

Matter, Mind, Quantum

M. Pitkänen¹, February 1, 2006

¹ Department of Physical Sciences, High Energy Physics Division,
PL 64, FIN-00014, University of Helsinki, Finland.
matpitka@rock.helsinki.fi, <http://www.physics.helsinki.fi/~matpitka/>.
Recent address: Puutarhurinkatu 10,10960, Hanko, Finland.

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Abstract

The chapter is devoted to the TGD inspired theory of consciousness, which can be also regarded as a generalization of quantum measurement theory. The basic elements of the theory are following.

a) Physical realities correspond to quantum histories, configuration space spinor fields, which can be regarded as generalized Schrödinger amplitudes in the world of classical worlds identified as space-time surfaces. The quantum jump between deterministic quantum histories is identified as a moment of consciousness. Quantum jump begins with the step $\Psi_i \rightarrow U\Psi_i$, where U is informational "time development" operator defining S-matrix. There is actually no real time development involved. The requirement that quantum jump involves a state function reduction in the sense of quantum field theories implies that the unitary time development is followed by a localization in zero modes: $U\Psi_i \rightarrow \Psi_{f_0}$. Hence Ψ_{f_0} corresponds to a quantum superposition of space-time surfaces which are perceptively equivalent and the world of conscious experience looks classical in space-time degrees of freedom.

The localization in zero modes is followed by a cascade of self measurements $\Psi_{f_0} \rightarrow \dots \Psi_f$ leading to a minimally entangled product state: this sequence affects the state only in quantum fluctuating degrees of freedom. Only bound state entanglement is stable against self measurements. This process is equivalent with the state preparation process. Self measurement is governed by the so called Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given sub-system is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement.

Also p-adic-real (or cognitive) entanglement makes sense if entanglement coefficients are algebraic numbers. In this case a number theoretical definition of the entanglement entropy is possible. The number-theoretical entanglement entropy can be also negative, and in this case self measurement cannot reduce entanglement. A very attractive identification for the cognitive entanglement with positive entanglement negentropy is as a correlate for the experience of understanding.

b) The concept of self is absolutely essential for the understanding of the macroscopic aspects of consciousness. Self corresponds to a subsystem able to not generate bound state entanglement during quantum jumps. It is assumed that the experiences of the self after the last 'wake-up' sum to single average experience. This means subjective memory identifiable as a conscious short term memory. Selves form infinite hierarchy with entire Universe, God, at the top. Later a more ambitious approach reducing self hierarchy to a hierarchy of quantum jumps emerged. It seems now clear that these definitions are consistent with each other if the earlier characterization of self is restricted to apply to sub-selves (sub-quantum jumps).

A natural hypothesis is that self X experiences the experiences of its subselves as kind of abstracted experience: the experiences of subselves X_i are not experienced as such but represent kind of averages $\langle X_{ij} \rangle$ of sub-subselves X_{ij} . Entanglement between selves, most naturally realized by the formation of join along boundaries bonds between the space-time sheets, provides a mechanism building wholes from parts at the level of mental images represented by subselves. The fusion of mental images gives rise to what might be called stereo consciousness (stereo vision is the basic example of this). The notion of sub-system motivated by the many-sheeted space-time concept allows the sub-selves of un-entangled selves to entangle. This makes possible fusion and telepathic sharing of mental images. Self can be regarded as a statistical ensemble consisting of quantum jumps and various qualia are identified as statistical averages for the increments of quantum numbers and zero modes over the sequence of the quantum jumps defining self.

c) The quantum theory of self-organization is based on the identification of quantum jump as the basic iterative step of self-organization. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of slaving hierarchy. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes

so that Haken's classical theory of self organization applies almost as such. The possibility of the reversal of the arrow of geometric time (negative energy space-time sheets) below p-adic time scales means that the second law of thermodynamics is broken below p-adic time scale with respect to the geometric time although it still holds true with respect to subjective time. There are good reasons to expect that the temporal reversal of the arrow of geometric time in various p-adic time scales is a crucial element in the function of living matter and identifiable as a universal healing mechanism.

d) p-Adic physics provides the physics cognition and intentionality. To unify real and p-adic physics a generalization of number concept obtained by gluing reals and p-adic together along rationals and common algebraics is needed. TGD space-time decomposes into regions obeying real and p-adic topologies labeled by primes $p = 2, 3, 5, \dots$. p-Adic space-time regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive binary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. p-Adic spacetime sheets are also correlates of intentionality and the transformation of p-adic space-time sheet to a real one in the quantum jump has interpretation as a transformation of intention to action. The freedom of imagination could be basically due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. Real *resp.* p-adic space-time sheets are interpreted as symbolic *resp.* cognitive space-time correlates for conscious experience.

e) Quantum-classical correspondence is absolutely essential for the interpretation of the theory and understanding of how psychological time emerges. The classical non-determinism of Kähler action makes it possible to interpret space-time surfaces as symbolic representations for the contents of consciousness (not faithful). In particular, the concepts of association sequence and mindlike space-time sheet are made possible by the classical non-determinism. The understanding of the detailed relationship between subjective and geometric time turned however to be a difficult challenge and only the progress in the formulation of quantum TGD proper in terms of zero energy ontology led to what I believe to be a final breakthrough. The identification of the space-time correlate of self as causal diamond of the imbedding space -rather than space-time sheet- solved the problems concerning the relationship between geometric and subjective time.

f) The new view about space-time is crucial for the understanding of brain consciousness. Bio-systems are identified as macroscopic quantum systems and the quantum criticality of TGD Universe predicts the existence of quantum systems in all length scales and fractality. The notion of many-sheeted space-time provides several mechanisms making bio-systems macroscopic quantum systems. The generation of bound state entanglement makes possible macro-temporal quantum coherence implying that de-coherence time increases from CP_2 time to a macro-temporal time interval. An essential prerequisite of the macro-temporal quantum coherence is the quantum spin glass degeneracy of TGD Universe and classical gravitation is essentially involved with the mechanism. Macro-temporal quantum coherence implies a genuine breaking of the second law of thermodynamics since dissipation is effectively absent in quantum coherent degrees of freedom, and processes analogous to quantum computation become possible in the time scales relevant to human consciousness. From the point of view of consciousness this means that a sequence of moments of consciousness effectively integrates to a single moment of consciousness of macro-temporal duration, and that various qualia defined as subjecto-temporal averages for the increments of quantum numbers and zero modes stay sharp.

Topological field quantization forces to assign to any material system also a field body, in particular magnetic body. The notion of the magnetic body plays a pivotal role in the understanding of how sensory representations, long term memories, and motor actions are realized. Living organisms become in TGD Universe essentially objects of astrophysical size.

The fractal hierarchy of massless extremals (MEs) represents genuinely quantum gravitational states at a more abstract level of existence than ordinary quantum states. MEs interacting with fractal hierarchy of magnetic flux tube structures in many-sheeted ionic flow equilibrium with ordinary bio-matter at the atomic space-time sheets provide the hardware of bio-consciousness. The sign of energy depends in TGD Universe on the time orientation of the space-time sheet. Negative energy MEs serve as space-time correlates for bound state entanglement, and allow to understand an amazing variety of phenomena related to consciousness and biocontrol. The models of long term memory, sensory experience, and motor actions rely crucially on negative energy MEs serving as quantum entanglers and positive energy MEs serving as tools of precisely targeted classical communications.

1 Introduction

Topological Geometro-Dynamics (TGD) is a unified theory of fundamental interactions. TGD involves a quite far-reaching generalization of the space-time concept and, apart from the notion of quantum jump, reduces quantum theory to infinite-dimensional geometry. Quantum TGD requires the introduction of several new mathematical tools and concepts, in particular p-adic numbers. TGD-based theory of consciousness has developed gradually during the last fifteen years side by side with TGD based quantum measurement theory. For a summary of TGD and p-adic aspects of TGD see [1, 6]. The basic concepts and ideas of TGD based theory of consciousness can be summarized as follows.

1.1 Identification of quantum states as quantum histories

General coordinate invariance forces the identification of the quantum states as quantum histories rather than time=constant snapshots of single quantum history. Quantum history can be regarded as a classical spinor field in the space of all possible classical worlds so that rather abstract concept is in question. This identification has several important consequences.

1. The possibility to regard state function collapse as a quantum jump between quantum histories solves the basic paradox posed by the determinism of the Schrödinger equation contra non-determinism of the state function collapse¹.
2. A radical reconsideration of the concepts of psychological time and observer becomes necessary and forces a profound generalization of the standard views about time.

1.2 Quantum notion of self

An important step in the development of the theory was the discovery of the quantum level definition of the concept of self. Self can be identified as a subsystem able to not generate bound state entanglement during subsequent quantum jumps. A subsystem possessing self behaves thus like its own independent sub-Universe. The quantum notion of self together with some natural assumptions about how the contents of consciousness are determined, leads to an understanding of the phenomenology of the everyday consciousness and to some rather dramatic and often testable predictions. One of the newest ideas related to the notion of self is that the sub-selves of two unentangled selves can entangle although selves remain unentangled. This is possible by the modification of the subsystem concept forced by the p-adic length scale cutoff. The entanglement of sub-selves means fusion and sharing of mental images providing a universal telepathy like quantum communication mechanism and presumably making possible both molecular, cellular, and human societies.

¹The notion of quantum jump is more general than the notion of state function collapse which suggests a localization of wave packet

1.3 Generalization of quantum measurement theory

One must reformulate quantum measurement theory. The hypothesis that each quantum jump involves localization in the so called zero modes having interpretation as classical variables characterizing the observable geometric properties of the space-time surface, and thus of external macroscopic observer, together with an additional condition guaranteeing that the density matrix characterizing the entanglement between quantum fluctuating degrees of freedom and zero modes is diagonal, implies standard quantum measurement theory. Needless to emphasize, the reduction of the standard quantum measurement theory to fundamental quantum physics is a triumph of TGD approach.

This is however not the whole story. The standard quantum measurement is followed by a cascade self measurements inside self, which reduces entanglement between some subsystem and its complement in quantum fluctuating degrees of freedom: again a measurement of the density matrix is in question. This cascade is equivalent with the process of state preparation which is a phenomenological notion in the standard quantum measurement theory. The dynamics of self measurement is governed by Negentropy Maximization Principle (NMP), which specifies which subsystems are subject to quantum measurement in a given quantum jump. NMP can be regarded as a basic law for the dynamics of quantum jumps and states that the information content of the conscious experience is maximized. In p-adic context NMP dictates the dynamics of cognition.

1.4 Quantum criticality

The systems possessing self correspond to macroscopic quantum phases. In standard physics context the existence of the required macroscopic quantum phases is not at all obvious whereas the new physics implied by TGD predicts their existence. The point is that the Universe according to TGD is a quantum critical system. Quantum criticality is mathematically very similar to thermodynamical criticality and implies long range quantum correlations in all length scales. This in turn implies the existence of macroscopic quantum phases. TGD Universe is also quantum spin glass with state degeneracy broken only by the classical gravitational energy of the space-time sheets having same induced Kähler field. This degeneracy makes it possible to have quantum coherence over time periods longer than CP_2 time of order 10^{-39} seconds characterizing the duration of single quantum jump so that biosystems can act as quantum computers in macroscopic time scales.

1.5 TGD based space-time concept and the existence of macroscopic quantum phases

TGD implies a radical generalization of the space-time concept in all length and time scales. The concept of many-sheeted space-time leads to fresh proposals for how biosystems manage to be macroscopic quantum systems. Examples of these mechanisms are so called wormhole superconductivity, electronic high T_c super-conductivity, neutrino super-conductivity, ionic and a mechanism for generating coherent light and gravitons [J1, J2, J2, J4]. The notion of many-sheeted ionic equilibrium summarizes the basic vision about quantum control and coordination according to which the space-time sheets associated with the superconducting magnetic flux tube structures control ordinary biomatter at the atomic space-time sheets.

The so called massless extremals (MEs), which can be regarded as 'topological light rays', are carriers of especially important example of macroscopic quantum states. The lightlike boundaries of MEs act as quantum holograms and carry representations of the superconformal and supercanonical algebras. These states have gigantic almost-degeneracies, and are genuine quantum gravitational states (state functionals in the configuration space of 3-surfaces, 'the world of worlds') and thus correspond to higher abstraction level than ordinary quantum states. MEs can control the supercurrents at superconducting magnetic flux tube structures by magnetic interactions, act as

Josephson junctions, and induce magnetic quantum phase transitions. Therefore the quantum holograms associated with MEs are excellent candidates for quantum correlates of higher level consciousness.

1.6 p-Adic numbers and consciousness

p-Adic number fields R_p (one number field for each prime $p = 2, 3, 5, \dots$) are analogous to real numbers but differ from them in that p-adic numbers are not well-ordered. p-Adic numbers play an absolutely essential role in the formulation of quantum TGD and of TGD inspired theory of consciousness. The inherent non-determinism of p-adic differential equations motivates the identification of the p-adic space-time sheets as cognitive representations of ordinary matter with p-adic non-determinism identified as non-determinism of imagination. Mind-matter duality is realized at the level of space-time geometry and mind stuff corresponds to p-adic regions of space-time. TGD Universe performs self mimicry in all length scales. Besides p-adic nondeterminism there is nondeterminism of Kähler action: these two nondeterminisms allow to represent some aspects of quantum jump sequences, that is contents of consciousness of selves, at space-time level cognitively and symbolically (language). This in turn makes possible self referentiality of consciousness: it is possible to become conscious about being conscious about...

1.7 Implications of dynamical Planck constant and dark matter hierarchy for TGD inspired theory of consciousness

The identification of dark matter as a phase characterized by large value of quantized Planck constant led to a vigorous evolution of ideas still continuing while I am writing this. An entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [A8]. Also a good educated guess for the spectrum of Planck constants emerges. The hierarchy with $\hbar = \lambda^k \hbar_0$, $\lambda \simeq 2^{11}$, $k = 0, 1, \dots$, seems to be especially important for living matter.

The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

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.

Dark matter hierarchy has implications also for the basic theory by giving justification for the earlier vision about hierarchy of moments of consciousness analogous to hierarchy elementary particles-hadrons-nuclei-atoms...characterized by their average geometric duration identifiable as the typical duration of the memory span. Also the notion of quantum parallel dissipation emerges: self at the highest level of dark matter hierarchy assignable to it correspond to single moment of consciousness experiencing the quantum jumps sequences at lower level as sub-selves.

This onion-like structure of self helps to answer more convincingly the question how the experienced continuous stream of consciousness can be consistent with the notion of quantum jump. What fuses the lower level quantum jumps to a longer sequence is the presence of higher level self containing this sequence as a mental image.

The developments related to the dark matter hierarchy are added to the end of the chapter together with the newest view about p-adic physics as physics of cognition and intentionality.

2 TGD inspired theory of consciousness

Before continuing some comments about the definition of quantum history concept are in order. In TGD quantum states corresponds to Diff^4 invariant configuration space spinor fields defined in the space of 3-surfaces. By general coordinate invariance the value of the configuration space spinor field is same for all 3-surfaces $X^3 \subset X^4(Y^3)$ related by diffeomorphisms, especially by time translations of $X^4(Y^3)$. This means that configuration space spinor field cannot be localized temporally unless $X^4(Y^3)$ has finite time duration and is therefore vacuum 4-surface. Hence it is natural to speak of quantum history. Note that 'quantum history' in this sense does not refer to Schrödinger time evolution (since the Schrödinger evolution operator is generalized by TGD) nor evolution by quantum jumps (since, in TGD, these are jumps between entire quantum histories) but is quantum history with respect to the geometric time of $X^4(Y^3)$ and determined by the requirement of general coordinate invariance. Quantum history is defined in the world of all possible classical worlds (3-surfaces or equivalently allowed space-time surfaces).

Quantum histories can be also regarded as superpositions of classical space-time surfaces since the definition of the configuration space geometry assigns to each 3-surface Y^3 a unique space-time surface $X^4(Y^3)$ and since configuration space spinor field is invariant under general coordinate transformations. As a consequence, classical TGD becomes an exact part of quantum TGD.

2.1 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"

$$\Psi_i \rightarrow U\Psi_i$$

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

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

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

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

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 development². 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-determinism³. 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].

2.1.1 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 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 $S_{nm}^\dagger |m, z_1(z, n)\rangle$.

²From 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.

³This 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.

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.

2.1.2 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.

2.1.3 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 $U(-t, t)$, $t \rightarrow \infty$, 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)⁴.
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.

2.1.4 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 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

⁴Quantum histories can be regarded as superpositions of Boolean statements represented by many fermion Fock states (fermion number=1 \leftrightarrow true, fermion number =0 \leftrightarrow false), hence *logos*=*cosmos* identification.

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.

2.1.5 Information gain of the conscious experience

Quantum jump cannot be described by any model obeying deterministic dynamics. Thus one can claim that it is impossible to write any formula for the contents of the conscious experience in terms of, say, final quantum history: qualities are not in the world but in the no-where-land between the initial and final worlds of the quantum jump. This might indeed be the case at least when the component of the conscious experience is not about quantities as sensory experiences might be.

Despite this it is possible to assign well-defined information measures for the contents of conscious experience associated with single quantum jump. The idea is simple: interpret conscious systems as "information eaters" in the sense that information gain⁵ ΔI in conscious experience is difference for the information measures for the initial and final states $U\Psi_i$ and Ψ_f respectively:

$$\Delta I = I(U\Psi_i) - I(\Psi_f) .$$

Since one can write a formula for a quantum history (quantities are in the world), it is possible to assign well defined information measures to them.

In real context these information measures would be typically infinite by the mere reason that universe is infinite. A crucial role is played by the unique pinary cutoff associated with any mapping of a real geometric object to its p-adic counterpart and by the fact that the real counterpart of integer n regarded as p-adic integer is finite even in the case that n is infinite as ordinary integer. p-Adicization and pinary cutoff suggest a universal manner to characterize the finiteness of the mental capacity of particular self caused by its finite size (information gains are bounded by $p \times \log(p)$). One could perhaps call the p-adic image of the reality with pinary cutoff as "personal p-adicity" of self characterized by p-adic prime p .

The assumption that information measures are local with respect to configuration space together with the fact that configuration space spinors are analogous to ordinary single particle Schrödinger amplitudes, makes it possible to assign unique measure to a given type of information. These kind of measures are not possible in quantum field theory [H8].

One can question the claim that a formula for the contents of conscious experience is not possible⁶. In particular, one could claim that sensory experiences are exceptional since they represent basically quantities. Indeed, a working hypothesis worth of studying is that the values of the zero modes (which are same for all the macroscopically equivalent space-time surfaces present in the final quantum history,) determine the contents of the sensory experience. If this is the case, then the p-adic information measures $I(\Psi_f)$ for the final state of the quantum jump provide measures for the information contents of the sensory experience. Pinary cutoff would automatically take care of the finite resolution of the sensory experience caused by the finite size of the experimenter.

The information measures characterizing single quantum jump are not practical. The work done with the formulation of the Negentropy Maximization Principle (NMP) however led to the discovery that one can and must introduce number-theoretic information measures. p-Adic-real entanglement is possible if the entanglement coefficients are algebraic numbers so that they can be

⁵Information gain can be also negative.

⁶I am grateful for Philip van Loocke for representing this objection.

interpreted as belonging to any number field (algebraic extensions of p-adics are allowed). In this case a modification of the logarithm function ($Log_p(x) = \log_p(|x|_p)$) allows an infinite series of real-valued entropies labelled by primes p . These entropies can be also negative and therefore serve as genuine information measures. For instance, the experience of understanding has as a correlate p-adic-real cognitive entanglement with negative entanglement entropy. These information measures could mean a revolution in the understanding of the information theoretic aspects of conscious experience. These information measures make sense also in the case of real-real bound state entanglement if it reduces to an algebraic entanglement, and a unique prime p can be assigned to the information measure by maximizing it.

2.2 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.

2.2.1 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 subsystem) 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 $R_{p_1} \rightarrow R_{p_2}$ inside p_1 -adic self generate new p_2 -adic sub-selves.

2.2.2 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 cascade separately, and is therefore in a well-defined sense a local principle. Every un-entangled sub-system X in Ψ_{f_0} participates in quantum jump $\Psi_{f_0} \rightarrow \Psi_{f_1}$, 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 sub-system. 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, one 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.

2.2.3 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 unconscious 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.

2.2.4 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 involving extension of self [H3, H5]. Quantum entanglement could make possible communication between selves belonging to different levels of the self hierarchy.

2.2.5 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 enhanced oxidative metabolism [44]. 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.

2.2.6 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 [H8]. 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.

2.2.7 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.

2.2.8 Implications of the dark matter hierarchy for the notion of self

The identification of dark matter as phases having large value of Planck constant [D6, J6, A8] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [A8]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

1. *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.

2. *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 hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the basic hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^{11}$ is integer. Also sub-harmonics and integer valued sub-harmonics of λ are possible [A8]. 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.

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. 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.

2.3 About geometric correlates of selves

Space-time sheets with a finite time duration serve as geometric correlates for selves. There are several questions to answer. For instance, one should understand how the conscious experiences associated with the p-adic and real space-time sheets differ. Also one should understand how psychological time and its arrow emerge in this picture.

2.3.1 Cognition, imagination and p-adic physics

The problem about geometric correlates of cognition is not yet completely resolved. An important problem is what one understands with cognition and loose definitions might generate additional confusion. Intuitively it is clear that cognition should correspond to thinking. The simplest model for logical thinking is based on Boolean algebra: one could however argue that 'this is true' experiences are actually much like ordinary sensory experiences. Besides true/false dichotomy there are also beautiful/ugly and right/wrong dichotomies which suggests that aesthetics, moral, and logic might correspond to various aspects of some Boolean structure having physical interpretation and that cognition involves logic as one aspect only. Imagination is an important aspect of thinking and one could also consider the identification of the most fundamental aspect of cognition as imagination and perhaps even identify cognition as imagination.

The notion of the many-sheeted space-time decomposing into real and p-adic space-time sheets, and the classical non-determinism of the Kähler action making possible experiences with temporally localized information contents, are the key elements of TGD based model of consciousness.

The notions of mindlike space-time sheet (space-time sheet with a finite temporal duration) and association sequence were originally identified as geometric correlates of thoughts quite generally. On the other hand, the inherent non-determinism of p-adic differential equations means that the solutions of p-adic counterparts of field equations consist of pieces which are characterized by ordinary integration constants glued together. This is very much like the non-determinism of imagination and dreams, and inspires the hypothesis that p-adic space-time sheets serve as cognitive representations.

Real mindlike space-time would be the geometric correlates of sensory mental images rather than cognition. The difference between real and imagined experiences would correspond to real-p-adic distinction. One must be however very cautious here: one cannot exclude the possibility that also cognition is one aspect of sensory experience and that the notion of imagined cognition makes sense. It is also somewhat a convention, what is counted as cognition.

What we regard as imagination presumably involves p-adic-to-real transitions giving rise to initial values determining nerve pulse patterns generating almost motor actions and almost sensory perceptions. Also cell membrane oscillation patterns could represent imagination whereas nerve pulses give rise to sensory experiences. Thus p-adic physics would represent the core element of imagination and cognition. There are still unclear points: what seems certain that p-adic physics represents intentionality but one can debate about whether it represents also imagination and cognition.

2.3.2 What space-time surfaces look like?

The notion of the space-time surface appears often in the sequel and deserves some explaining. Mathematician's notion of the space-time surface is more general than the intuitive notion about it. For instance, space-time surface can be union of disjoint surfaces (2-D visualization: 2-surface can consist of several disjoint 2-surfaces: sphere here and piece of plane there,..). Space-time sheet is near to what one intuitively would understand with a space-time surface.

The TGD based notion of space-time surface is roughly the following.

1. One obtains piece of Minkowski space as a 4-surface defined by putting CP_2 coordinates constant: this is simplest kind of a vacuum extremal. By suitably deforming one obtains infinitely many vacuum extremals. Vacuum extremals can have finite time duration: in this case they correspond to mindlike space-time sheets.
2. Allowing several values for CP_2 coordinates one obtains several 'parallel' pieces of Minkowski space which can be deformed to more general vacuum extremals. These sheets can be glued together by wormhole contacts and deformed so that they are not vacua anymore.
3. By gluing extremely small surfaces representing elementary particles to this complex one obtains a rough view about what TGD space-time surface looks like.
4. Besides real regions there are also p-adic regions but these look like fractal dust in real topology. p-Adic and real regions are glued together at rational points of imbedding space.

Two-dimensional visualization might also help. Put z-coordinate constant in 3-space and allow several values of z-coordinate: you get several parallel pieces of plane. Deform them and glue them together by wormhole contacts. Glue elementary particle like surfaces, represented by, say, extremely tiny spheres and tori.

2.3.3 Association sequences and mindlike space-time sheets

The concepts of mindlike space-time sheet and association sequence are crucial for TGD based quantum model of intelligent system [H8].

Mindlike space-time sheets are geometric correlates of selves (see Fig. 2). They are made possible by the huge vacuum degeneracy of the Kähler action, TGD and more standard theories of physics. By gluing vacuum extremals to nonvacuum space-time surfaces and suitably deforming, one obtains new degenerate absolute minima. One manner to see mindlike space-time sheets is as the classical counterparts of the virtual particles of the quantum field theories (in TGD particles are 3-surfaces!) created from vacuum and returning to it. By definition material space-time sheets have infinite temporal extension whereas mindlike space-time sheets have *finite* temporal extension. Finite temporal extension is possible since classical conserved quantities like energy can flow to mindlike space-time sheet begins and flow back to a material space-time sheet when mindlike space-time sheet ends. The finite temporal extension implies that the information contents of the conscious experiences for selves associated with the mindlike space-time sheets are temporally localized. Thus a rough idea about the origin of the psychological time emerges. Mindlike space-time sheets provide cognitive representations for the material space-time sheets to which they are glued by wormhole contacts and/or join along boundaries contacts. Since the sign of the classical energy in TGD correlates with the time orientation of the space-time sheet, pairs of mindlike space-time sheets with vanishing net energy are possible. Direct mimicry is the simplest possible cognitive representation and this kind of a two-sheeted structure makes it possible! If this is indeed true, TGD universe would be physicist's version of the computer scientist's universe populated by computers emulating each other.

The original belief was that association sequence provides a model for thought understood as a simulation of the classical time development. This model does not necessitate p-adicity and one can ask whether all cognition is p-adic or whether also real cognition based on the classical non-determinism of Kähler action is possible. It is quite possible that the classical non-determinism of Kähler action provides sensory rather than cognitive simulation of the classical time development in the real context. This simulation could be naturally regarded as a symbolic representation whereas p-adic nondeterminism would make possible cognitive representations. Thus real association sequences would make possible language as symbolic representation of thoughts rather than thoughts as believed originally.

1. The original motivation of the association sequence concept is the vacuum degeneracy of the Kähler action. p-Adic non-determinism gives also rise to association sequences. This degeneracy implies classical non-determinism in the sense that the absolute minimum $X^4(Y^3)$ of the Kähler action associated with a given spacelike 3-surface Y^3 on lightcone boundary $\delta M_+^4 \times CP_2$ is not unique in general. In order to get rid of this non-determinism one must generalize the concept of 3-surface. "Association sequences", defined as 3-surfaces consisting of unions of some minimal number of disjoint 3-surfaces with timelike(!) separations, must be allowed (see Fig. 1) in order to fix uniquely which degenerate absolute minimum is in question.
2. A simple model for association sequence is obtained by considering a non-deterministic motion of a point in, say, plane. Suppose that there are N bifurcations. One can clearly fix single branch by fixing $N + 1$ points on the orbit. The union of these points, which have time like distances and are not clearly unique, defines association sequence. Non-determinism brings in finite number of degrees of freedom characterized by a sequence of N binary digits.
3. Association sequence provides a simulation of the classical time evolution and gives rise to what might be called "geometric memory" involved with the intentional aspects of consciousness (planning, expectations, desires,...). Geometric memory can be regarded as a "prophecy" for what will happen and what must have happened earlier provided the world were classical (no quantum jumps replacing the macroscopic classical space-time with a new one). Each quantum jump involves naturally a comparison of the expected time development provided by the "geometric memory" and the actual subjective time development stored in the subjective memory.
4. Association sequences of ... of association sequences are also possible and the average spatial and temporal distances ΔL and ΔT between fundamental building blocks of the association sequence give measures for the temporal and spatial resolutions of the cognitive/sensory representation provided by the association sequence.

The notions of mindlike space-time sheet and association sequence are frustratingly abstract concepts. It has however become clear that MEs (massless extremals) provide very general, if not even universal, identification for the geometric correlates of selves. The lightlike boundaries of MEs carry representations of superconformal and supercanonical algebras and act as quantum holograms. The general concepts of quantum information theory, the notion of quantum hologram in the sense of both quantum information theory and quantum gravity, and perhaps even quantum computation (in a suitably generalized sense) at the lightlike boundaries of MEs, seem to emerge as basic aspects of TGD inspired theory of conscious information processing.

A genuinely TGD based aspect is the possibility of negative time orientations making possible MEs carrying negative energies and representing classical signals proceeding into the direction of the geometric past, and the communication to the direction of the geometric past distinguishes TGD based and ordinary quantum information theory. This is especially interesting from the

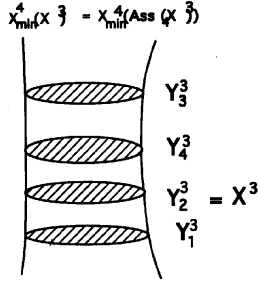


Figure 1: 'Association sequence': a geometric model for cognitive/sensory simulation as a sequence of disjoint 3-surfaces with timelike separations.

viewpoint of lightlike quantum computation since the classical restrictions coming from the huge length of MEs for reasonable computation times can be circumvented.

2.3.4 How to understand psychological time and its arrow?

If quantum states are entire quantum histories, it is not at all obvious how the contents of our everyday consciousness can be concentrated around a definite moment of the geometric time. One must show that the theory predicts the emergence of selves with the property that the information contents of their conscious experiences are concentrated around a definite value of the geometric time or possibly several of them. One must also understand why the value of this time parameter increases in a statistical sense.

The classical non-determinism of the Kähler action gives excellent hopes that the time localization for the information contents of the conscious experience takes place. Mindlike space-time sheets are the geometric correlates of selves and psychological time can be identified as the average center of mass time coordinate for the mindlike space-time sheet, which has finite time duration. This coordinate is naturally a zero mode and therefore has the same value for all space-time surfaces appearing in the superposition of the macroscopically equivalent space-time surfaces defined by the final quantum history Ψ_f . Since there is much more room in the future of a given point of the future lightcone than in its past and since the presence of the lightcone boundary is felt in each quantum jump (the magnitude for the increase of the psychological time can be arbitrarily large whereas the magnitude for the decrease is bounded by the presence of the lightcone boundary), the average increase of the psychological time in quantum jump is non-negative. Thus the evolution by quantum jumps is analogous to diffusion in the presence of a future directed drift force and leads to a drift of the mindlike space-time sheet to the direction of future. Therefore a local arrow of psychological time results (see Fig. 2).

The simplest guess is that the average increment of the psychological time in a single quantum jump does not depend on properties of the self and is of the order of CP_2 time about 10^4 Planck times. This means that consciousness in biological length scales is in a well defined sense macroscopic phenomenon and that single quantum jump corresponds to a microscopic building block of self. A natural assumption is that self hierarchy starts already from selves having duration of few quantum jumps (elementary particles?).

If the space-time sheet is not in self state, it is part of a larger self. Thus space-time sheets drift towards the geometric future irrespective of whether they are in self state or not. The simplest

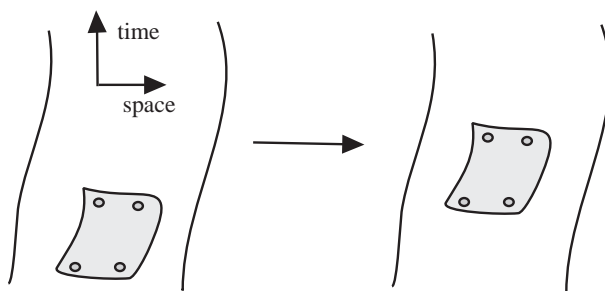


Figure 2: The mechanism giving rise to the arrow of psychological time

possibility is that the drifting velocity is constant so that the increment of the geometric time, most naturally identifiable as the lightcone proper time a , is given by

$$\Delta a = k\tau ,$$

where k is some numerical constant and τ is some fundamental time scale, most naturally of the order of CP_2 time τ_{CP_2} is CP_2 time about 10^4 Planck times.

Drifting rate could in principle depend on the p-adic length scale associated with the self and also on the gradient of the total entropy of self with respect to subjective time. For instance, one could have

$$\frac{dn}{da} = \frac{k}{\tau} \frac{dS}{dn} ,$$

where k is a dimensionless constant. The idea that self which approaches thermal equilibrium begins to drift towards geometric future with arbitrary high rate does not certainly make sense. The only sensible interpretation is that the gradient of entropy with respect to subjective time tells the fraction of time spent by the system in self state. When the entropy gradient is small, geometric time is experienced to flow very fast, very few moments of consciousness per geometric time. The approach of 'our' self to thermal equilibrium could thus explain why old people feel that time flows fast. When the entropy gradient is large, as it perhaps is in a very emotional situation like car accident, the flow of the geometric time would be experienced to stop since the number of moments of consciousness per geometric time is very high.

The new concept of the psychological time means a dramatic generalization of the standard view about subjective existence. mindlike space-time sheets are distributed everywhere around material space-time sheets of infinite time duration and all of them can participate in a given quantum jump. Therefore one can say that the entire space-time is a conscious, living being. Civilizations of the geometric past and future exist simultaneously with us. We are members of a four-dimensional society in the sense that our actions affect the life of selves of both geometric past and future since each quantum jump performed by us changes the macroscopic space-time in both past and future. It is quite possible that there are new versions of me in the geometric past represented by mindlike space-time sheets drifting in future time direction along the material space-time sheet describing "material me". Therefore this particular life of mine is only one among very many ones. p-Adic evolution implies that in the statistical sense the quality of these lives tends to get better. We in our youth now experience in slightly more deeper manner and live in a society having slightly higher level of moral.

2.3.5 What distinguishes 'now' from memories and plans?

The new notion of psychological time leads to a very elegant mechanism of long term memory and memories in general: to remember something at temporal distance T in the past is to look at a mirror with length $L = cT/2$. There is no need to store the memories of the geometric past in the geometric now. The conscious experience contains contributions from both the geometric past, from the geometric now, and probably also from the geometric future (plans, dreams, expectations). This raises an obvious question: what distinguishes so dramatically the geometric now from memories and plans so that the illusion about reality as a time=constant snapshot of the geometric time development is created?

The most plausible answer is based on the identification of the p-adic physics as physics of cognition. p-Adic space-time regions represent thoughts, intentions, plans, etc. and quantum jumps in which a p-adic region is transformed to a real region correspond to the transformations of intentions to actions. Psychological now corresponds to a front of a phase transition in which p-adic space-time sheets (perhaps massless extremals (MEs) which are topological counterparts of light rays) transform to real ones. Psychological now corresponds to the front of enhanced volition. In the geometric future intentions are still intentions represented by p-adic MEs whereas in the geometric past they have transformed to actions. Of course, also the reverse transformation, during which the arrow of psychological time presumably changes and things get undone (a possible mechanism of healing), might occur but should occur with a low probability.

If the front of the p-adic-to-real phase transition is common to the entire biosphere, one avoids many paradoxes. Consider only a situation in which the friends living at different psychological times participate to the funeral of a common friend. This picture implies that the geometric past is relatively stable as is required by the fact that our personal identities do not suffer sudden changes (consider only the situation in which the me of my geometric past decides to choose differently in some turning point of life!). The stability below a given time scale holds true above certain length scale. For instance, the very fact that our memories are surprisingly unstable suggests that geometric memories which result from the information processing at brain level are not stable against quantum jumps.

2.3.6 How selves wake-up and fall asleep?

If the impossibility of entanglement between different number fields is what makes selves possible, the wake-up of the mental image most probably means generation of space-time region with topology different from that of surrounding space-time region. For instance, p-adic space-time regions surrounding real regions with different p could serve as shields allowing real space-time sheets to stay in self state and vice versa. Topologically the death of the mental image would mean a phase transition in which the topology of the mental image becomes that of the surrounding space-time region or a fusion with a larger region when it forms an extrusion through the shielding region. If our sensory mental images are real (as opposed to p-adic), this could be one of the mechanisms involved. For instance, falling asleep could involve either phase transition or fusion mechanism.

Sleep would have obvious function: when mental image ages, its entropy grows and it becomes fuzzy. One manner to avoid this is a temporary death and re-incarnation as a brisk and young mental image. Of course, also we are mental images and the reason for why we die physically might be precisely this. This would encourage to believe that our bodily sub-self (also mental image!) has a duration determined by our lifetime. Second manner to achieve this is to somehow reduce the entropy growth rate or change its sign. Very probably biosystems are full of mechanisms tending to achieve this kind of state. For instance, de-differentiation of cells to stem cell stage would be an example of this mechanism. The basic function of metabolism would be to help this fight against second law. Note however that this war against second law could occur both at the level of mental images and the matter at atomic space-time sheets and it might be that a negligible fraction of

metabolic energy is needed to to keep our mental images sharp.

2.3.7 Estimate for the "wake-up time" of sensory selves from p-adic length scale hypothesis

The basic question relates to the age of selves representing sensory mental images and also to the age of our own self which at least apparently seems to be of order of our wake-up period. The question is not trivial.

1. It is not at all clear whether the wake-up state is continuous: also our self could exist only a fraction of time and memories could create the illusion about continuity of self.
2. Maximally entropic long-aged sub-selves in thermal equilibrium need not contribute to conscious experience and their disappearance from our consciousness need not mean that they die: they could simply give rise to a background sensory and cognitive noise which is certainly present.

Consider first some arguments supporting a short wake-up time.

1. The identification of subjective memory as a short term memory and the fact that sensory sub-selves with too long age cannot provide the needed time resolution of sensory experience encourages the idea that sensory sub-selves have a short wake-up period of order .1 seconds. Since sensory sub-selves seem to have finite wake-up time also our self should have.
2. The duration of short term memory seems to be of order second so that the periods of, at least, sensory wake-up should be of order second. On the other hand, memory sub-selves of sufficiently short duration can give rise to sensory memory with sufficient resolution even if our self has much longer wake-up period.
3. A good guess seems to be that the duration of our self is not longer than wake-up period. But again it could be that we simply do not remember what we experience during sleep: to remember what happened during sleep we must perhaps be in sleep state! It is known that dreams experienced during some period of time for logical stories. Thus it seems that at least dreaming involves memories about previous dreams.

The fact that the entropy of an ageing sub-self tends to increase means that mental image gets fuzzy. This allows the possibility that our sensory mental images are rather quite long-lived but get rapidly fuzzy so that only the youngest sensory mental images would dominate our consciousness.

p-Adic length scale hypothesis suggests that the typical duration of a self characterized by p-adic prime p is given by the p-adic time scale $T_p = L_p/c$, where $L_p \simeq 10^4 \sqrt{p}$ Planck lengths is the p-adic length scale. The duration of our immediate sensory memory of about .1 second would correspond to a p-adic length scale of the order of the circumference of the Earth! Either the estimate is wrong or our picture about brain as a seat of consciousness is quite not correct! TGD predicts entire self-hierarchy so that it is not all obvious which option is correct.

One could also adopt a purely formal approach and try to estimate the wake-up time using p-adic length scale hypothesis. The time scale of .1 seconds corresponds to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of Earth size. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies [32] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and neural instabilities [60]. Furthermore, the estimate for the thickness of the magnetic flux tubes of Earth's magnetic

field based on the quantization of the magnetic flux is about cell size. These observations raise the question whether our "physical" body is only a tip of an iceberg and formed by the topological condensation of the biomatter around electromagnetic topological field quanta serving as templates for the biostructures[13].

Our self hierarchy could contain also higher levels and the fact that we experience continuity of personal existence suggests that this is the case. This consistent with the basic assumptions about conscious experience if the temporal averaging involved with the temporal binding is weighted so that only the most recent experiences are present with large weight. An interesting possibility is that entire fractal hierarchy of magnetic flux tube structures carrying superconducting BE condensates of ions is involved so that also a hierarchy of cyclotron time scales defining a hierarchy of durations for selves (mental images) is involved. Same is true for MEs and Uncertainty Principle suggest that MEs with size of order light life time are involved with our long term memories.

2.3.8 How fast subjective time runs?

An interesting challenge is to understand the relation of the subjectively experienced time to the psychological time (essentially geometric time). In order to experience time self must have a clock. The simplest assumption is that the sequence of quantum jumps defines the sequence of ticks for the clock. Therefore subjective time would be measured as the number n of quantum jumps occurred after the wake-up of the self. The rate for the running of subjective time would be dn/da and just the inverse for the rate of running for psychological time and same for all systems if the average duration of chronon is of order of CP_2 time: this is certainly not consistent with the fact subjectively experienced time can run faster or even stop. One could also kill this naive hypothesis by noticing that self should be able to distinguish between the ticks of the clock: obviously we cannot experience quantum jumps as separate events.

A more realistic model is based on the idea that the average time interval Δa between two wake-ups of a 'clock' sub-self, which exists periodically in a wake-up state defines a natural unit of subjective time. The number N of ticks for the clock is given by the age of self divided by the duration of single wake-up period for the 'clock' self

$$N(a) = \frac{a}{\Delta a} .$$

N would naturally define a measure of subjectively experienced time. Slowing down of subjective time would correspond to the slowing down of the internal clock in the sense that Δa increases.

Consider now whether this simple model can explain basic facts about experienced rate of subjectively experienced time.

1. Experienced time is said to run slowly, when we get bored and drowsy. Actually the situation is just the opposite since the number of ticks of the internal clock per unit of psychological time must be large. In order to understand what might be involved, assume that also the internal clock gets drowsy so that the average wake-up period Δa_W for the internal clock gets shorter. If internal clock wakes up spontaneously, one can assume that the average duration Δa_S for the sleeping periods for clock self is not changed. Hence $\Delta = \Delta a_W + \Delta a_S$ is reduced so that $N(a) \propto 1/\Delta a$ increases and geometric time is experienced as longer.
2. Quite different situation is encountered, when person is in the state of whole-body-consciousness. In this kind of situation there is no internal clock and one can indeed say that there is no time! This would explain the reports of meditators about state of 'timelessness' [45] Oliver Sacks has described in his book 'Awakenings' patients who have lived for years in 'no-time' state with frozen contents of conscious experience, which presumably meant that everything in the external world seemed to happen extremely slowly. It would be natural to assume that the lifetime Δa of the 'clock' self was very long in this kind of situation or even that person

was in the state of whole-body-consciousness. The only clock is person itself and the entire experience corresponds to single tick of this clock. There are also reports that when person is in dramatic situation like traffic accident, time is experienced to stop. One explanation is that person experiences state of whole-body consciousness. Second possibility is that in this kind of situation involving very high level of alertness Δa becomes very short so that all motions seem to occur very slowly: in this manner person gets a lot of subjective time to react to the situation.

One could also try to understand why persons at older age feel that time runs faster. This statement is clearly not about what person immediately experiences but impression about what has happened. One possible explanation is however that the period Δa of the internal clock indeed gets longer at older age. This could be caused by the increase of the period Δa_S of the sleeping period of the internal clock. This is consistent with the previous idea that the wake-up time of mental images gets shorter, which also explains why old people experience that geometric time flows faster. Thus, if the total fraction of geometric time spend by the person and his/her sub-selves in wake-up state decreases when person gets older, one can understand why the time is experienced to run faster at the older age.

2.3.9 Time delays of consciousness and other anomalies

TGD based concept of time has rather dramatic implications and it is important to show that the new time concept indeed solves the conceptual problems and anomalies of the standard physics. One should also device experiments to test the new time concept.

1. Dissipation is the black sheep in the family of theoretical physics and quantum jump between quantum histories concept explains dissipation in an elegant manner. The ad hoc addition of various parameters characterizing dissipation to the reversible fundamental equations of the classical physics can be understood as a phenomenological model for the subjective time evolution as a sequence of macroscopic space-times defined by the final states of the quantum jumps. Dissipative space-time is kind of an envelope for a sequence of non-dissipative space-times. Dissipation is a signature of quantum jumps which, by the basic assumptions related to the formulation of NMP, correspond to a sequence of quantum measurements and can occur only inside selves. Hence dissipation gives direct evidence for consciousness. TGD predicts the possibility of whole-body consciousness with anomalously low dissipation and this spectacular effect provides a test of TGD approach [13].
2. Quantum jumps between quantum histories concept together with the notion of self explains also the peculiar time delays of consciousness revealed in the experiments [47, 49] relating to the active and passive roles of consciousness and described by Penrose in his book [51]. The basic observation is that quantum jump replaces macroscopic space-time with a new one and that both the geometric past and future change. For instance, the EEG activity preceding the conscious decision to raise the index finger in experiments of Libet related to the active aspects of consciousness [49] can be interpreted as classical electromagnetic fields present in the geometric past of the new macroscopic space-time generated by the decision to raise the finger.
3. It is also possible to explain the causal anomalies revealed by the experiments of Radin and Bierman [62, 63, 64]. In these experiences pictures with emotionally provocative content generated galvanic skin responses already before they were seen. A natural looking assumption about the contents of conscious experience is that the change of the geometric past is larger for emotional than for non-emotional quantum jumps (e-motion!): this is also consistent

with the important role of emotion as a motivator and with the fact that neural transmitters involved with the emotion induce long term synaptic changes. With this assumption the change of the past recordings about galvanic skin response is predicted to be larger for the emotional pictures than for the non-emotional ones. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept [H5].

2.4 Biosystems as macroscopic quantum systems

The empirical fact that energy conservation holds true holds true in space-time assumed to be single sheeted requires that the energy transfer between atomic and non-atomic space-time sheets must be very small. Thus there are good hopes that non-atomic space-time sheets can be in extremely low temperatures and are indeed superconducting. Also self measurements governed by NMP allow macroscopic quantum systems to fight against thermalization.

In the standard physics context there are not many candidates for the macroscopic quantum systems required. In the TGD framework the situation is different since quantum criticality predicts long range quantum correlations in all length scales.

1. Coherent photons and coherent gravitons created by vacuum electromagnetic currents and vacuum energy density are a phenomenon characteristic for TGD and might be crucial for the functioning of biosystems as macroscopic quantum systems [J4].
2. Wormhole contacts feeding gauge fluxes between space-time sheets behave like bosons and form BE condensates.
3. Neutrino super conductivity, made possible by the presence of the classical long range Z^0 fields, might provide the realization of thinking systems as magnetized defects in type I superconductors near criticality. The geometric form of the cellular and endoplasmic membranes and chiral selection support this picture.
4. A new form of electronic super conductivity is made possible by the many-sheeted space-time concept: what happens is that electrons drop to a larger space-time sheet at which there is cold, dry and silent. The new form of electron superconductivity is a good candidate for the mechanism behind high T_c super conductivity. Also ionic superconductivity for the ions dropped to larger space-time sheets from the atomic space-time sheet is possible. Ordinary atoms and ions can be regarded as fully ionized Z^0 ions and similar mechanism allows also Z^0 super conductivity. Thus an entire zoo of bio-superconductors associated with magnetic flux tube structures in turn forming a fractal hierarchy, is predicted [J1, J2, J3].
5. The states of supercanonical representations at the lightlike boundaries of MEs define a hierarchy of genuinely quantum gravitational states in the sense that these states genuine state functionals in the space of 3-surfaces (world of worlds) and therefore correspond to a higher abstraction level than ordinary quantum states for which orbital configuration space degrees of freedom are not excited. This suggests strongly that 'our' consciousness corresponds more or less to that associated with MEs and that the consciousness associated with, say, the magnetic quantum phase transitions at superconducting magnetic flux tubes corresponds to more primitive chemical senses not directly conscious to us.

The recent view about biosystems as macroscopic systems boils down to fractal hierarchies of MEs and superconducting magnetic flux tube structures living in symbiosis with ordinary biomatter at atomic space-time sheets. The basic control mechanism is many-sheeted ionic flow equilibrium allowing to amplify extremely small superconducting ion densities to large ion densities at the atomic space-time sheets. The magnetic interaction of MEs with the magnetic flux tubes can

induce both supracurrents and quantum coherent phase transitions making possible biochemical control. For instance, protein conformations could be quantum controlled by electronic super currents at protein space-time sheets in turn being controlled by MEs which are at the top of the hierarchy.

This picture explains naturally the observed effects of ELF em fields on living matter at multiples of magnetic cyclotron frequencies [56], the observed DC current circuits [58] and collagen circuitry [38] as parts of this circuitry, and the strange findings challenging the notions of ionic channels and pumps [37].

3 Various types of conscious experiences

In the following the general structure and classification of conscious experiences is discussed. Most predictions are brain independent. Assuming that zero modes of the configuration space, characterizing the geometry of macroscopic classical space-time, determine the geometric information contents of conscious experience and identifying macroscopic quantum phases as quantum correlates of various sensory modalities, one can make rather far reaching predictions about basic aspects of, say, sensory experience of any experiencer, be it human brain or some strange life form in distant galaxy.

3.1 Basic structure of conscious experience

Before continuing, it is perhaps useful to recall the basic anatomy of the quantum jump: $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_{f_0} \rightarrow \dots\Psi_f$, where the final quantum history Ψ_f is a superposition of space-time surfaces, which are macroscopically equivalent and only bound state entanglement is present. Every space-time surface of the superposition consists of parallel space-time sheets (connected by wormhole contacts). Some of these space-time sheets have infinite time extension and some have not. The latter ones are 'mindlike space-time sheets'. One must make a clear distinction between the quantum superposition of the space-time surfaces and the decomposition of the space-time surface to space-time sheets.

3.1.1 Real and imagined experiences

The assumption that p-adic physics is physics of imagination means division of qualia to real qualia and imagined qualia. There are good arguments based on mathematical consistency that in p-adic configuration space degrees of freedom complete localization occurs in each quantum jump (see Appendix). This means that there are no quantum fluctuations in p-adic degrees of freedom and since non-geometric sensory qualia like color correspond to quantum number increments in quantum fluctuating degrees of freedom, there are no p-adic non-geometric qualia. This however leaves p-adic geometric qualia determined by the increments of p-adic configuration space coordinates. This view is certainly consistent with intuitive notion that cognitive qualia are only about the geometric aspects, like shape and size, of the objects of the external world.

One could debate about whether cognition can be identified as imagination but this is the working hypothesis made. The transformations of thoughts into actions or sensory experiences and of sensory inputs into thoughts correspond to p-adic-real phase transitions for mindlike space-time sheets so that one can speak about matter-mind interaction in a well-defined sense. Cognition is predicted to be present already at elementary particle length scales and this assumption is crucial for understanding the success of the p-adic length scale hypothesis works and p-adic mass calculations.

One can identify p-adic space-time sheets as memes [41] and relate them to the morphic fields of Sheldrake. The p-adic vision about cognition is discussed in [H9].

3.1.2 Whole-body consciousness and ordinary consciousness

TGD predicts two basic modes of consciousness.

1. Reducible self is the state in which sub-selves are "falling asleep" and "waking up" all the time, corresponds naturally to the ordinary state of consciousness. Sub-selves represent mental images which pop out and disappear all the time.
2. In case of irreducible self quantum jumps do not lead to a generation of sub-selves. Thus the sub-systems of irreducible self have only bound state entanglement and self measurement cascade stops at irreducible self. This state is presumably accompanied by the experience of "oneness" and could therefore be called a state of "whole-body consciousness". The absence of the sub-selves means the absence of mental images so that the identification as a state of pure self awareness without any contents is natural. Less ideal situation is that sub-selves are generated but are very short lived and represent short flashes against background awareness. "Whole-body-consciousness" presumably means abnormally low metabolism since dissipation inside sub-selves is not present.

3.1.3 Active and passive aspects of conscious experience

Conscious experience involves two fundamental contributions.

1. The "non-classical" contribution from the quantum measurement reducing quantum entanglement associated with the fermionic degrees of freedom and with the quantum fluctuating configuration space degrees of freedom (as opposed to zero modes).
2. The "classical" contribution determined by the localization in zero modes and by the selection between different degenerate absolute minimum space-time surfaces having different decompositions into p-adic regions.

The natural guess is that the experienced free will corresponds to the non-determinism of the quantum jump somehow. The standard objection is that the non-determinism of the quantum measurement gives rise to randomness rather than volition. Quantum numbers relate to microscopic aspects of the quantum jump and the average quantum numbers measured in quantum jumps probably sum up to zero in the presence of energy feed and external perturbations. Indeed, if temporal binding for the experiences of self involves averaging, this component of experience need not give rise to an experience of volition since it is expected to average out for large number of quantum jumps (10^{38} per second by the argument for the arrow of psychological time). Therefore the time averaging involved with the temporal binding smooths out this non-determinism.

Here the special features of TGD however come in rescue.

1. The first candidate for the quantum correlate of volition is the localization in zero modes. This localization corresponds to the spontaneous symmetry breaking of quantum field theories which selects one classical configuration among many degenerate ones. Spontaneous symmetry breaking has been suggested to be a basic aspect of the quantum jump also by Joel Henkel [34]. Asymptotic localization in zero modes seems to be however determined statistically by the self-organization process taking the system to the bottom of some valley of the spin glass energy landscape. Hence volition need not be in question.
2. The second candidate for volition is classical non-determinism of Kähler action (which gives rise to the geometric model of thought as "association sequence"). The selection between the different degenerate alternative classical time evolutions, that is different degenerate absolute minima $X^4(Y^3)$ going through a given 3-surface Y^3 , is an excellent candidate for

the volitional act. The reason is that absolute minima differ macroscopically so that the choice between degenerate minima dramatically affects the entire geometric future. Note also that the selection between branches of a multifurcation of macroscopic space-time is in question, the choice can be done only when mindlike space-time sheet is located in a narrow time interval around multifurcation and is hence irreversible. The identification of the classical non-determinism as a geometric correlate of the volitional non-determinism is in nice accordance with the "ontogeny recapitulates phylogeny" principle stating that the geometric time evolution at the level of the space-time surface reflects the time evolution by quantum jumps at the level of the configuration space. One can however argue that this kind of volition is still passive in that it is only a selection between given alternatives rather than a transformation of an intention to action. The second objection is that there are actually infinite number of options between which to select in the state function reduction: why do we not experience these alternatives consciously?

3. The third candidate for volition is a quantum jump in which p-adic-to-real transformation for a p-adic space-time sheet representing cognitively intention occurs so that it becomes an action. This identification of the volitional act seems to be the most realistic one and indeed allows to understand how the notion of psychological time emerges. Since complete localization occurs in p-adic degrees of freedom in the state function reduction stage, there is no selection between infinite number of alternatives but only a selection of the p-adic space-time sheet which is transformed to a real one and induces the self-organization process possibly leading to the desired goal.

An interesting possibility is that the zero modes characterizing the macroscopic features of the macroscopically equivalent space-time surfaces present in the *final* quantum state of quantum jump determine the contents of at least sensory experiences. This would be in accord with the idea that pure sensory experiences represent quantities which indeed 'are in the world', the world being identified as the macroscopic space-time associated with the final quantum history of the quantum jump. One could however argue that it is only *the increments of zero modes* in quantum jump, which are perceived directly consciously: this claim is consistent with the fact that insects are able to see only the motion and that also human visual consciousness is crucially dependent on saccadic motion. Localization in the zero modes involves the fixing of the parameters characterizing the shape and size of the 3-surface X^3 as well as the Kähler field of $X^4(X^3)$. Kähler field can reduce to a purely electromagnetic or Z^0 type classical gauge field and is in general also accompanied by a classical color field. The spatio-temporal patterns of the induced Kähler field should correlate strongly with the contents of the conscious experience.

3.2 Cognition and p-adic physics

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the binary cutoff of their arguments and replace integration constants in p-adic differential equations. In case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that a unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique binary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected

to have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

If one accepts the idea that real and p-adic space-time regions are correlates for matter and cognitive mind, one encounters the question how matter and mind interact. A good candidate for this interaction is the phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations can take place in quantum jumps. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or to an action. The reverse phase transition might relate to the transformation of the sensory experience to cognition. Sensory experiences could be also transformed to cognition by initial values realized as common rational points of a real space-time sheet representing sensory input and a p-adic space-time sheet representing the cognitive output. In this case the cognitive mental image is unique only in case that p-adic pseudo constants are ordinary constants.

The identification of p-adic physics as physics of cognition satisfies quite a number of consistency constraints.

1. Consistency constraints force to assume that p-adic regions of 3-surface do not contribute to the line element of the configuration space. This means that p-adic degrees of freedom are zero modes and thus completely classical in the sense that a localization occurs in p-adic configuration space degrees of freedom in each quantum jump. Thus the word of cognition is completely classical.
2. Classicality of cognition implies that there are no non-geometric cognitive qualia determined by the increments of quantum numbers in quantum jumps but only geometric cognitive qualia determined by the increments of zero modes. Thoughts are indeed non-colored. Same applies to emotions if emotions correspond to rates of the entropies associated with various non-geometric sensory qualia. Since it is not possible to talk about the sign of the p-adic entropy gradient (p-adic numbers are not well-ordered), one cannot classify possible geometric p-adic emotions to positive and negative. p-Adic Boolean mind is however possible and should represent what we call rational mind.

Various identifications for the quantum correlate of volition were already discussed and it was found that the most realistic option is the identification of volition as associated with a quantum jump in which a p-adic space-time sheet representing an intention is transformed to a real region representing action. This identification leads also to the assignment of the psychological time with the phase transition front at which intentions transform to action proceeding to the direction of the geometric future. The difference between intentions and memories would be that intentions are p-adic whereas memories are real.

3.3 Reflective- and proto-levels of consciousness and Boolean mind

The decomposition into proto consciousness and reflective consciousness (consciousness about being conscious) is one of the fundamental features of conscious experience. Logical thinking is also a fundamental component of conscious mind and probably also the mind unconscious-to-us, in fact so fundamental one that it has inspired the computationalistic approach to consciousness. One can consider two alternative identifications for the reflective level of consciousness.

3.3.1 Boolean mind as reflective mind?

The state basis of the Fock space generated by N fermionic creation operators is isomorphic with the Boolean algebra consisting of 2^N possible statements about N basic statements. This follows from the simple observation that by Pauli exclusion principle the fermion number associated with a given fermion state can have only two values: 0 (false) or 1 (true). This observation leads to the idea that many fermion states give representation for what might be called reflective consciousness in the sense that the information contents for experiences about conscious experiences could correspond to the quantum jumps in the fermionic sector.

A more convincing interpretation is in terms of Boolean mind. In p-adic case only quaternion conformal degrees of freedom are possible for configuration space spinors (see appendix) and since pure cognition involves no emotions and no values it must correspond to logic (true/false). In real case the spin associated with the configuration space metric correlates with the sensory experience and naturally corresponds to the logic of aesthetics (beautiful/ugly) whereas real quaternion conformal degrees of freedom having no correlation with the sensory experience correspond naturally to the logic of ethics (right/wrong), or more generally the true/false logic of belief system having strong right/wrong emotional coloring. Thus the Goodness-Truth-Beauty trinity would thus have a reduction to the Boolean algebra defined by the Fock basis for the configuration space spinors.

TGD based model of abstraction process involves a hierarchy of statements about statements about.... starting from 2 basic statements such that the statement represented by empty set in the set theoretic realization of Boolean algebra is thrown away at each step. The model predict besides the genetic code also a memetic code consisting of 127-bit code words such that 126-bit statements form a maximal number of mutually consistent statements. In case of genetic code 7-bit code words represent all possible statements and 64-bit codewords represent mutually consistent statements.

In real context, 6-bit code words for the genetic code and 126 bit code words for the memetic code code form a maximal number of mutually consistent 'this is right thing to do' beliefs. 7-bit resp. 127-bit code words can be interpreted as coding these statements and their negations: all bits must be realized in p-adic case since formal logic requires also the negations of the basic statements. Lying is a cognitive skill. Genetic code would represent in case of the molecular society the moral and social rules whereas memetic code would represent these rules in case of the ordinary society. DNA would provide a symbolic representation for the 64 fundamental truths, kind of a legal code.

3.3.2 Symbolic and cognitive representations as means of becoming conscious about beng conscious about?

An alternative identification of the reflective mind is in terms of language and cognitive representations made possible by the nondeterminism of Kähler action and inherent nondeterminism of p-adic differential equations. These nondeterminisms allow to represent contents of consciousness of self (quantum jump sequence) cognitively and symbolically and to become conscious these representations: this is nothing but becoming conscious about being conscious about...

The (inconvinced) Boolean identification of reflective mind predicts a single directly experienced reflective level. In the second case given quantum jump allows the emergence of only single new reflective level. Indeed, it is easy to become conscious about seeing red but one cannot have direct experience of being conscious about being conscious about seeing red. It is also easy to build theorems about theorems (or imagine what happens under given circumstances) but deriving theorems about theorems about theorems looks impossible without paper and pencil.

3.4 Boolean mind and neutrinos

Recall that Boolean mind means more than just ordinary logic in TGD framework. In case of p-adic antineutrinos Boolean mind means logical mind without any emotional aspects whereas real antineutrinos would represent beliefs as right/wrong type statements if the proposed general identification for the correlates of ethical/aesthetical/logical statements makes sense. As already noticed, real neutrinos could represent belief system which includes moral statements as a special case. Obviously the notion of cognitive neutrino is somewhat misleading since it refers to both real and p-adic neutrinos: I apologize for the use this term.

3.4.1 Zero energy neutrino-antineutrino pairs

Very low energy neutrino physics in TGD differs from that predicted by standard model dramatically because TGD predicts the presence of classical Z^0 fields coupling to neutrinos. Even more, classical Z^0 fields become important above cell length scale.

One ends up with a rather concrete quantum model for Boolean mind based on neutrinos by

1. combining the concept of association sequence with the fermionic realization of Boolean algebra ;
2. requiring that fermionic states exist only in a finite time interval defined by the duration of the mindlike space-time sheets;
3. assuming that timelike entanglement is possible for many-fermion states.

Ordinary fermions cannot reside on mindlike space-time sheets unless they are created as pairs with vanishing total quantum numbers (in particular energy!). In p-adic case there should be no obstacle for this but in the real case this is presumably not possible unless negative energy fermions are allowed.

Real neutrinos are however exceptional [F9, J2]. Neutrinos are an ideal for consciousness since they do not couple to electromagnetic interactions and, having couplings only to the classical Z^0 fields, dissipate extremely weakly. TGD based model of condensed matter predicts that the classical Z^0 binding energy of neutrino with condensed matter makes neutrino energy in condensed matter negative and large [F9, M6]. Thus neutrino pairs can have vanishing total quantum numbers. The creation of zero energy neutrino pairs by the decay of a wormhole contact connecting material and mindlike space-time sheet is indeed possible. Boolean statement and its negation correspond naturally to Fock states of antineutrinos (resp. neutrinos) condensed to mindlike (matter) like space-time sheets. Fermion number could be also fixed and spin direction could code the Boolean truth values.

Zero energy neutrino pairs could reside in the defect regions of neutrino super conductor which is superconductor of type I having complicated stripe like defect regions near criticality. TGD based model for the interaction of neutrinos with condensed matter predicts that the thickness of the defect regions is of order 10^{-8} meters. Hence cell membranes are excellent candidates for the defect regions. One indeed ends up to a detailed quantitative model of Boolean mind and memetic code by combining this idea with the observation about magnetic and Z^0 magnetic transitions as a fundamental element of our consciousness [L1].

Quantum-classical correspondence (or "ontogeny recapitulates phylogeny" principle as I have used to call it) suggests that it is localization in zero modes, in fact the conscious selection between degenerate absolute minima of Kähler action, which selects between various configurations of the classical Z^0 field. If the pattern of zero energy neutrino pairs is fixed by the classical Z^0 field, the premises and conclusions of the logical deductions are represented in terms of cognitive neutrinos. This assumption is also in accordance with the hypothesis that the exponent of the Kähler action

provides a measure for the cognitive resources of 3-surface defined as the number of degenerate absolute minima of Kähler action associated with the 3-surface [H8].

3.4.2 Possible realizations of genetic and memetic code using zero energy neutrino pairs

From the previous picture it is still a long way to concrete models and one can make only educated guesses for the concrete realizations of belief systems.

1. "Moral codes", or more generally, belief systems, seem to be represent an evolutionary newcomer and should be related to the neuronal dynamics of neocortex and frontal lobes. The full realization of the memetic code requires precise temporal coding: the 126-bit memetic code word as a temporal sequence of cognitive neutrinos has duration $\sim .1$ seconds so that single bit would have duration about $1/1260$ seconds, which is slightly below the duration of a single nerve pulse. The realization of the full memetic code in terms of nerve pulse patterns would require temporally precise nerve pulse patterns with a maximal firing rate and it is not clear whether this is possible. Also neuronal membrane oscillations realize memetic code. Nerve pulse patterns with frequency coding could represent more primitive form of cognition than cell membrane oscillations. The evolution of moral codes, belief systems, and social structures, and of cognition should have as a correlate increasing number of significant bits of memetic code meaning gradual increase of the maximal firing rate. The p-adic memetic code words could also represent intentions and the value of the 127:th binary digit would tell whether the intention represents right or wrong deed.
2. Also chromosomes (having same thickness as cell membranes) could be identified as defect regions of neutrino super conductor. Very simple model for the abstraction process as a hierarchy of Boolean statements about Boolean statements about... starting from two basic statements explains the basic numbers of the genetic code [H8]. It is difficult to believe that this could be a mere accident. Zero energy neutrino pairs indeed allow to construct a model of a many-sheeted DNA realizing gene level Boolean mind using 64 basic statements and possibly explaining the mystery of introns [39] and the role of zero energy neutrino pairs is very similar to that in cell membrane cognition. Since real neutrinos are in question the interpretation would be that DNA neutrino pairs represent kind of rules of behaviour for an individual of cell society.
3. Microtubules are cylindrical surfaces with inner and outer radii of $15 \text{ nm} = 1.5 \times L(151)$ and 25 nm respectively. The diameter of the microtubule interior corresponds therefore to the magic p-adic length scale common to cell membrane and chromosomes. This suggests that also microtubules or microtubule interiors are defects of neutrino super conductor and carriers of axial or helical, Z^0 magnetic fields generated by spontaneously magnetized cognitive antineutrinos. An interesting possibility is that 3 neutrino generations could correspond to three types of cognition associated with DNA, microtubules and axonal membrane.

3.5 General model for sensory experiences

The concept of self provides considerable insight to the model of sensory experiencing.

1. If temporal binding involves averaging over the experiences occurred after the wake-up, experiences are reliable.
2. Also the averaging over the experiences of separate sensory subsub-selves implied by the summation hypothesis could be involved.

3. Sensory experiences can involve more than the direct experiencing: also a comparison with the earlier sensory data could quite well be involved and is made possible by subjective and geometric memories. Sensory experiences certainly involve computational aspects.

In the following the general model of sensory experiencing is discussed only briefly [H3].

3.5.1 Macroscopic quantum phases are needed

Self must be able to remain unentangled in subsequent quantum jumps. The presence of the macroscopic quantum condensate means usually energy gap between ground state and excited states. This can make the generation of real entanglement very slow process and self can exist.

The fact that macroscopic quantum phases have coupling to the classical gauge fields, suggests that the order parameters of the macroscopic quantum phases are completely determined by the localization in the zero modes. Thus the contents of the sensory experience should correlate with these order parameters. This motivated the original attempt to identify macroscopic quantum phases as quantum correlates of the sensory qualia. A more refined approach identifies quantum phase transitions of the macroscopic quantum phases as correlates of sensory qualia so that the increments of quantum numbers in the phase transition label various qualia. This identification is completely general and almost brain independent (cell length scale turns however be crucially important p-adic length scale).

Many-sheeted space-time concept makes possible large number of macroscopic quantum phases not possible in standard physics context. In particular, the so called massless extremals (MEs) representing 'topological light rays' provide a model for how linear structures such as DNA and microtubules could act as quantum antennae emitting and absorbing coherent photon distribution fixed completely by localization in zero modes. Coherent photons could realize the concept of global workspace [40] and could make possible "mass media" at neural level. Also the concept of "neural window" abstracting the notion of holographic brain suggests itself [H8, K3]. MEs form a fractal hierarchy and are carriers of supercanonical representations for which states are genuine functionals in the space of 3-surfaces ('world of worlds') and thus correspond to higher abstraction level than ordinary quantum states. Supercanonical states have also gigantic almost degeneracies. MEs act also as quantum holograms.

For these reasons MEs are ideal candidates for a hierarchy of life forms [K3]. In particular, the assignment of 'our' sensory qualia with supercanonical quantum transitions looks reasonable whereas magnetic quantum phase transitions might well correspond to more primitive chemical qualia not directly conscious to us.

3.5.2 The functions of nerve pulses

The identification of the sensory qualia in terms of the quantum phase transitions associated with macroscopic quantum phases is in conflict with the general belief that neuronal activity determines completely the contents of the sensory experiences. In TGD framework one can understand the role of the nerve pulse activity differently. Brain is quantum spin glass and the evolution of sub-selves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape. The contents of the sensory experiences are determined by the zero modes which in turn determine the ground state patterns of the order parameters of various macroscopic quantum phases.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. One role of the nerve pulses is to provide this metabolic energy feed. This suggests that the axons are seats of the self-organization patterns coding at least part of the neuronal experience. Brain seems to systematically maximize the length of the axons feeding sensory data (for instance, right ear feed its sensory input to the left hemisphere). Brain anatomy

seems also to favour long pyramidal axons. This phenomenon, which seems to be in conflict with the principles of good metabolic economy, is consistent with the maximization of the expressive power of the sensory pathways. Microtubule conformations are excellent candidates for realizers of declarative memory and this would also explain why the lengths of sensory axons tend to be maximized. Myelin sheets guarantee that external perturbations do not affect the self-organization patterns. It is also possible that myelin sheets form together with the axon Josephson junctions for various superconductors predicted by TGD and are thus essential for the generation of neuronal sensory experiences.

Nerve pulses affect also the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is that the incoming nerve pulses push and pull the postsynaptic cell in different directions and in this manner cause frustrations typical for spin glass like systems. The assumption that neural transmitters give rise to some kind of chemical senses at neuronal level as well as neuronal emotions is in accordance with this. Also frequency coding is consistent with the identification of the nerve pulse activity as a control function.

Of course, spatio-temporal patterns of nerve pulses might also code information about sensory experience. There is indeed evidence that various odours are coded into spatio-temporal nerve pulse patterns [46]. For instance, for the neurons of the associative regions of cortex receiving inputs from several sensory modalities this kind of discrimination is obviously highly desirable. One can even consider the possibility that nerve pulse patterns, in some parts of brain at least (in output axons of association regions), provide a precise naming for axonal experiences.

The notion of memetic code encourages to consider this idea quite seriously and the physical model of the memetic code [L1]. realizes a precise coding of the nerve pulse patterns to 126 bit temporal sequences represented in terms of time-varying Z^0 magnetization direction of cognitive anti-neutrinos. Bits could correspond to Boolean truth values or bits in a binary expansion of an integer providing measure for the intensity of the net presynaptic sensory experience represented by the cognitive neutrino pairs of the postsynaptic axon: this would be essentially a mapping of experience to its symbol. This naming would serve also as the basis of our language and duration of a phoneme could correspond to the predicted duration of codeword of order .1 seconds. A degenerate form of memetic code would be based on nerve pulses and realize frequency coding whereas full memetic code would be based on neuronal membrane oscillations.

The model for sensory qualia and sensory representations [K3, M1] assumes that nerve pulse patterns generate EEG MEs (massless extremals) entangling brain with the sensory magnetic canvas. The question where the mental images responsible for the sensory qualia are located, still lacks a convincing answer. Primary qualia could even correspond to mental images associated with the sensory receptors and sensory pathways could serve as cortex-receptor entanglers. Brain would give names for sensory inputs and percepts rather than creating the primary qualia. This would require feedback from brain to the sensory organs.

Frequency coding is not the only manner to code information to nerve pulse patterns and delicate temporal coding mechanisms exist. For instance, frequencies can be coded to peaks of the spike interval distribution by stochastic resonance [33]. Also the coding of spike interval distribution to EEG frequencies is possible (a kick to a harmonic oscillator at the correct half period leads to a resonant amplification [M5]).

3.5.3 How qualia are associated with neural pathways?

Since TGD predicts entire hierarchy of selves, it is important to specify whose sensory experience one is talking about. In TGD framework nerve pulse patterns as such need not give rise to our sensory experience and it is quite possible that also primary sensory organs have sensory experiences.

Frustratingly, the question about the seat of qualia mental images remains unanswered.

1. The assumption that primary qualia are somehow associated with or determined by the sen-

sory receptors would resolve a difficult question about how sensory pathways, which do not seem to have any obvious differences at the level of brain, give rise to qualia. The entanglement of the sensory receptors with brain in turn entangled with the magnetic body would give rise to the sensory representations. Our sensory experience would not be localizable to what happens in the brain region: indeed, MEs in EEG frequency region have size of order Earth size.

Various objections (hallucinations, experiences generated by the stimulation of the sensory pathways, phantom leg phenomenon, dreams) against this view can be circumvented if there is a feedback between brain and sensory organs (as there indeed is), and if sensory experiences can also correspond to geometric memories (say in case of phantom leg experience). If sensory receptors are the experiencers of the primary sensory qualia, then conscious experience can precede the neural activity in the cortex, as observed by Libet in his classical experiments concerning the timing of the sensory experiencing [49].

2. A more general view is that the neuronal receptors (also "field receptors" responsible for neuronal vision and hearing can be present) along the sensory pathway are specialized to experience only special sensory qualia characterizing the sensory pathway.

How the primary and possible also secondary sensory receptors or sensory pathways could then give rise to particular qualia? Quite generally qualia correspond to average increments of quantum numbers for the quantum jump sequence defining sub-self. In the case of color qualia one has a partial answer. For MEs supercanonical quantum transitions are characterized by configuration space Hamiltonians carrying spin and color ($SU(3)$) quantum numbers. For configuration space photons state functional in configuration space degrees of freedom is nontrivial and characterized by configuration space Hamiltonian with quantum numbers characterizing a particular quale. This suggests that somehow neural pathway or sensory receptor should be able to generate 'configuration space photons' (MEs) BE condensing on larger MEs and inducing visual color qualia at least. This would mean that configuration space photons would in a well-defined sense carry qualia: the photons generated by sensory receptors and brain could be colored after all!

The educated guess is that the EEG transition frequencies coded the spike interval distributions associated with the sensory pathway characterize the sensory pathway partially. EEG frequencies in turn determine partially the quantum phase transitions which can be stimulated by that particular sensory pathway. The minimal option is that these transitions relate only with what parts of magnetic body the sensory pathway is entangled with. This would make possible very high functional flexibility in accordance with the observed plasticity of brain.

3.5.4 Only changes are perceived

One of the basic laws about sensory experiencing is that only changes and novelties are perceived. For instance, totally monochromatic illumination is experienced as darkness. The zero modes characterizing the macroscopic space-time associated with the final quantum history of the quantum jump should determine the contents of the sensory experience. Part of the zero modes corresponds to the induced Kähler of CP_2 which is nonlinear Maxwell field closely related to the classical electromagnetic and Z^0 fields. There are also zero modes representing the size and shape of 3-surface: these might be related to the discriminative sense of touch. A possible generalization of the law is that sensory stimulus generates Kähler electric field proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go in this kind of situation?

The solution of the problem might be very simple: mindlike space-time sheet is generated and the flux goes to the mindlike space-time sheet through wormhole contacts. Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mindlike space-time sheets and give rise to selves, mental images already at the level of the sensory organ or the sensory pathway leading to thalamus.

The extreme generality of the mechanism suggests that it could be at work also at the level of brain. Understanding of the computational aspects of sensory experience (say stereovision) is not possible unless one assumes that mindlike space-time sheets in sensory pathway combine with the primary sensory organs to form coherent quantum systems. "Ontogeny recapitulates phylogeny" principle requires that these space-time sheets are connected by join along boundaries bonds most naturally associated with axons leading from sensory organ to brain.

3.5.5 Are the ultimate sensory representations realized outside brain?

One of the dramatic almost predictions of TGD inspired theory of consciousness is that our physical body is accompanied by a hierarchy of field bodies, in particular magnetic body. A given field body provides abstract representations about quantum aspects of the physical body, kind of a manual. This prediction plus some general arguments lead to the view that sensory representations are most naturally realized outside the physical body at the personal magnetic body (first person aspect of consciousness) and at the magnetic body of Earth (third person aspect of consciousness).

This vision leads to the interpretation of EEG as being involved with MEs projecting sensory data to the magnetic body. EEG ME would generate quantum entanglement between two mental images: a feature inside brain and a 'simple feeling of existence' mental image at the magnetic body and representing a point of the external world. Thus the main function of brain would be the construction of features and sensory representations would be completely separated from their construction. Note that also in the case of computers the representation of the data is separated from the generation of the data.

3.6 Emotions

TGD suggests several visions about emotions and it is not yet completely clear whether these views are really mutually consistent.

3.6.1 Emotions and comparisons

The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. Subjective and geometric memories make it possible to compare the expectations with what really occurred during the time interval since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. Many higher emotions such as sorrow, depression, frustration, desire, happiness, feeling of relief, pain, fear, anger, envy, hatred, etc... clearly involve comparison of expectations and reality. This could perhaps mean that these emotions are created by the comparison of the predicted or desired geometric time history and subjective time history (what really happened). This would mean that at least higher emotions differ from the sensory qualia, which seem to be determined solely by the localization into zero modes representing the non-quantum fluctuating aspects of space-time geometry.

One might however argue that very primitive emotions such as rage without any object and involving only the activity of the limbic brain could be quale like and that hormones are the quantum correlates of these emotions. These emotions involve however a change of behaviour (e-motion!) so that one could argue that also now there is a simple comparison involved. Perhaps

changes in the hormone concentrations could be regarded as consequences of the change of the emotional state. Or vice versa, if hormones are messengers telling to very simple selves of limbic brain whether the real course of events was the desired one or not, then hormones indeed effectively control the emotional state and can be regarded as quantum correlates of emotions.

It is difficult to assign any comparison to an emotion like deep love since it involves a complete acceptance of the object of love and is free of desires. Perhaps the claim of mystics that deep experience of love means that subject and object of love cease to exist as separate objects, makes sense. Lovers quantum entangle and die as separate selves (for some fraction of time only, of course!) and the higher self consisting of lovers experiences whole-body consciousness. Perhaps more mundane love means that my sub-selves representing me and the loved one entangle to form a sub-self experiencing whole-body consciousness. Perhaps also feelings like empathy belong to this class of emotions.

3.6.2 Emotions and entropy

The concrete model of qualia to be developed in [K3] provides an alternative general vision about emotions which allows to understand the difference between comparison type emotions and other emotions as well as the role of emotions in control.

1. The statistical physics approach to qualia leads to the hypothesis that emotions correspond to rates for the generation of various type of entropies for the sub-selves of self. The sign of the rate tells whether emotion is positive or negative. Negative emotions would thus be conscious control variables warning self when some sub-system is generating entropy. The holistic nature of the emotions can be understood easily in this picture and also the fact that they are not directly related to sensory input. One could perhaps also understand higher level emotions like sorrow as reflecting the growing disorder of the virtual world of brain resulting from the primary cause of sorrow.
2. It is known that peptides correlate strongly with emotions and moods [52] and they are even called molecules of emotions. Peptides are also regarded as information molecules. This connection between information and emotions fits nicely with the fact that peptides and other important biomolecules certainly induce strong entropy gradients with respect to subjective time.
3. Sensory qualia can be divided to geometric and non-geometric ones. One can classify also emotions in this manner. Emotions corresponding to the localization in zero modes would perhaps correspond to 'higher level emotions' about external world (say, aesthetic qualia) whereas the non-geometric emotions associated with the state preparation would correspond to 'self-centered' emotions about the state of body (pain, physical pleasure,...).
4. Also pure emotions which seem to involve no obvious comparison (love, joy, excitement,..) are possible. For instance, the emotions produced by music might represent this kind of emotions. The view about emotions as entropy gradients allows to understand also emotions of this kind. In state of deep love, self enters into very low-entropy state and mental images (not necessarily even present in 'enlightened states') become very pure.
5. An interesting question is whether the entropy growth of our sensory sub-selves is only sensory representation for the entropy growth occurring at the level of atomic space-time sheets or corresponds directly to it. The enormous difference of the temperatures associated with the atomic space-time sheets (ordinary matter) and superconducting magnetic flux tube structures would suggest that the growth rates for these entropies are of totally different order of magnitude and our emotions serve have the role of conscious control variables telling whether things are going well at the atomic space-time sheets.

Consider now the comparison type emotions and the relation of emotions to control in more detail.

1. Many emotions are comparison type emotions. These emotions tend to be negative (say envy). The first option is that comparison type emotions result from the comparison of geometric and subjective memories occurring automatically in any quantum jump and thus to some degree with any quale. Unfortunately, it is very difficult to imagine how to concretely test this kind of hypothesis and it is also difficult to see how the connection with entropy gradient could emerge.
2. One must also seriously consider the possibility that emotions result from the comparison of remembered/anticipated experience and real experience rather than the fundamental comparison involved with anticipation and memory: kind of quasi-computerized version of geometric memory would be in question. The result of comparison would be coded to the sign of the growth rate of some entropy variable. The comparison could perhaps be realized in such a manner that subsequent quantum jumps for comparing sub-system could represent either the anticipated or real quale. If this were the case, the difference between anticipated and real would automatically induce growth of entropy and negative emotion would result. This would be the basic mechanism of dissatisfaction. In this picture comparison type emotions could be seen as a system of rewards and punishments used to control the self (the controller could be higher level self (conscience) or higher levels selves which also want to survive (the emotions generated by hunger, thirst, and physical pain)). Punish/reward mechanisms could basically involve negentropy/entropy feed to some sub-self.
3. One could also regard emotion as induced by generalized sensory qualia giving information about CNS itself rather than external world or the boundary between external world and body. The regulation involved with the homeostasis involves comparison in an essential manner so that one could perhaps regard emotions as analogous to control variables representing consciously the result of comparison of expected and desired forcing the organism to behave in a manner to reduce this difference and end up to a rest and digest state. This aspect is consistent with the statistical interpretation since the entropy gradients associated with the organism are stronger than those associated with the surrounding world. Also amplification mechanisms exaggerating the entropy gradients might have developed. For instance, our reactions to some odours or tastes could involve this kind of amplification.
4. A hypothesis consistent with these views is that emotional component is involved with all sensory experiences and that we are used to call generalized sensory experiences emotions when they are about body. The emotionality of qualia indeed increases in the sequence of perceptive fields external world – CNS-world boundary – body. The degree of emotionality of experience should be characterized by the deviation of real from expected or desired and this suggests that the emotional component is much stronger for sensory experiences about CNS itself, since the system in question is much less predictable than the external world consisting of dead objects. Interpretation of emotion as measure for entropy gradient explains also this hierarchy.
5. Depression could be seen as a lost ability to experience emotions, be they positive or negative. Depression indeed involves emotional flatness. This state results when mental images become maximally entropic (emotional counterpart of heat death). That depression can follow deep sorrow is natural since negative emotions tend to increase the entropy of the mental images. It is known that depression involves over-activity of the amygdala and under-activity of some forebrain regions and an abnormally small population of glial cells known to be closely involved with metabolism and 'cleansing activities' at brain level. This supports the view

that glial cells might be warriors in the war against second law at the level of atomic space-time sheets and the loss of this war is sensorily mapped to the level of mental images and leads to depression. One function of serotonin, dopamin and various other neuropharmaca tending to produce pleasant experiences could be a reduction of entropy either at atomic space-time sheets or, less probably, directly at the level of our sensory sub-selves.

3.7 Directed attention

The possibility to interpret self as a statistical ensemble suggests that the entropy of the mental image measures its fuzziness. Thus both attentiveness, alertness and level of arousal should relate very closely to the entropy of the mental images. Attention to a mental image could mean fight against second law to keep the mental image in a low entropy state and this requires metabolism (the icons on the computer screen provide a good example of this). Also alertness means mental images with low entropy content. 7 ± 2 rule of cognitive science suggests that the maximum number of our cognitive sub-selves which can be awake simultaneously, is rather limited. The rule might be based on the metabolic limitations: sub-selves can have low entropy content only in the presence of an external negentropy feed and metabolism must provide the needed negentropy feed. Note however that the needed metabolic energy might be extremely low.

Directed attention is one of the basic processes of consciousness occurring continually. Directed attention seems to involve free choice but focusing of attention could also occur spontaneously. One can imagine several models for the focusing of attention.

1. One possibility is that subsub-self inside sub-self representing mental image (say 'monitor screen' as average over subsub-selves representing the visual objects) somehow pops up one level higher in the self hierarchy so that it becomes mental image. Geometrically this could correspond to the re-gluing of the corresponding space-time sheet to the space-time sheet of self instead of that of sub-self. In this case attended object would not pre-exist.
2. A further aspect of the focused of attention is as a wake-up of sub-self and keeping it in wake-up state and hence in short term memory. This could occur at the expense of the other sub-selves, which would be in wake-up state for only short times. A possible mechanism of selection is a phase transition changing the topology of chosen region (say from p-adic to real or from p_1 -adic to p_2 -adic) so that a new sub-self pops up from the background.
3. Self directs automatically its attention only to sub-systems immediately below it in the hierarchy. It seems however possible to direct attention to lower levels of the self hierarchy. For instance, I can direct my attention to the entire sentence, which I am writing here or to some word of this sentence or to individual letters of this word. The phenomenon of bio-feedback demonstrates that it is possible to learn to direct the attention to even single neuron. This suggests that selves are able to modify the hierarchy of selves by raising some sub...sub-self to the role of sub-self temporarily and thus experience the former sub...sub-self as a direct mental image. Formation of the join along boundaries bonds between mindlike space-time sheets at various levels of the self hierarchy provides a general geometric mechanism making possible temporary changes of the structure of the self hierarchy. Also the learning taking place during sleep [53] might involve interaction between different levels of the self-hierarchy.

3.8 Four-dimensional brain and long term memories

Four-dimensionality of brain is crucial for the understanding long term memories as multitime experiences receiving contributions from several moments of geometric time. This identification makes it unnecessary to have any memory storage mechanisms. Rather, the activities of the memory circuits can be seen as increasing the probability that memory recall occurs. Reverberating

memory circuits in which experience is echoed indeed do this by extending the deep memory valley in spin glass landscape to a long canyon in time direction. This increases the probability that mindlike space-time sheets enter in the region of four-dimensional spin glass landscape representing the memory. The deepness of the spin glass valley correlates with the emotionality of the memory. Childhood memories are especially emotional and therefore stable. Memories are result of creative action and memory circuit involving hippocampus seem to be active in carving out the art works representing geometric memories worth of remembering. TGD based approach solves the basic problems of the neural net approach resulting from the fact that the formation of new memories destroys old memories and from the fact that it is difficult to understand how the component of experience is known to be a memory.

Long term memories and memories in general can be understood as resulting from a very simple mechanism. When I remember something that happened, say two years ago, I look at a mirror at distance of one light year and see myself in mirror as I am at a distance of two geometric years in the geometric past. Massless extremals (MEs) representing topological light (and graviton) rays and carrying the classical information about the memory are reflected in some kind of a mirror structure. Mirrors could correspond end points, branching points, curved parts or cross sections of magnetic flux tubes and MEs or in case of gravitonic rays to curved parts of the background spatetime surface.

The reflected ME could be seen as topological counterpart of self-energy diagram involving emission and absorption of massless virtual particle such photon or graviton. At quantum level timelike entanglement, which is possible by the non-determinism of the fundamental variational principle, binds the mental images 'now' and 'then' to a single mental image. MEs could be generated in the transitions between almost degenerate quantum spin glass states. Since the energy difference corresponds to the classical gravitational energy, topological gravitonic rays, which also interact very weakly with the external world, are good candidates for MEs responsible for long term memories. The interpretation of these MEs as gravitonic $1/f$ noise suggest itself strongly.

Note that the continual occurrence of quantum jumps between quantum histories explains why our long term memories are unstable. It seems however that it is probably only sensory and cognitive representations which are altered appreciably. In human time scales geometric past should be relatively stable in macroscopic length scales: otherwise dramatic changes of the recent reality induced by macroscopic quantum jumps in the geometric past would occur. Four-dimensional brain provides a completely new view about how generalized sensory experiences are generated, how generalized motor actions are planned and how memories are constructed. This process is like creating an artwork. *Four*-dimensional spin glass landscape representing a rough scetch is gradually refined by adding details and corrections in increasingly shorter time scales: this corresponds to neural activities of four-dimensional brain generating motion leading to the desired part of spin glass energy landscape. This picture is consistent with the observed $1/f$ noise and fractality of nerve pulse patterns. Absolutely essential is self-organization and related dissipation forcing the Darwinian selection leading to end product which is charicature rather than photo.

3.9 Altered states of consciousness

The proposed concept of self provides allows rather rich a palette of altered states of consciousness and one cannot avoid the temptation to a concrete modelling of various altered states of consciousness.

3.9.1 Whole-body consciousness and ordinary consciousness

Krishnamurti has described in his books states of consciousness having natural identification as states of 'whole-body consciousness'. For instance, according to Krishnamurti, one can achieve this state only if one is able to stop thinking entirely. If thoughts correspond to cascades of selves

decomposing into sub-selves, then this is just what is required. The characteristic of this state of consciousness is the experience of one-ness and the absence of all separations: this is certainly true in the sense that there is only single irreducible self present. Also 'timelessness' characterizes these experiences: the explanation is that internal clock is provided by some sub-self waking up periodically and since there are no sub-selves there can be no time.

I have personally experienced states of whole-body consciousness and also states in which whole-body consciousness is limited to some part of body. These states begin with a sudden fall of silence: all the usual 'noise' from the body disappears suddenly although ordinary physical sounds are still heard. This could be interpreted as disappearance of sub-selves from body. There is experience like thrill in spine going through the entire body. Interesting experience of this kind occurred when my cat was sleeping over my breast: I woke up and realized that my breast was in the state of whole-body consciousness. Could this mean that sleeping cat was also in this state and that my breast had entangled with the quantum state of cat? Could this in turn mean that during sleep we indeed are in a state of whole-body consciousness or even that our entire body is entangled with some large self? Could the absence of neuronal quantum jumps explain why we do not remember anything about these states? Are remembered states of whole-body-consciousness always such that at least some part of brain is awake?

Possession of self means dissipation, aging and eventual physical death (note however that self lives as a conscious memory realized as a sub-self of higher level self providing kind of summary about the lifetime of self). The absence of neuronal and cell level dissipation during states of whole-body consciousness provides a possible test for the phenomenon. Test persons could be trained meditators and test should involve the measurement of neural or cellular dissipation occurred during the state of whole-body consciousness. Reduced rate of metabolism could be a measurable signature of whole-body consciousness. Dissipation should be absent or should be very small during this state at least if it is present for sufficiently large fraction of time. The absence of dissipation means that all changes suffered by the cells during whole-body consciousness are reversible and curable. This could explain various miraculous healings. Whole-body consciousness, if possible to arrange artificially, could provide medical means of saving the lives of victims of accidents (say of victim of heart attack or bleed in brain).

Second signature is the liberation of the binding energy when bound state entanglement leading to whole-body consciousness is generated. This energy could be used for metabolic purposes at some level of the self hierarchy. The anomalously low value of neuronal oxidative metabolism could be due to the binding energy liberated when synchronously firing neuron group forming many neuron bound state is generated .

Whole-body consciousness could explain some spectacular phenomena (not of course taken seriously by skeptics).

1. The claimed ability of yogis to survive for months without eating anything and even without oxygen could have explanation in terms of whole-body consciousness. Oxygen consumption compensates the loss of chemical energy caused by the quantum jumps in biochemical length scales. These quantum jumps occur only if neuronal and lower level chemical selves exist. Under usual circumstances the continuous supply of oxygen makes the ageing of cells slow and the lack of oxygen leads to rapid dissipation and neuronal death. The situation is analogous to Benard flow: if heat feed is stopped, the beautiful flow pattern rapidly dissipates away. If all cells are entangled during whole-body consciousness, no dissipation occurs and the lack of the oxygen supply does not have any irreversible effects and possible effects might be cured automatically. An alternative explanation for the the mystery of yogis who need not eat is that the generation of bound state entanglement involves the liberation of the binding energy as a usable energy possibly compensating for the ordinary metabolic energy.
2. In certain cultures people in trance are able to dance with their bare feet on burning charcoals

without any disastrous effects. The disastrous effects of the interaction of heat from burning charcoals with cells in soles of foot must be irreversible changes. If these persons are in a state of whole-body consciousness, then the changes of the individual cells are reversible.

3.9.2 That-which-is experiences

Irreducible self does not possess any sub-selves. This requires that the sub-systems of self have only bound state entanglement stable against the state preparation process. The absence of sub-selves in turn means the absence of mental images. This kind of situation could correspond to that-which-is experience. The reports of Buddhist meditators about pure awareness with discrete twinkles of consciousness identifiable as short-lived sub-selves are in accord with this view.

In principle meditation could make possible to silence higher sub-selves and make it possible to directly experience quantum jumps occurring at elementary particle level! In this speculative spirit one could even consider the possibility that the abstract theories of elementary particle physics result basically as a summation of the experiences of matter-mind sub-systems entangled with elementary particles! The state function collapses occurring in particle physics probably result from the entanglement of the states of elementary particles with macroscopic states of matter which in turn entangle with our mindlike space-time sheets.

Interestingly, irreducible selfness is a necessary prerequisite of quantum computation since it guarantees that state preparation process has no effect in the state so that in quantum fluctuating degrees of freedom one can approximate the sequence of quantum jumps as a single quantum jump. As a consequence, in these degrees of freedom time evolution can be approximated by a power of unitary operator U and system indeed behaves effectively as a quantum computer for times much longer than CP_2 time of order 10^{-39} seconds. Thus the total emptiness of mind would make possible quantum computation and immense information processing capacities by computation in parallel universes. Perhaps this is why the emptiness of mind is paradoxically associated with a source of infinite wisdom in eastern philosophies.

The formation of bound states essential for the state of irreducible selfness is accompanied by the formation of join along boundaries bonds between space-time sheets representing binding sub-systems. In this process only 'center of mass' zero modes of join along boundaries-condensing space-time sheets are expected to remain zero modes so that in very many particle bound state most of the zero modes become quantum fluctuating degrees of freedom. State function reduction does not occur in these degrees of freedom anymore, macroscopic quantum coherence is preserved from quantum jump to quantum jump, and the system behaves as macroscopic multiverse with new macroscopic degrees of freedom making possible macroscopic quantum computation. This might be the mechanism for how water, DNA, protein, tubulin,... molecules and even neurons bind to quantum computing macroscopic multiverses.

3.9.3 Zen type experiences and $S = 0$ cognitive entanglement

$S = 0$ entanglement between sub-systems is possible only in p-adic context and results when p-adic entanglement probabilities have p-adic norm equal to one. $S = 0$ cognitive system can be defined as a p-adic system for which all sub-systems have $S = 0$ entanglement. NMP does not say anything about state preparation of $S = 0$ p-adic systems. The simplest interpretation is that $S = 0$ entanglement represents the p-adic variant of bound state entanglement so that self measurements reducing the entanglement are not possible and there is conscious analysis yielding separations in these states. Kind of generalization for that-which-is states in which there are no real mental images to states in which there are only $S = 0$ cognitive mental images stable against state preparation suggests itself. Note that $S = 0$ sub-self could act as a p-adic quantum computer in spin degrees of freedom with quantum computation lasting as long as $S = 0$ state lasts. Thus cognitive $S = 0$ mental images provide huge cognitive resources.

The possible identification as states of oneness for cognitive consciousness reported by Zen Buddhists suggests itself. $S = 0$ property means absence of entropy and this could be interpreted as absence of illusions. For ordinary quantum jumps NMP forces a complete selection of final state even when the density matrix is degenerate: this has interpretation as a necessity to select between logically inconsistent alternatives. In quantum jumps to entangled state this kind of choice is not performed: final state is like the famous superposition of dead and living Schrödinger cat. Therefore $S = 0$ entanglement would provide loophole allowing to cognitively experience what it is to be entangled. In real context bound state entanglement between all sub-systems of self makes possible similar experience. Zen Buddhists experiences are often characterized as states of consciousness in which no selection is made between mutually exclusive alternatives. Hofstadter has described this aspect of Zen in hilarious manner in his book 'Gödel, Escher, Bach'.

The absence of desires is one characterization of that-which-is and Zen type experiences. Desires are particular kind of intentions and thus represented by p-adic sub-selves. If p-adic sub-self has sub-system pair for which entanglement is not bound state entanglement ($S > 0$), NMP implies that this sub-self decomposes into sub-selves in state preparation process so that the state of cognitive oneness is lost. Thus one could say that $S > 0$ cognitive mental images represent desires whereas $S = 0$ p-adic sub-selves represent intentions free of desire. Prediction (in the sense of plan or expectation) is represented as p-adic space-time sheet. The comparison of p-adic expectation with the real subjective memory of what happened would cause the frustration if p-adic expectation represents desire.

The absence of external-world-me separation is also reported to be one characteristic feature of that-which-is and Zen type experiences. This can be understood as absence of cognitive mental images representing both world and me. This is indeed the case if self possesses only single $S = 0$ cognitive sub-self. If there are several such sub-selves with same value of the p-adic prime, they can develop $S > 0$ mutual entanglement if they correspond to same p-adic prime. Thus it is possible to have single $S = 0$ sub-self corresponding to each p-adic prime.

3.9.4 Extended states of consciousness

Extended states of consciousness seem to be the exact opposite of that-which-experiences. Psi experiments concern subtle connections between subjects removed in space, and occasionally also in time. These experiments are reviewed in [66] and the following representation follows this review closely. The pioneering work related with card and dice-guessing was done by J. B. Rhine in 1930s.

Sharing and fusion of mental images provides an attractive explanation for extended states of consciousness. The sharing can occur only by the entanglement of sub-selves characterized by the same value of p-adic prime. One can also consider the possibility that the process is preceded by a phase transition in which the p-adic prime of experiencer increases: this would make it possible to share mental images of very advanced selves.

The notions of geometric memory and electromagnetic self allow also to understand basic features of these experiences. For instance, the notion of geometric memory allows to understand memories about previous lives and prenatal experiences in which the contents of consciousness is time shifted. The model for sensory representations leads to the conclusion that the topological field quanta of ELF fields, having frequencies in EEG range and by Uncertainty Principle having size of Earth, are crucial element of our sensory experience. The formation of join along boundaries contacts between topological field quanta associated with different selves could explain a large variety of paranormal experiences.

1. *The experiments of Russel Targ and Harold Puthoff*

The experiments of Russel Targ and Harold Puthoff [69] were carried in the 1970's some of the best known experiments on subtle connections among distant subjects in regard to the transference of thoughts and images. Both sender and receiver were closed in a sealed, opaque, electrically

shielded chamber so that no sensory communication was possible. Sender was subjected to light flashes at regular intervals. This caused a characteristic pattern in the EEG of the sender. In some cases also the receiver exhibited these rhythms.

In remote vision experiments sender served as a beacon. Receiver tried to describe verbally or by sketches what the beacon saw. Independent judges matched on the average 66 per cent of time with what was actually seen by the beacon. There are also remote viewing experiments from other laboratories. The distances between sender and receiver vary from miles to thousands of miles and it seems that distance does not matter.

Distance independence supports the interpretation of both experiments in terms of fusion and sharing of mental images.

2. The experiments of Stanley Krippner

In the experiments of Stanley Krippner [70] image transmission was studied while receiver was asleep. Experimenter, sender and volunteer met each other in the beginning of the experiment. Sender spent the night concentrating on an art print, which he/she had received in the beginning of the experiment in a closed envelope. The brain waves and eye movements of the volunteer were recorded. The experimenter woke the volunteer at the end of the REM period by intercom and the volunteer described the dream.

A correlation between the contents of the dream and of the art print was observed. The score was higher on nights, when there were few or no electric storms in the area and sunspot activity was lowest.

The simplest interpretation is again in terms of fusion of mental images of the subject persons. These mental images are perhaps represented at the personal magnetic sensory canvas. Electric storms and sunspot activity affect directly Earth's magnetic field and should affect the communication mechanism since the experiments of Blackman and other suggest that em selves could correspond to magnetic transition frequencies associated with magnetic field of .2 Gauss which is near to the nominal value .5 Gauss of the Earth's magnetic field. In fact, there exists independent evidence for a general correlation of geomagnetic activity with psi experiences [71].

3. The experiments of J. Grinberg-Zylverbaum

In the experiments of J. Grinberg-Zylverbaum [67] the transfer of EEG potentials was studied. Two subject persons were involved. They were closed in Faraday cages. The sender was meditating. Another subject person was subject to a stimulus in random intervals; not even the experimenter knew, when they were applied. Non-stimulated subject person was in a relaxed state. Stimulus was sudden, short light or sound or short electric shock to index and ring fingers of the right hand causing a characteristic pattern in the EEG of the stimulated person.

The EEG's of the subject persons were synchronized. The possible presence of transferred potentials in the EEG of nonstimulated subject was studied. Transferred potentials were detected in 25 percent of all cases *provided* persons had met before the experiment. A dramatic example was young couple, deeply in love, whose EEGs remained synchronized throughout the experiment.

The fusion of ELF selves means synchronization of ELF em fields and since ELF selves correspond directly to EEG frequencies, synchronization of EEGs is an immediate consequence and can transfer the synchronous firing in brain circuit of the sender to corresponding brain circuit of the receiver. The personal contact before the experiment certainly enhances the probability for the fusion of ELF selves. Also quantum entanglement between sub-selves of subject persons might be involved.

It is known that the EEGs of right and left brain are synchronized in deep meditation. There are also experiments of synchronization of EEGs for different subjects in group meditation [65]. The explanation is same as in above case. Also quantum entanglement might be involved. For instance, quantum entanglement is crucial for the fusion of left and right perceptive fields to single

perceptive field.

4. *Telesomatic effects*

Also the transfer of actual bodily effects from subject person to another has been studied: references to these experiments can be found in [66]. Physiological changes are found to be triggered in the targeted person by the mental process of another. Distance makes little or no difference. Thus the interpretation in terms of quantum entanglement suggests itself.

There are also countless reports of the transference of pain between persons having very close mutual relationship. Identical twins, mothers and their sons or daughters, couples in love, etc.,. Also the relationship between psychiatrist and patient provides example of this kind and is known as projective identification. The general rule seems to be that the relationship between individuals is always involved with psi effects. This is in accordance with the hypothesis about sharing of mental images having ELF em fields and field bodies as physical correlates. For instance, the field bodies of persons in an intimate relationship might develop gradually direct contacts (say magnetic flux tubes connecting physical bodies).

5. *Grof's experience with altered states of consciousness*

Findings of modern psychotherapists, especially the work of Stanislav Grof [68, 66] suggest that besides the ordinary 'biographic-recollective' domain of psyche also perinatal and transpersonal domains of psyche exist. Transpersonal domain can mediate connection between our mind and practically any part or aspect of the phenomenal world. Grof studied for several decades altered states of consciousness induced by psychedelic drugs or holotropic breathing.

In the experience of '*dual unity*', loosening and melting of the boundaries of the body ego happens but in the merging with another person, own identity is not lost. In the *identification* with another person loss of own identity occurs. Body image, physical sensations, emotional reactions and attitudes, thought processes, memories, facial expressions, typical gestures and mannerisms, postures, movement and even the inflection of the voice become those of the second person. The other can be someone in the presence or absent. Identification involving time shift is also possible. Part of an experience can come from subject's childhood, his or her ancestry or even of a previous lifetime.

Also group identification and group consciousness is possible. Person can identify with an entire group of people having some racial, cultural, national, ideological, religious, political or professional characteristics. People may experience the totality of suffering of all the soldiers or tenderness of all lovers and dedication of all mothers in regard to their babies.

Identification with animals is possible. This involves body image, specific physiological sensations, instinctual drives, unique perceptions of the environment, emotional reactions, etc.. Person can identify with plants and botanical processes. Also identification with inorganic world can occur. People can identify with rivers, storms, tornadoes, mountains,... Or stones, quartz crystals, minerals.... Even the identification with structures of atomic and sub-atomic world is claimed to be possible. At the second end of spectrum are racial and collective experiences and identification with entire human species and the experiences in which one identifies with the whole Earth or even entire cosmos. Also out of body experiences, clairvoyance, clairaudience and telepathy are common. Displacement in time is possible. Patient can have embryonic and fetal experiences and even ancestral experiences as well as past incarnation experiences.

Identification experiences can be generally understood as sharing and fusion of mental images. The fusion of mental images can occur between very many individuals, say members of a species and would give rise to kind of stereo consciousness analogous to the stereo vision resulting in the fusion of left and right visual fields. We could also share this stereoconsciousness: for instance, shamanist could share the mental images of animal species.

Perinatal experiences and memories extending beyond the lifetime of individual could be ex-

plained in terms of geometric memory and the notion of 4-dimensional body: actually these experiences do not in any significant manner differ from ordinary memories. The content of the conscious experience is multilocal both in subjective and geometric time in the sense that the experience contains contributions from several moments of geometric time simultaneously.

Our personal self hierarchy could actually contain higher levels than the levels represented by ELF emf fields associated with EEG. This hypothesis makes sense if the contribution of the higher levels of our self hierarchy to our conscious experience under normal circumstances is only some kind of general awareness ('silent observer'). These higher levels could actually explain the experienced continuity of self. For instance, during sleep there would be some kind of basic awareness present: the lack of memories about sleep state would lead to, in this framework, erroneous conclusion that sleep state is unconscious.

The assumption that we are doomed to have selves characterized by the same p-adic prime forever, looks rather disconsolate. Also the notion of p-adic evolution suggests that it can change or that the self hierarchy contains always arbitrarily large primes but that they do not contribute to our conscious experience much more than some kind of general awareness.

4 Quantum correlates of qualia

The basic theoretical ingredients described above lead to the following general vision about qualia described in detail in [K3]. In the following the latest view about theory is summarized. The notion of quale is understood in an extremely general sense: 'primary attribute of conscious experience' might serve as a synonym for 'quale' in the sense as it is used in the following.

4.1 Development of ideas

To achieve something which would deserve to be called a general theory of qualia required almost a decade. During the first years, and in lack of any general theory of qualia, I could only make educated guesses, which were doomed to be wrong.

1. A connection between qualia and EEG MEs emerged, when I learned about the effects of classical electromagnetic fields on brain at frequencies which are cyclotron frequencies or amplitude modulated by cyclotron frequencies [57, 59].
2. The discovery that p-adic physics is physics of cognition (or at least imagination, one should be very cautious in order to avoid over generalizations!) clarified the views about the relationship between cognition and sensory experience [H9].
3. The notion of the many-sheeted ionic flow equilibrium was a further important breakthrough [J1, J2, J3]. It allowed to realize that MEs, superconducting magnetic flux tubes, and ordinary biomatter at atomic space-time sheets form a three-levelled master-slave hierarchy.
4. The realization that MEs carrying supercanonical representations at their lightlike boundaries are excellent candidates for the carriers of at least some of our qualia, gave a totally new perspective to the problem of qualia [J4]. It seems however that MEs are not all that is needed: our qualia involve both supercanonical and magnetic quantum phase transitions.
5. The work with the problems related to the precise formulation of Negentropy Maximization Principle led to the realization that each quantum jump defines a quantum measurement followed by a state preparation leading to an unentangled product state. This means the reduction of the quantum measurement theory to basic quantum TGD. The next realization was that the quantum jump sequence defining self defines a statistical ensemble of prepared states. One can identify the fundamental statistical ensembles of statistical physics as selves

and implied a deep and precise connection between thermodynamics and the theory of qualia allowing a general classification of qualia and an identification of their thermodynamical correlates.

6. The last breakthrough in development, which is still continuing, was the realization that very general arguments lead to the view that ultimate (conscious-to-us) sensory representations are realized outside the body on the magnetic canvas provided by the magnetic flux tube structures associated with brain and having most plausibly size for which Earth size as a natural unit. One can see cortex as a collection of standard features some of which are associated to the objects of the perceptive field represented as magnetic sub-selves. Frequency place coding (MEs generate magnetic quantum phase transitions) plays a key role in this association.

4.1.1 Music metaphor at axonal level

Music metaphor has been one philosophical guideline behind the identification of the quantum correlates of the sensory qualia.

1. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes and this generates EEG MEs at EEG frequencies serving as entanglers to the sensory magnetic canvas and the variation of these frequencies could code for the distance to the object of the perceptive field.

A stronger interpretation of the metaphor is that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a sensory modality associated with the sensory pathway. Nerve pulse patterns determine the experience as chords from from the notes of various instruments in the same sense as the musician produces the music. This leads to a generalization of the idea about brain as an associative net.

More concretely, postsynaptic receptors act as neuronal sensory receptors and transmitters emitted and MEs generated by the presynaptic neuron induce neuronal sensory experiences in the postsynaptic neuron. The specialization of the neuronal receptors would be same for the entire sensory pathway and determine the qualia associated with it.

2. Resonance is an essential aspect of music instrument as is resonant frequency modulation which can involve several levels. The frequencies characterizing the hierarchical modulation provides a partial characterization of the sensory representations. Quantum mechanically resonance corresponds to a harmonic perturbation with frequency which is difference of energies for the states of some sub-system. In this kind of situation quantum jumps can be amplified to quantum phase transitions and sub-self representing mental image wakes up.

Unfortunately, music metaphor is only a metaphor and has led to a plethora of various models for qualia.

4.1.2 ME's and qualia

The identification of MEs as building blocks of sensory and cognitive structures leads to a rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other, magnetic flux tube structures, and the matter at atomic space-time sheets. The realization that MEs serve as quantum holograms and the properties of the supercanonical stats gave the final justification for this identification. The model allows to understand EEG as a direct physical correlate of mindlike space-times sheets

(MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also what might be called RF (radiofrequency) and MW (microwave) MEs representing our mental images are crucial for the model.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our radiation body. Also the notion of magnetic body is needed. It took a long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; or with self having literally infinite size. The last two options seems to be more plausible than the first two: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body. The simplest option is that the relevant magnetic flux tube structures have same sizes as ELF MEs. During sleep our attention might be directed to transpersonal levels of consciousness.

4.1.3 MEs, magnetic superconductors, and many-sheeted ionic flow equilibrium

The lack of clearcut empirical evidence for the predicted supra phases has been a stumbling block for the quantitative development of the theory for a long time. The situation changed dramatically when I learned about the effects of ELF em fields on living matter⁷. This article provided the ingredients making possible a general quantitative model of quantum control and coordination in which self hierarchy has as its dynamical correlate hierarchy of weakly coupled super conductors and massless extremals (MEs) interacting with the ordinary matter at atomic space-time sheets. MEs indeed provide a model of Josephson junction and an explanation for the amplitude windows observed in the experiments of Blackman and others [59, 56].

Later the experimental findings challenging the notions of ionic channels and pumps [37] led to the identification of homeostasis as many-sheeted ionic flow equilibrium in which the ionic concentrations at atomic space-time sheets are controlled by much smaller ionic concentrations at superconducting magnetic flux tubes. MEs control superconducting magnetic flux tubes via magnetic induction, by inducing magnetic phase transitions and by acting as Josephson junctions between magnetic flux tubes.

Magnetic transitions at superconducting magnetic flux tubes serve as seeds for phase transitions in quantum critical quantum spin glass type phase of macroscopic super conductor leading to generation of a region of new kind of phase whose quantum numbers differ from old one by the quantum numbers associated with magnetic transition frequency. Thus quantum transitions are amplified to macroscopic quantum transitions and Bose-Einstein condensation (analogous to induced emission) is the basic mechanism behind the process.

The first natural guess was that magnetic quantum phase transitions correspond to our qualia. That transition frequencies are involved is indeed in nice accordance with quantum jumps between histories as moment of consciousness identification. However, the fact that magnetic states correspond to a lower level of abstraction than supercanonical states associated with MEs, suggests that magnetic qualia do not correspond to our qualia directly. Rather primitive chemical qualia experienced by cell level selves might be in question.

4.1.4 The role of supercanonical algebra

An important step in the development of the theory of qualia was the realization of the importance of supercanonical symmetries. The answer to this question might have been guessed by taking quantum measurement theory as a starting point.

⁷I am grateful for Gene Johnson for sending me the popular article of Yarrow [57] about bio-electromagnetism.

1. Basic geometric objects is the configuration space of all possible three-surfaces in $M_+^4 \times CP_2$. In absence of non-determinism of Kähler action everything would reduce to the boundary of the future lightcone ($\delta M_+^4 \times CP_2$) carrying representations of supercanonical and superconformal algebra localized with respect to the lighthlike radial coordinate of the lightcone boundary. These symmetries are obviously cosmological. Also quaternion conformal symmetries are possible and these can be identified as the TGD counterparts of string model conformal symmetries responsible for elementary particle quantum numbers.
2. The non-determinism of Kähler action forces to introduce supercanonical representations at the lightlike boundaries X^3 of MEs acting as quantum holograms. Thus superconformal and supercanonical symmetries become macroscopic symmetries and must be crucial for consciousness.
3. There are two kinds of configuration space degrees of freedom: quantum fluctuating non-zero modes and zero modes which can be regarded as classical, non-quantum fluctuating degrees of freedom in complete consistency with the reduction of standard quantum measurement theory to the localization in zero modes occurring in each quantum jump. Zero mode algebra contains the generators of supercanonical algebra with even conformal weight. In particular, zero modes contain the points of an infinite-dimensional flag-manifold extended to contain the radial Virasoro algebra of the lightlike boundary of ME localized with respect to CP_2 . Radial coordinate corresponds to the lightlike coordinate of the the lightlike boundary of ME. This flag-manifold parametrizes all possible choices of the quantization axes for the canonical Lie-algebra.

4.2 Qualia and thermodynamics

The connection between thermodynamics and qualia was the real breakthrough in the development of ideas. In some sense this finding is not a news: the close connection between pressure sense and temperature sense and thermodynamics is basic facts of psychophysics. In TGD framework the contents of consciousness is determined as some kind of average over the sequence of very large number of quantum jump and this suggests strongly that non-geometric qualia allow statistical description generalizing ordinary thermodynamical ensemble to the ensemble formed by the prepared states in the sequence of quantum jumps after the last 'wake-up' of self. This picture allows to see the ageing of self with respect to subjective time as an approach to thermal equilibrium.

1. There are geometric qualia corresponding to zero modes expressing the result of quantum measurement in each quantum jump. All geometric information about space-time surface should reduce to geometric qualia. For instance, geometric data given by visual, auditory, and tactile senses should reduce to conscious information about zero modes or about increments of zero modes in quantum jump.
2. The sequence of the prepared states can be modelled as a statistical ensemble of Fock states, which suggests that thermodynamics is basically part of theory of consciousness. The ensemble of prepared states gives rise to a large number of statistical qualia. The relationship $dE = TdS - PdV + \mu dN + B \cdot dM...$ generalizes to TGD context: note however that in case of ME selves energy is replaced with the Super Virasoro generator L_0 associated with the lightcone boundary of ME. Each intensive-extensive variable pair in the differential should correspond to a non-geometric quale, which results only when there is gradient (flow) of the extensive variable in the direction of the subjective time. Supercanonical thermodynamics should obviously map ordinary thermodynamics to the level of conscious experience.
3. Since subjective experience corresponds to quantum jumps, it is natural to assume that only the increments of zero modes and quantum numbers are experienced consciously. Statistical

interpretation also suggests that an averaging over increments occurs. The possibility of sub-selves makes possible to have mental images of finite time duration and this makes possible structured subjective memories (for instance, it becomes possible to remember the digits of phone number). A further working hypothesis is universality: qualia associated with quantum phase transitions depend only on the quantum number increments. In particular, the increments of Poincare and color and electroweak quantum numbers define what might be called universal kinesthetic qualia.

The thermodynamical expression for dE suggests a general classification of qualia consistent with the 'holy trinity' of existences implied by TGD.

1. *Emotions as order-disorder qualia*

$T - S$ pair correspond subjective existence and generalizes to disorder-order type, information theoretic qualia about the state of self: hot-cold and pain-pleasure type sensations and also more abstract experiences associated with various sub-selves of self. These qualia are strongly emotional single-pixel holistic qualia measuring whether some kind of an entropy variable is increasing or decreasing. The total entropy for the statistical ensemble defined by self determines how sharp the the mental image is. Low entropy content means alertness and attentiveness. High entropy content means fuzzy mental image. Getting tired means inability to keep mental images in low entropy state.

2. *Kinesthetic qualia defined by generalized forces*

$p-V$ pair corresponds to the geometric existence and is replaced with generalized force-generalized coordinate pairs in quantum fluctuating degrees of freedom. The increments of maximum number of mutually commuting Poincare, color and electroweak quantum numbers define this kind of qualia. The increments of four-momentum code for the sensation of force whereas the increments of orbital angular momentum code for the sensation of torque. Spin flip could code for something else. Tactile senses such as pressure sense and their generalizations involve kinesthetic qualia. The increment of energy or equivalently, increment of frequency, can be identified as correlate for hearing in generalized sense responsible for the dynamical nature of auditory experience (hearing is timelike version of force sense). It is not clear whether spin flip has interpretation as torque or possibly as figure background separation. In TGD based model of auditory experience hearing relates to Z^0 magnetic spin flip phase transitions for cognitive neutrino pairs.

The rate for the increase of the two diagonal color quantum numbers should code intensity type variables associated with color sensation. The rate for the increase of electric charge of sub-self should code for electric sense possessed by, say, fishes. Also $B - M$, $\phi\rho$ and $E - P$ pairs correspond to generalized forces since electromagnetic fields are reduced to space-time geometry in TGD framework.

3. *Generalized chemical qualia* νm

$\mu - N$ pair corresponds to 'objective existence' defined by quantum histories and N is generalized to a number of particle like excitations in the Fock state resulting in the state preparation. In this case there must be a flow of particle number in the direction of the subjective time, that is Bose-Einstein condensation type process for, say Cooper pairs. Quite generally, supercanonical and quaternion conformal super algebras should define these qualia and the number of these qualia is very large.

i) One can assign particle numbers to phases with various magnetic quantum numbers and these could define generalized chemical qualia which could perhaps be regarded as qualia and subqualia of chemical qualia defined by a particular ion and chemical qualia could actually reduce to magnetic qualia. Since the changes of magnetic field induce these quantum phase transition, it would seem that magnetic and Z^0 magnetic quantum phase transitions at superconducting

magnetic flux tubes could correspond to this kind of qualia. In principle, endogenous NMR and its generalizations induced by the interaction of magnetic and Z^0 magnetic fields of MEs with magnetic and Z^0 magnetic flux tube structures are possible. Chemical qualia would very naturally correspond to the Bose-Einstein condensation of ions to the superconducting magnetic flux tubes: these ions could be even the ions of tastant or odorant. Also secondary representations at the level of cortex in terms of superconducting light ions are possible and would give rise to classification of tastes and odours. Magnetic qualia are characterized by definite transition frequencies and this makes possible place-/time coding by magnetic transition frequencies if magnetic or Z^0 magnetic field varies along magnetic flux tube/is a function of time. The activation of a point of living map would generate some quale at that point.

ii) For super canonical qualia the number of Bose-Einstein condensed 'configuration space photons' having nontrivial dependence on configuration space degrees of freedom replaces number of molecules. The condensation rates for the numbers of the configuration space photons with nonvanishing color quantum numbers could be interpreted as correlates of color qualia whereas the condensation rates for color singlet configuration space photons could relate to the intensity of color sensation. If the rates for the transfer of color quantum numbers define intensity type variables associated with color experience then BE condensation to color singlet states does not give rise to experienced quale so that only non-diagonal color generators correspond to visual colors. Also the BE condensation of the ordinary coherent light should give rise to some kind of quale: perhaps vibratory sense which can be developed to effective vision, could correspond to non-colored vision. Configuration space Hamiltonians are also labelled by 2-dimensional orbital spin quantum number and longitudinal momentum. Polarization sense and sensation about motion of the object of visual field would naturally relate to spin and longitudinal momentum.

iii) Tactile senses involve topological phase transitions involving the creation of join along boundaries contacts between object and skin whose number would thus be the relevant variable. The purely sensory aspect of physical pain could correspond to a topological phase transition involving the splitting of join-along boundaries bonds between space-time sheets (MEs could even define these bonds) so that N would be now the number of join along boundaries bonds. The simplest picture requires that the MEs associated with sensory organs are connected to the MEs responsible for our experience. Of course, splitting and generation of join along boundaries contacts could occur also at the level of sensory representations.

4. Boolean qualia

The transitions associated with the fermionic generators of supercanonical algebra can be identified as Boolean consciousness with intrinsic meaning ('This is true'). Boolean cognition without intrinsic meaning and/or conscious feeling of quantity can be understood as associated with sequences of cognitive neutrino pairs. A general model for abstraction process not only explains the basic numbers of the genetic code but also suggests an entire hierarchy of codes [L1] in accordance with fractality of TGD Universe.

The next code in the hierarchy is very attractive candidate for a 'memetic code'. The hypothesis predicts correctly the .1 second time scale for the duration of 'our' self (immediate short term memory, duration of psychological moment). Code-words correspond to the sequences of 126 bits with a duration of 1/1260 seconds: this is slightly below the time scale of nerve pulse so that membrane oscillations are perhaps a more natural realization for the code. Temporal sequences of Z^0 magnetized cognitive antineutrino systems with a varying direction of magnetization and having a duration of order millisecond would realize the memetic code. The frequency of about 10 Hz is in EEG frequency range and also corresponds to ELF topological field quanta with size of Earth representing our cognitive sub-self. Remarkably, the Z^0 cyclotron frequencies of all particles with non-vanishing neutron number are around 10 Hz.

4.3 Geometric qualia and zero modes

The zero modes of the configuration space are special in the sense that in each quantum jump localization occurs in this space. Zero modes characterize the size and shape of 3-surface and are excellent candidate to represent information about the state of organism (3-surface itself) geometrically. Zero modes can be parametrized as an infinite-dimensional flag-manifold associated with the algebra of the infinitesimal canonical transformations of $E^2 \times CP_2$, where S^2 is sphere at the lightcone boundary extended by Virasoro algebra acting in radial direction of lightcone boundary. Physically this space corresponds to all possible choices of the quantization axes for generators of Super Canonical Algebra and, in accordance with the basic assumptions of quantum measurement theory, each quantum jump involves this kind of choice. Infinite-dimensional flag manifold contains as sub-flag-manifold $S^2 \times F_3$ parameterizing choices of quantization axes of spin and color ($F_3 = SU(3)/U(1) \times U(1)$). Lorentz invariance suggests the extension of S^2 to 2+2 dimensional flag-manifold $F = SO(3,1)/SO(2) \times R$ parameterizing various choices of the quantization axes for Lorentz quantum numbers [K3].

There are continuous, geometric and kinesthetic (both geometric in four-dimensional sense) qualia like position and velocity; orientation and angular velocity, and also geometric time and experienced rate of time flow. All these pairs correspond to mutually in-compatible observables quantum mechanically. The hypothesis motivated by the work of Barbara Shipman [Shipman_{1,2,3}] is that some coordinates of F_3 parametrize positions. The generalization of this hypothesis is that the infinite-dimensional flag-manifold associated with the zero mode part supercanonical algebra somehow gives rise to a conscious representation of continuous, classical qualia basically assignable to the choice of quantization axes. The hypothesis indeed makes sense: the entire isometry group of the configuration space, in particular the sub-group defined by zero modes, leaves induced Kähler form invariant but affects magnetic and Z^0 magnetic fields and hence magnetic transition frequencies. Also color rotations act in F_3 nontrivially and, although they leave Kähler form invariant, they affect magnetic and Z^0 magnetic fields and thus the corresponding magnetic transition frequencies. This means that a curve of the infinite-dimensional flag-manifold can be mapped to a varying cyclotron frequency.

5 Solutions to some paradoxes

The TGD inspired theory of consciousness provides a solution to the many paradoxes related to the basic quantum physics and the philosophy of conscious mind. The solution of these paradoxes is basically due to the replacement of the dualistic and monistic world views by the tripartistic world view of TGD.

5.1 Paradoxes related to quantum physics

The basic paradox is the conflict between the non-determinism of the state function reduction and the determinism of the Schrödinger equation. At a more general level this paradox is the conflict between the subjectively experienced actuality of the free will and the determinism of the objective world. The resolution of this paradox is simple in TGD context. One must give up the idea of single objective reality and replace it with a deterministic quantum history, which changes in each quantum jump, which is a genuine act of free will occurring outside the realm of the geometric space-time. Thus the objective reality, in the sense of a physical theory, is indeed deterministic, apart from the non-determinism related to the special properties of the Kähler action. In fact, a determinism of the Kähler action is achieved by replacing the ordinary concept of the 3-space with the concept of an association sequence and this naturally leads to a model for thinking systems. Volition seems to correspond to the selection between various degenerate absolute minima of the

Kähler action and has thus a direct classical counterpart.

In the context of the deterministic physics, theoretician encounters two rather unpleasant paradoxes. The determinism implies that the unique objective reality corresponds to a single solution of the field equations. The first question is “What determines the initial conditions, say at the moment of the big bang?” and the attempt to answer this question leads necessarily outside the physical theory: one possibility is to postulate anthropic principle. In TGD objective reality changes at each quantum jump and the localization in zero modes and NMP imply a genuine evolution: therefore the recent objective reality is an outcome of conscious selections. The second problem encountered by a theoretician is that in principle it is not possible to test a deterministic theory since only single solution of the field equations is realized and a genuine testing would require the comparison of the time developments for various initial data. In practice this problem can be circumvented by assuming the existence of identical sub-systems having very weak interactions with the external world but in principle the problem remains unsolved.

The famous Einstein-Bohr debate was related with the question whether God plays dice or not. Amusingly, in TGD context both were correct in their own ways! Quantum histories are indeed deterministic but God can replace the old quantum history with a new one: perhaps one should not however call this act dice playing but simply an act of free will. Einstein was also an advocate of local realism: this led to Einstein-Podolski-Rosen paradox created by the possibility of quantum entanglement between distant system. In TGD framework local realism holds true at the level of the infinite-dimensional configuration space but not at the level of space-time since point like particles are replaced with 3-surfaces.

The Schrödinger cat paradox has also an elegant solution in TGD context. The point is that conscious experience is associated with a quantum jump leading to a final state in which cat is either dead or alive. There is no conscious experience about the situation in which the cat is both dead and alive giving answer to the question “Dead or alive?”. More generally, this feature of consciousness also could explain why the world of our conscious experience looks classical: it simply cannot look but classical since the very moment of consciousness makes it classical. In fact, the world *is* predicted to be genuinely classical to the extent that mutual quantum entanglement between different p-adic sub-Universes seems impossible for purely mathematical reasons. The localization into zero modes occurring in quantum jumps strengthens this conclusion considerably since it implies that the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces: the world of conscious experience is genuinely classical.

The phenomenon of dissipation is paradoxal from the point of view of standard physics. It is generally accepted that the fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of the fundamental physics and the irreversible and mathematically rather ugly “real” world, seem to exist simultaneously. The quantum jumps between quantum histories concept solves the paradox and one can understand the dissipative world as an effective description forming an ‘almost’-envelope for the sequence of reversible worlds (time developments).

5.2 Paradoxes related to the theories of consciousness

Chalmers describes in his book ‘Conscious Mind’ [43] several paradoxes related to the materialistic and dualistic theories of mind. A common denominator for these problems is the assumption that consciousness is a property of a physical state: hence these paradoxes disappear in TGD context. These paradoxes are encountered also in the quantum theories of consciousness identifying consciousness as a property of a macroscopic quantum state, say Bose Einstein condensate.

In the materialistic theories of mind, postulating a unique objective reality, consciousness is an epiphenomenon and free will is necessarily a peculiar illusion and one can always ask why the

consciousness is needed at all: nothing changes in the physical reality if consciousness is dropped away. It is also very difficult to understand how the contents of consciousness are determined by the state of the material world.

In the dualistic theories postulating a unique objective reality (say the theory of Chalmers [43]), the problems are related to the coupling between matter and mind. The basic problem of the dualistic theories is what Chalmers calls hard problem: how the physical processes in the brain give rise to conscious experience? If the laws of the physics determine the behaviour of the system completely then one ends up immediately either with a complete separation of the mind and matter so that our conscious experience tells nothing about the material world or with materialism and epiphenomenalism. One can also consider a non-trivial coupling between matter and “mind like” fields but assuming a deterministic physics one ends up with a situation in which the mind fields are effectively just additional physical fields and consciousness is again redundant.

An exotic example of this kind of a paradox is the following one described in [43]. In the dualistic theories in which the physical laws determine the objective reality, all psychological (third person) aspects of the mind are in principle purely physical. The book written by Chalmers about consciousness is obviously an example of a completely physical phenomenon. Therefore the contents of the book need not have anything to do with Chalmers’s ideas about consciousness! More generally, the reports about the states of consciousness need not have anything to do with the states of consciousness in the dualistic theories of this kind. The only manner to save the day (and the uniqueness of the objective reality) is to accept materialism and epiphenomenalism.

In TGD framework, which could be called tripartistic, hard problem and other problems of the dualistic theories disappear since there is no need to assign consciousness to quantum history. Moment of consciousness as quantum jump between quantum histories hypothesis allows even to define measures for the information contents of the conscious experience despite the fact that one cannot write explicit formulas for the contents of conscious experience.

5.3 Logical paradoxes and concept of time

Many logical paradoxes could be resolved if one assumes that there are two times: geometric and subjective and that the space-time surface providing linguistic representations changes quantum jump by quantum jump. In particular, during the conscious argument leading to the logical paradox!

The objections of Uri Fidelman [28] against the Platonic vision about reality involve the paradoxes of the cyclic cosmology (one might think that Turing machine in cyclic cosmology might be able to ‘know’ whether it has halted immediately after starting and thus be much more powerful than ordinary Turing machine). Basic paradox is that in cyclic cosmology allowing time travel one can imagine a son who murders his mother.

It is interesting to consider this paradox as resulting from identification of the identification of subjective time with geometric time, which I see only as an approximation. In TGD the counterpart of time travel would be sequence of quantum jumps changing the entire classical history quantum jump by quantum jump and inducing the shift of the space-time region, where the contents of consciousness of time traveller are concentrated, to the geometric past. No paradoxes result since space-time is not a fixed arena of dynamics but changes in each quantum jump.

As a second example one can take the second objection of Uri Fidelman [28] against Penrose’s program known as Berry’s paradox. *Non-formalizable theory cannot provide a model of the physical world which includes the brain’s cognitive function, since such a model must be lingual, written or spoken. However, such a model implies the following paradox of Berry: Let n be the smallest number which cannot be defined by an English sentence having less than, say, a hundred letters. This number exists, since the number of all possible combinations of a hundred letters is finite. Nevertheless, it has just now been defined by a sentence comprising less than a hundred letters.*

Berry's paradox could be understood when the piece of text is seen as inducing a sequence of quantum jumps in which the space-time region at which the argument is represented symbolically changes. For the initial space-time region representing my cognitive state there is indeed smallest number n which cannot be defined by using less than one hundred words (using the English in that space-time!). After reading the statement quantum history is replaced by a new, more complex one in which this number can be defined by using less than one hundred words since a new reflective level of cognitive consciousness has emerged and is represented at space-time level.

This example encourages to think the possibility of replacing the idea of a fixed axiomatic system with a living and dynamically evolving system becoming conscious of new axioms from which new theorems can grow. Mathematician would not be anymore an outsider but an active participator affecting the mathematical system he is studying. For instance, when paradoxical statement represented symbolically becomes conscious in quantum jump sequence, also the context in which it was originally stated changes. This dynamical view about mathematical system could allow to solve antinomies.

6 Hyper-finite factors of type II_1 , dark matter hierarchy, and consciousness

This section is devoted to the progress that has occurred during the period 2004-2006, about one decade after the first draft of this chapter was written. The realization that the von Neumann algebra known as a hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition. One of the most important outcomes is a prediction of a hierarchy of quantum phases with arbitrarily large values of quantized Planck constant identified as dark matter and assumed to be the quintessence of living matter.

6.1 Hyper-finite factors of type II_1 and quantization of Planck constant

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of the configuration space of 3-surfaces ("world of classical worlds"). As a matter of fact, it seems that the infinite-dimensional character of this algebra implies the rest of TGD. 4-D space-time, imbedding space $M^4 \times CP_2$, and the entire quantum TGD could emerge from the extension of the hyper-finite factor of type II_1 to a local algebra. This extension is local with respect to an octonionic coordinate whose non-associativity guarantees that the algebra does not reduce back to a mere hyper-finite factor of type II_1 . The dynamics of quantum TGD would follow from the associativity condition: in particular, space-time surface would be maximal associative or co-associative sub-manifolds of imbedding space.

The quantization of Planck constants assignable to M^4 and CP_2 degrees of freedom as integer multiples of the ordinary Planck constant is strongly suggestive in this framework and the phases with large Planck constant are interpreted as a dark matter quantum controlling ordinary matter in living matter. The average geometric durations of quantum jumps are naturally quantized as multiples of the integer characterizing M^4 Planck constant. This allows the reduction of the notion of self to that of quantum jump at higher level of hierarchy. A strong quantitative prediction for the preferred geometric durations of quantum jumps emerges.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled sub-systems. This makes possible sharing and fusion of mental images central for TGD inspired theory

of consciousness. These concepts find a justification from the quantum measurement theory for hyper-finite factors of type II_1 .

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II_1 and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II_1 and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

6.2 Dark matter hierarchy

The identification of dark matter as phases having large value of Planck constant [D6, J6, A8] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [A8]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

6.2.1 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.

6.2.2 Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1 . The characteristic property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [A9].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [A8]. In particular, the notions space-time as a hyper-quaternionic four-surface of imbedding space emerges.

2. One can understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to M^4 and CP_2 and appearing as scaling constants of their metrics as integer multiples of standard value \hbar_0 of Planck constant: $\hbar(M^4) = n_a \hbar_0$ and $\hbar(CP_2) = n_b \hbar_0$. This in terms of a mild generalization of standard Jones inclusions [A8]. The emergence of imbedding space means that the scaling factor of these metrics given by the scaling factor of Planck constant have spectrum: their is no landscape as in M-theory. Also the fusion of real and various p-adic variants of imbedding space along common rational (algebraic) points is involved.
3. In ordinary phase Planck constants of M^4 and CP_2 are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2, C)$ and $SU(2)_L \times U(1)$ which also acts as a subgroup of $SU(3)$. Space-time sheets are $n(G_b)$ -fold coverings of M^4 and $n(G_a)$ -fold coverings of CP_2 generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of M^4 and CP_2 Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings.
4. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = \exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by 3, 5, 17, 127, $2^{16} + 1$. In particular, experimentally favored values of \hbar in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2, C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. The most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2, C) \times SU(2)$.
5. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_{2n}, E_6, E_8 are possible so that TGD seems to be able to mimic these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

6.3 Dark matter hierarchy and the notion of self

The introduction of dark matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed. The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the most important hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. 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.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. 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. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump unnecessary. It is perhaps unnecessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

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. 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.

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n, p)$ for a given value $\hbar = m\hbar_0$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m, n, p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by 3, 5, 17, 127, $2^{16} + 1$. $m = 2^{11}$ seems to be favored in living matter [M3]. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

7 The most recent view about cognition and intentionality at level of basic physics

In this section, which is probably somewhat too technical for the reader without strong background in quantum TGD, I try to describe the most recent view (the date while I am writing this is 30 July 2006) about quantum TGD, and how it leads to a rather detailed view about cognition and intentionality as basic elements of physics even at elementary particle level.

Forgetting technicalities the first message is that in TGD Universe all quantum states have vanishing net conserved quantum numbers and decompose into positive and negative energy parts with positive energy part identified as ordinary matter in the usual ontology. This makes possible to identify p-adic-to-real transition as a transformation of intention to action.

The so called infinite primes [O2] were one of the first mathematical fruits of TGD inspired theory of consciousness. The hypothesis has been that they code for the space-time correlates of quantum states. The second message is that a detailed view about this coding is possible and reveals the difference between the space-time correlates of intentions and cognitions besides showing that quantum classical correspondence relates to each other the identification of the p-adic

space-time sheets as space-time correlates of cognition and the identification of fermionic degrees of freedom as correlates of Boolean cognition.

7.1 Zero energy ontology, cognition, and intentionality

One could argue that conservation laws forbid p-adic-real phase transitions in practice so that cognitions (intentions) realized as real-to-padic (p-adic-to-real) transitions would not be possible. The situation changes if one accepts what might be called zero energy ontology [C1, C2].

7.1.1 Zero energy ontology classically

In TGD inspired cosmology [D5] the imbeddings of Robertson-Walker cosmologies are vacuum extremals. Same applies to the imbeddings of Reissner-Nordström solution [D3] and in practice to all solutions of Einstein's equations imbeddable as extremals of Kähler action. Since four-momentum currents define a collection of vector fields rather than a tensor in TGD, both positive and negative signs for energy corresponding to two possible assignments of the arrow of the geometric time to a given space-time surface are possible. This leads to the view that all physical states have vanishing net energy classically and that physically acceptable universes are creatable from vacuum.

The result is highly desirable since one can avoid unpleasant questions such as "What are the net values of conserved quantities like rest mass, baryon number, lepton number, and electric charge for the entire universe?", "What were the initial conditions in the big bang?", "If only single solution of field equations is selected, isn't the notion of physical theory meaningless since in principle it is not possible to compare solutions of the theory?". This picture fits also nicely with the view that entire universe understood as quantum counterpart 4-D space-time is recreated in each quantum jump and allows to understand evolution as a process of continual re-creation.

7.1.2 Zero energy ontology at quantum level

Also the construction of S-matrix [C2] leads to the conclusion that all physical states possess vanishing conserved quantum numbers. Furthermore, the entanglement coefficients between positive and negative energy components of the state define a unitary S-matrix. S-matrix thus becomes a property of the zero energy state and physical states code by their structure what is usually identified as quantum dynamics.

Also the transitions between zero energy states are possible but general arguments lead to the conclusion that the corresponding S-matrix is almost trivial. This finding, which actually forced the new view about S-matrix, is highly desirable since it explains why positive energy ontology works so well if one forgets effects related to intentional action.

At space-time level this would mean that positive energy component and negative energy component are at a temporal distance characterized by an appropriate p-adic time scale and the integer characterizing the value of Planck constant for the state in question. The scale in question would also characterize the geometric duration of quantum jump and the size scale of space-time region contributing to the contents of conscious experience. The interpretation in terms of a mini bang followed by a mini crunch suggests itself also.

7.1.3 Hyper-finite factors of type II_1 and new view about S-matrix

The representation of S-matrix as unitary entanglement coefficients would not make sense in ordinary quantum theory but in TGD the von Neumann algebra in question is not a type I factor as for quantum mechanics or a type III factor as for quantum field theories, but what is called hyper-finite factor of type II_1 [A8]. This algebra is an infinite-dimensional algebra with the almost defining, and at the first look very strange, property that the infinite-dimensional unit matrix has

unit trace. The infinite dimensional Clifford algebra spanned by the configuration space gamma matrices (configuration space understood as the space of 3-surfaces, the "world of classical worlds") is indeed very naturally algebra of this kind since infinite-dimensional Clifford algebras provide a canonical representations for hyper-finite factors of type II_1 .

7.1.4 The new view about quantum measurement theory

This mathematical framework leads to a new kind of quantum measurement theory. The basic assumption is that only a finite number of degrees of freedom can be quantum measured in a given measurement and the rest remain untouched. What is known as Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of von Neumann algebras allow to realize mathematically this idea [A8]. \mathcal{N} characterizes measurement resolution and quantum measurement reduces the entanglement in the non-commutative quantum space \mathcal{M}/\mathcal{N} . The outcome of the quantum measurement is still represented by a unitary S-matrix but in the space characterized by \mathcal{N} . It is not possible to end up with a pure state with a finite sequence of quantum measurements.

The obvious objection is that the replacement of a universal S-matrix coding entire physics with a state dependent unitary entanglement matrix is too heavy a price to be paid for the resolution of the above mentioned paradoxes. Situation could be saved if the S-matrices have fractal structure. The quantum criticality of TGD Universe indeed implies fractality. The possibility of an infinite sequence of Jones inclusions for hyperfinite type II_1 factors isomorphic as von Neumann algebras expresses this fractal character algebraically. Thus one can hope that the S-matrix appearing as entanglement coefficients is more or less universal in the same manner as Mandelbrot fractal looks more or less the same in all length scales and for all resolutions. Whether this kind of universality must be posed as an additional condition on entanglement coefficients or is an automatic consequence of unitarity in type II_1 sense is an open question.

7.1.5 The U-matrix for p-adic-real transitions makes sense

In zero energy ontology conservation laws do not forbid p-adic-real transitions and one can develop a relatively concrete vision about what happens in these kind of transitions. The starting point is the generalization of the number concept obtained by gluing p-adic number fields and real numbers along common rationals (expressing it very roughly). At the level of the imbedding space this means that p-adic and real space-time sheets intersect only along common rational points of the imbedding space and transcendental p-adic space-time points are infinite as real numbers so that they can be said to be infinite distant points so that intentionality and cognition become cosmic phenomena.

In this framework the long range correlations characterizing p-adic fractality can be interpreted as being due to a large number of common rational points of imbedding space for real space-time sheet and p-adic space-time sheet from which it resulted in the realization of intention in quantum jump. Thus real physics would carry direct signatures about the presence of intentionality. Intentional behavior is indeed characterized by short range randomness and long range correlations.

One can even develop a general vision about how to construct the U-matrix elements characterizing the process [C2]. The basic guideline is the vision that real and various p-adic physics as well as their hybrids are continuable from the rational physics. This means that these U-matrix elements must be characterizable using data at rational points of imbedding space shared by p-adic and real space-time sheets so that more or less same formulas describe all these U-matrix elements. Note that also $p_1 \rightarrow p_2$ p-adic transitions are possible.

7.2 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.

7.2.1 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.

7.2.2 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 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.

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.

7.2.3 Number theoretical universality of S-matrix

The discreteness of the intersection of the real space-time sheet and its p-adic variant obtained by algebraic continuation would be a completely universal phenomenon associated with all fermionic states. This suggests that also real-to-real S-matrix elements involve instead of an integral a sum with the arguments of an n-point function running over all possible combinations of the points in the intersection. S-matrix elements would have a universal form which does not depend on the number field at all and the algebraic continuation of the real S-matrix to its p-adic counterpart would trivialize. Note that also fermionic statistics favors strongly discretization unless one allows Dirac delta functions.

Quantum classical correspondence requires that the flow of subjective time identified as a sequence of quantum jumps should have the flow of geometric time as a space-time correlate. The understanding of the detailed relationship between these two times has however remained a long standing problem, and only the emergence of zero energy ontology allows an ad hoc free model for how the flow and arrow of geometric time emerge, and answers why the relationship between geometric past and future is so asymmetric and why sensory experience is about so narrow interval of geometric time. Also the notion of self reduces in well-defined sense to the notion of quantum jump with fractal structure.

7.3 About the arrow of psychological time

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.

7.3.1 Two times

The notion of quantum jump implies a new view about time. Experienced/subjective time corresponds to a sequence of sub-quantum jumps and cannot be identified with the geometric time defined as the fourth space-time coordinate. This is of course obvious for anyone: consider only the reversibility of geometric time contra irreversibility of experienced time, and the fact that both geometric past and future exist whereas only subjective past exists. The fact that the contents of conscious experience is about 4-D rather than 3-D space-time region, motivates the notions of 4-D brain, body, and even society. In particular, conscious existence continues after biological death since 4-D body and brain continue to exist.

7.3.2 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 represent basic types for them.

7.3.3 The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. 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. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. 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 space-time sheet that perceiver identifies itself 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-astronomical) 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 Alfvén wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

7.4 Questions related to the notion of self

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 has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

7.4.1 Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

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.

Even slightest entanglement would destroy self unless one introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

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 labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck

constant) and this level would correspond to the self. What might be called irreducible self would correspond 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 original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.
2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.
3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p} T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p . One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.
4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This

asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seeing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of \hbar/\hbar_0 the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configurations space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.
2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M -matrix - requires tensor product.
4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

7.4.2 Does entanglement mean loss of consciousness?

The ability to avoid entanglement with environment would be essential for the original notion of self and in case of sub-selves it would explain the finite life-time of mental images. 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 westerners 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.

7.4.3 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 sooner later brings into the volume of attention (which might also change) 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 she might call enlightenment.

7.5 Memory and time

7.5.1 Do declarative memories and intentional action involve communications with geometric past?

Communications with geometric past using time mirror mechanism in which phase conjugate photons propagating to the geometric past are reflected back as ordinary photons (typically dark photons with energies above thermal threshold) make possible realization of declarative memories in the brain of the geometric past [H7].

This mechanism makes also possible realization of intentional actions as a process proceeding from longer to shorter time scales and inducing the desired action already in geometric past. This kind of realization would make living systems extremely flexible and able to react instantaneously to the changes in the environment. This model explains Libet's puzzling finding that neural activity seems to precede volition [48].

Also a mechanism of remote metabolism ("quantum credit card") based on sending of negative energy signals to geometric past becomes possible [K6]: this signal could also serve as a mere control signal inducing much larger positive energy flow from the geometric past. For instance, population inverted system in the geometric past could allow this kind of mechanism. Remote metabolism could also have technological implications.

7.5.2 Episodal memories as time-like entanglement

Time-like entanglement explains episodal memories as sharing of mental images with the brain of geometric past [H7]. An essential element is the notion of magnetic body which serves as an intentional agent "looking" the brain of geometric past by allowing phase conjugate dark photons with negative energies to reflect from it as ordinary photons. The findings of Libet about time delays related to the passive aspects of consciousness [49] support the view that the part of the magnetic body corresponding to EEG time scale has same size scale as Earth's magnetosphere. The unavoidable conclusion would be that our field/magnetic bodies contain layers with astrophysical sizes.

p-Adic length scale hierarchy and number theoretically preferred hierarchy of values of Planck constants, when combined with the condition that the frequencies f of photons involved with the communications in time scale T satisfy the condition $f \sim 1/T$ and have energies above thermal energy, lead to rather stringent predictions for the time scales of long term memory. The model

for the hierarchy of EEGs relies on the assumption that these time scales come as powers $n = 2^{11k}$, $k = 0, 1, 2, \dots$, and predicts that the time scale corresponding to the duration of human life cycle is ~ 50 years and corresponds to $k = 7$ (amusingly, this corresponds to the highest level in chakra hierarchy).

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