original points inside the p-adic spheres. In real sense the rational points have finite distances and could belong to disjoint real space-time sheets. The failure of the strict non-determinism for the field equations in

the real sense gives hopes for gluing these sheets partially together (say in particle reactions with particles represented as 3-surfaces).

3. All rational points q of the p-adic space-time sheet can be interpreted as real rational points and one can solve the field equations in the real sense in the neighborhoods $U_n(q) = \{x = q+p^n y\}$ corresponding to real numbers in the the range $p^n \leq x \leq p^{n+1}$. Real smoothness and continuity fix the solutions at finite rational points inside $U_n(q)$ and by the phenomenon of p-adic pseudo constants these values can be consistent with p-adic field equations. Obviously one can can continue the construction process indefinitely.

4.2.2 p-Adic scalings act only in M^4 degrees of freedom

p-Adic fractality suggests that finite real space-time sheets around points $x + p^n$, $x = 0$, are obtained as by just scaling of the M^4 coordinates having origin at $x = 0$ by p^n of the solution defined in a neighborhood of x and leaving CP_2 coordinates as such. The known extremals of Kähler action indeed allow M^4 scalings as dynamical symmetries.

One can understand why no scaling should appear in CP_2 degrees of freedom. CP_2 is complex projective space for which points can be regarded as complex planes and for these p-adic scalings act trivially. It is worth of emphasizing that here could lie a further deep number theoretic reason for why the space S in $H = M^4 \times S$ must be a projective space.

4.2.3 What p-adic fractality for real space-time surfaces really means?

The identification of p-adic and real M^4 coordinates of rational points as such is crucial for p-adic fractality. On the other hand, the identification rational real and p-adic CP_2 coordinates as such would not be consistent with the idea that p-adic smoothness and continuity imply p-adic fractality manifested as long range correlations for real space-time sheets

The point is that p-adic fractality is not stable against small p-adic deformations of CP_2 coordinates as function of M^4 coordinates for solutions representable as maps $M^4 \to CP_2$. Indeed, if the rational valued p-adic CP_2 coordinates are mapped as such to real coordinates, the addition of large power p^n to CP_2 coordinate implies small modification in p-adic sense but large change in the real sense so that correlations of CP_2 at p-adically scaled M^4 points would be completely lost.

The situation changes if the map of p-adic CP_2 coordinates to real ones is continuous so that p-adically small deformations of the p-adic space-time points are mapped to small real deformations of the real space-time points.

1. Canonical identification $I : x = \sum x_n p^n \to \sum x_n p^{-n}$ satisfies continuity constraint but does not map rationals to rationals.

2. The modification of the canonical identification given by

$$I(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \tag{3}$$

   is uniquely defined for rational points, maps rationals to rationals, has a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$.

3. The form of this map is not general coordinate invariant nor invariant under color isometries. The natural requirement is that the map should respect the symmetries of CP_2 maximally.

Therefore the complex coordinates transforming linearly under U(2) subgroup of SU(3) defining the projective coordinates of CP_2 are a natural choice. The map in question would map the real components of complex coordinates to their p-adic variants and vice versa. The residual $U(2)$ symmetries correspond to rational unitary 2×2-matrices for which matrix elements are of form $U_{ij} = p^k r/s$, $r < p, s < p$. It would seem that these transformations must form a finite subgroup if they define a subgroup at all. In case of $U(1)$ Pythagorean phases define rational phases but sufficiently high powers fail to satisfy the conditions $r < p, s < p$. Also algebraic extensions of p-adic numbers can be considered.

4. The possibility of pseudo constant allows to modify canonical identification further so that it reduces to the direct identification of real and p-adic rationals if the highest powers of p in r and s ($q = p^n r/s$) are not higher than p^N. Write $x = \sum_{n \geq 0} x_n p^n = x^{N)} + p^{N+1} y$ with $x^{N)} = \sum_{n=0}^{N} x_n p^n$, $x_0 \neq 0$, $y_0 \neq 0$, and define $I_N(x) = x^{N)} + p^{N+1} I(y)$. For $q = p^n r/s$ define $I_N(q) = p^n I_N(r)/I_N(s)$. This map reduces to the direct identification of real and p-adic rationals for $y = 0$.

5. There is no need to introduce the imaginary unit explicitly. In case of spinors imaginary unit can be represented by the antisymmetric 2×2-matrix ϵ_{ij} satisfying $\epsilon_{12} = 1$. As a matter fact, the introduction of imaginary unit as number would lead to problems since for $p \ mod \ 4 = 3$ imaginary unit should be introduced as an algebraic extension and CP_2 in this sense would be an algebraic extension of RP_2. The fact that the algebraic extension of p-adic numbers by $\sqrt{-1}$ is equivalent with an extension introducing $\sqrt{p-1}$ supports the view that algebraic imaginary unit has nothing to do with the geometric imaginary unit defined by Kähler form of CP_2. For $p \ mod \ 4 = 1$ $\sqrt{-1}$ exists as a p-adic number but is infinite as a real number so that the notion of finite complex rational would not make sense.

4.2.4 Preferred CP_2 coordinates as a space-time correlate for the selection of quantization axis

Complex CP_2 coordinates are fixed only apart from the choice of the quantization directions of color isospin and hyper charge axis in SU(3) Lie algebra. Hence the selection of quantization axes seems to emerge at the level of the generalized space-time geometry as quantum classical correspondence indeed requires.

In a well-defined sense the choice of the quantization axis and a special coordinate system implies the breaking of color symmetry and general coordinate invariance. This breaking is induced by the presence of p-adic space-time sheets identified as correlates for cognition and intentionality. One could perhaps say that the cognition affects real physics via the imbedding space points shared by real and p-adic space-time sheets and that these common points define discrete coordinatization of the real space-time surface analogous to discretization resulting in any numerical computation.

4.2.5 Relationship between real and p-adic induced spinor fields

Besides imbedding space coordinates also induced spinor fields are fundamental variables in TGD. The free second quantized induced spinor fields define the fermionic oscillator operators in terms of which the gamma matrices giving rise to spinor structure of the "world of classical worlds" can be expressed.

p-Adic fractal long range correlations must hold true also for the induced spinor fields and they are in exactly the same role as CP_2 coordinates so that the variant of canonical identification mapping rationals to rationals should map the real and imaginary parts of of real induced spinor fields to their p-adic counterparts and vice versa at the rational space-time points common to p-adic and real space-time sheets.

4.2.6 Could quantum jumps transforming intentions to actions really occur?

The idea that intentional action corresponds to a quantum jump in which p-adic space-time sheet is transformed to a real one traversing through rational points common to p-adic and real space-time sheet is consistent with the conservation laws since the sign of the conserved inertial energy can be also negative in TGD framework and the density of inertial energy vanishes in cosmological length scales [D5]. Also the non-diagonal transitions $p_1 \to p_2$ are in principle possible and would correspond to intersections of p-adic space-time sheets having a common subset of rational points. Kind of phase transitions changing the character of intention or cognition would be in question.

1. Realization of intention as a scattering process

The first question concerns the interpretation of this process and possibility to find some familiar counterpart for it in quantum field theory framework. The general framework of quantum TGD suggests that the points common to real and p-adic space-time sheets could perhaps be regarded as arguments of an n-point function determining the transition amplitudes for p-adic to real transition or $p_1 \to p_2$-adic transitions. The scattering event transforming an p-adic surface (infinitely distant real surface in real M^4) to a real finite sized surface (infinitely distant p-adic surface in p-adic M^4) would be in question.

2. Could S-matrix for realizations of intentions have the same general form as the ordinary S-matrix?

One might hope that the realization of intention as a number theoretic scattering process could be characterized by an S-matrix, which one might hope of being unitary in some sense. These S-matrix elements could be interpreted at fundamental level as probability amplitudes between intentions to prepare a define initial state and the state resulting in the process.

Super-conformal invariance is a basic symmetry of quantum TGD which suggests that the S-matrix in question should be constructible in terms of n-point functions of a conformal field theory restricted to a subset of rational points shared by real and p-adic space-time surfaces or their causal determinants. According to the general vision discussed in [C1], the construction of n-point functions effectively reduces to that at 2-dimensional sections of light-like causal determinants of space-time surfaces identified as partonic space-time sheets.

The idea that physics in various number fields results by algebraic continuation of rational physics serves as a valuable guideline and suggests that the form of the S-matrices between different number fields (call them non-diagonal S-matrices) could be essentially the same as that of diagonal S-matrices. If this picture is correct then the basic differences to ordinary real S-matrix would be following.

1. Intentional action could transform p-adic space-time surface to a real one only if the exponent of Kähler function for both is rational valued (or belongs to algebraic extension of rationals).

2. The points appearing as arguments of n-point function associated with the non-diagonal S-matrix are a subset of rational points of imbedding space whereas in the real case, where the integration over these points is well defined, all values of arguments can be allowed. Thus the difference between ordinary S-matrix and more general S-matrices would be that a continuous Fourier transform of n-point function in space-time domain is not possible in the latter case. The inherent nature of cognition would be that it favors localization in the position space.

3. Objection and its resolution

Exponent of Kähler function is the key piece of the configuration space spinor field. There is a strong counter argument against the existence of the Kähler function in the p-adic context. The

basic problem is that the definite integral defining the Kähler action is not p-adically well-defined except in the special cases when it can be done algebraically. Algebraic integration is however very tricky and numerically completely unstable.

The definition of the exponent of Kähler function in terms of Dirac determinants or, perhaps equivalently, as a result of normal ordering of the modified Dirac action for second quantized induced spinors might however lead to an elegant resolution of this problem. This approach is discussed in detail in [B4, D1]. The idea is that Dirac determinant can be defined as a product of eigenvalues of the modified Dirac operator and one ends up to a hierarchy of theories based on the restriction of the eigenvalues to various algebraic extensions of rationals identified as a hierarchy associated with corresponding algebraic extensions of p-adic numbers. This hierarchy corresponds to a hierarchy of theories (and also physics!) based on varying values of Kähler coupling constant and Planck constant. The elegance of this approach is that no discretization at space-time level would be needed: everything reduces to the generalized eigenvalue spectrum of the modified Dirac operator.

4. A more detailed view

Consider the proposed approach in more detail.

1. Fermionic oscillator operators are assigned with the generalized eigenvectors of the modified Dirac operator defined at the light-like causal determinants:

$$\begin{aligned} \Psi &= \sum_n \Psi_n b_n \ , \\ D\Psi_n &= \Gamma^\alpha D_\alpha \Psi_n = \lambda_n O \Psi_n \ , \ O \equiv n_\alpha \Gamma^\alpha \ . \end{aligned} \tag{4}$$

   Here $\Gamma^\alpha = T^{\alpha k}\Gamma_k$ denote so called modified gamma matrices expressible in terms of the energy momentum current $T^{\alpha k}$ assignable to Kähler action [B4]. The replacement of the ordinary gamma matrices with modified ones is forced by the requirement that the super-symmetries of the modified Dirac action are consistent with the property of being an extremal of Kähler action. n_α is a light like vector assignable to the light-like causal determinant and $O = n_\alpha \Gamma^\alpha$ must be rational and have the same value at real and p-adic side at rational points. The integer n labels the eigenvalues λ_n of the modified Dirac operator, and b_n corresponds to the corresponding fermionic oscillator operator.

2. The condition that the p-adic and real variants Ψ if the Ψ are identical at common rational points of real and p-adic space-time surface (the same applies to 4-surfaces corresponding to different p-adic number fields) poses a strong constraint on the algebraic continuation from rationals to p-adics and gives hopes of deriving implications of this approach.

3. Ordinary fermionic anti-commutation relations do not refer specifically to any number field. Super Virasoro (anti-)commutation relations involve only rationals. This suggest that fermionic Fock space spanned by the oscillator operators b_n is universal and same for reals and p-adic numbers and can be regarded as rational. Same would apply to Super Virasoro representations. Also the possibility to interpret configuration space spinor fields as quantum superpositions of Boolean statements supports this kind of universality. This gives good hopes that the contribution of the inner produces between Fock states to the S-matrix elements are number field independent.

4. Dirac determinant can be defined as the product of the eigenvalues λ_n restricted to a given algebraic extension of rationals. The solutions of the modified Dirac equation correspond to vanishing eigen values and define zero modes generating conformal super-symmetries and are not of course included.

5. Only those operators b_n for which λ_n belongs to the algebraic extension of rationals in question are used to construct physical states for a given algebraic extension of rationals. This might mean an enormous simplification of the formalism in accordance with the fact that configuration space Clifford algebra corresponds as a von Neumann algebra to a hyper-finite factor of type II_1 for which finite truncations by definition allow excellent approximations [C6]. One can even ask whether this hierarchy of algebraic extensions of rationals could in fact define a hierarchy of finite-dimensional Clifford algebras. If so then the general theory of hyper-finite factors of type II_1 would provide an extremely powerful tool.

4.3 Infinite primes, cognition and intentionality

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and TGD inspired theory of consciousness. What this role precisely is has remained an enigma although I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a representation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed. Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic variants as space-time correlates for the fermionic super generators. Intentions/actions are represented by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action. It must be emphasized that this interpretation is not identical with the one discussed above since it introduces different identification of the space-time correlates of infinite primes.

4.3.1 Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given level define the building blocks of the infinite primes of the next level. One can map infinite primes to polynomials and these polynomials in turn could define space-time surfaces or at least light-like partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B, n_B, and s_F are defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors. The integers m_B and n_B characterize the occupation numbers of bosons in modes labelled by p_i and q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the possibility that the quaternionic components represent some quantum numbers at least in the sense that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether configuration space degrees of freedom and configuration space spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly hyper-octonionic) primes would define as such the quantum numbers of fermionic super generators does not make sense. It is however possible to have a map from the quantum numbers labelling super-generators to the finite primes. One must also remember that the infinite primes

considered are only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

4.3.2 Precise space-time correlates of cognition and intention

The best manner to end up with the proposal about how p-adic cognitive representations relate bosonic representations of intentions and actions and to fermionic cognitive representations is through the following arguments.

1. In TGD inspired theory of consciousness Boolean cognition is assigned with fermionic states. Cognition is also assigned with p-adic space-time sheets. Hence quantum classical correspondence suggests that the decomposition of the space-time into p-adic and real space-time sheets should relate to the decomposition of the infinite prime to bosonic and fermionic parts in turn relating to the above mention decomposition of physical states to bosonic and fermionic parts.

   If infinite prime defines an association of real and p-adic space-time sheets and this association could serve as a space-time correlate for the Fock state defined by configuration space spinor for given 3-surface. Also spinor field as a map from real partonic 3-surface would have as a space-time correlate a cognitive representation mapping real partonic 3-surfaces to p-adic 3-surfaces obtained by algebraic continuation.

2. Consider first the concrete interpretation of integers m_B and n_B. The most natural guess is that the primes dividing $m_B = \prod_i p^{m_i}$ characterize the effective p-adicities possible for the real 3-surface. m_i could define the numbers of disjoint partonic 3-surfaces with effective p_i-adic topology and associated with with the same real space-time sheet. These boundary conditions would force the corresponding real 4-surface to have all these effective p-adicities implying multi-p-adic fractality so that particle and wave pictures about multi-p-adic fractality would be mutually consistent. It seems natural to assume that also the integer n_i appearing in $m_B = \prod_i q_i^{n_i}$ code for the number of real partonic 3-surfaces with effective q_i-adic topology.

3. Fermionic statistics allows only single genuinely q_i-adic 3-surface possibly forming a pair with its real counterpart from which it is obtained by algebraic continuation. Pairing would conform with the fact that n_F appears both in the finite and infinite parts of the infinite prime (something absolutely essential concerning the consistency of interpretation!).

   The interpretation could be as follows.

   i) Cognitive representations must be stable against intentional action and fermionic statistics guarantees this. At space-time level this means that fermionic generators correspond to pairs of real effectively q_i-adic 3-surface and its algebraically continued q_i-adic counterpart. The quantum jump in which q_i-adic 3-surface is transformed to a real 3-surface is impossible since one would obtain two identical real 3-surfaces lying on top of each other, something very singular and not allowed by geometric exclusion principle for surfaces. The pairs of boson and fermion surfaces would thus form cognitive representations stable against intentional action.

   ii) Physical states are created by products of super algebra generators. Bosonic generators can have both real or p-adic partonic 3-surfaces as space-time correlates depending on whether they correspond to intention or action. More precisely, m_B and n_B code for collections of real and p-adic partonic 3-surfaces. What remains to be interpreted is why m_B and n_B cannot have common prime factors (this is possible if one allows also infinite integers obtained as products of finite integer and infinite primes).

iii) Fermionic generators to the pairs of a real partonic 3-surface and its p-adic counterpart obtained by algebraic continuation and the pictorial interpretation is as fermion hole pair. Unrestricted quantum super-position of Boolean statements requires that many-fermion state is accompanied by a corresponding many-antifermion state. This is achieved very naturally if real and corresponding p-adic fermion have opposite fermion numbers so that the kicking of negative energy fermion from Dirac sea could be interpreted as creation of real-p-adic fermion pairs from vacuum.

If p-adic space-time sheets obey same algebraic expressions as real sheets (rational functions with algebraic coefficients), the Chern-Simons Noether charges associated with real partons defined as integrals can be assigned also with the corresponding p-adic partons if they are rational or algebraic numbers. This would allow to circumvent the problems related to the p-adic integration. Therefore one can consider also the possibility that p-adic partons carry Noether charges opposite to those of corresponding real partons sheet and that pairs of real and p-adic fermions can be created from vacuum. This makes sense also for the classical charges associated with Kähler action in space-time interior if the real space-time sheet obeying multi-p p-adic effective topology has algebraic representation allowing interpretation also as p-adic surface for all primes involved.

iv) This picture makes sense if the partonic 3-surfaces containing a state created by a product of super algebra generators are unstable against decay to this kind of 3-surfaces so that one could regard partonic 3-surfaces as a space-time representations for a configuration space spinor field.

4. Are alternative interpretations possible? For instance, could $q = m_B/n_B$ code for the effective q-adic topology assignable to the space-time sheet. That q-adic numbers form a ring but not a number field casts however doubts on this interpretation as does also the general physical picture.

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