TGD inspired theory of consciousness and biosystems as macroscopic quantum systems

M. Pitkänen[1]

[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: Kadermonkatu 16,10900, Hanko, Finland.

Abstract

In this introductory article I summarize briefly what Topological Geometrodynamics (TGD) and TGD inspired theory of consciousness are and describe the speculative picture about biosystems as macroscopic quantum systems provided by TGD. Also the applications of TGD to brain consciousness are discussed. The identification of quantum jump between quantum histories as a moment of consciousness reduces quantum measurement theory to fundamental physics. The identification of self as a subsystem able to remain unentangled in subsequent quantum jumps provides a quantum theory of observer and one can identify self also as a fundamental statistical ensemble. The entanglement of subselves of same or of two separate selves means fusion of mental images to a more complex mental image. In the latter case it means sharing of mental images crucial, not only for remote mental interactions, but also for genuine communications.

The notion of manysheeted spacetime allows to understand how biosystems manage to be macroscopic quantum systems. Topological field quantization implies that also classical fields have particle like aspects: these particle like aspects are crucial for the models of sensory qualia, sensory representations and long term memory as well as for the general model of control and coordination in living matter. One can fairly say that living systems have besides the ordinary physical body also electromagnetic body (actually a hierarchy of them). A further generalization of the spacetime concept involves the introduction of p-adic topologies besides the real topology. p-Adic spacetime regions are identified as cognitive representations for the real regions and thus correspond to the 'mind stuff' of Descartes. The transformation of intention to action correspond to a quantum jump in which p-adic spacetime regions is replaced with a real one. The realization of the sensory representations at the field body outside the brain represents the most radical departure from the views of standard neuroscience and a rather detailed theory for both 'personal' sensory representations and magnetospheric sensory representations presumably responsible for the third person aspects of consciousness results.

Contents

1 Introduction

In this introductory article I summarize briefly what Topological Geometrodynamics (TGD) and TGD inspired theory of consciousness are and describe the speculative picture

about biosystems as macroscopic quantum systems provided by TGD. Also the applications of TGD to brain consciousness are discussed. More detailed representations can be found from the online books "TGD inspired theory of consciousness with applications to biosystems" [cbook] and "Genes, Memes, Qualia, and Semitrance" [cbook2] at my homepage. The online books "Topological Geometrodynamics" [TGD] and "TGD and p-Adic numbers" [padTGD] represent the recent view about TGD as a unification of fundamental interactions. In the sequel my aim is to write more detailed articles about various topics touched in this introductory article trying to give an overview about the recent situation in TGD inspired theory of consciousness.

2 TGD in nutshell

The online books "TGD" [TGD] and "TGD and p-Adic Numbers [padTGD] provide a concice representation about TGD as a unification of fundamental interactions: in the following only the basic ideas and consequences of TGD are discussed.

2.1 Spacetimes as a 4-D surfaces in 8-D imbedding space

Topological Geometro-Dynamics (TGD) can be regarded as a unified theory of fundamental interactions. TGD was originally an attempt to construct a Poincare invariant theory of gravitation [TGD, padTGD, cbook, cbook2]. Spacetime, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a 4-surface in the 8-dimensional space $H = M_+^4 \times CP_2$, where M_+^4 denotes the interior of the future light cone of the Minkowski space (to be referred as light cone in the sequel) and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [TGD] (see Fig. 1). The size of CP_2 which is about 10^4 Planck lengths replaces Planck length as a fundamental length scale in TGD Universe.

The identification of the spacetimes as a submanifolds of $M_+^4 \times CP_2$ leads to Poincare invariance broken only in cosmological scales and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity. Even more, sub-manifold geometry, being considerably richer in structure than the abstract manifold geometry behind General Relativity, leads to a geometrization of all basic interactions and elementary particle quantum numbers. In particular, classical electroweak gauge fields are obtained by inducing the spinor curvature of CP_2 to the spacetime surface. One can say, that the mere hypothesis that spacetimes are representable as 4-surfaces of $M_+^4 \times CP_2$ realizes Einstein's great dream in a very elegant and economical manner.

2.2 The notion of manysheeted spacetime

TGD approach forces a generalization of the conventional spacetime concept to what might be called manysheeted spacetime or 'topological condensate'. The topologically trivial 3-space of General Relativity is replaced with a 'topological condensate' containing matter as particle like 3-surfaces "glued" to the topologically trivial background spacetime sheet by extremely tiny connected sum (wormhole) contacts having CP_2 size connecting the spacetime sheets (see Fig. 2). Spacetime sheets can be connected to each other also by join along boundaries bonds (see Fig. 2)

Spacetime sheets have outer boundaries and form a hierarchical structure. Macroscopic material bodies are identified as 3-surfaces with boundary identified as the outer surface of the macroscopic body. For instance, my physical body is a spacetime sheet with my skin representing its outer boundary whereas external world is represented by a larger spacetime sheet at which the spacetime sheet representing my body is 'topologically condensed'. This generalization implies a radical reformulation of the condensed matter physics. Spacetime sheets are connected to each other by wormhole contacts and join along boundaries bonds. Various new physics effects related to the manysheeted spacetime concept are discussed in the four books about TGD: see for instance, the chapters "TGD and Nuclear Physics" and "Anomalies Explainable by TGD Based Spacetime Concept" of [padTGD].

Manysheeted spacetime concept is especially important in TGD inspired theory of consciousness and its applications to biosystems [cbook, cbook2] since it makes possible macroscopic quantum systems. The reason is simply that the large non-atomic spacetime sheets contain very few elementary particles so that the temperature at these spacetime sheets can be extremely low and therefore various kinds of macroscopic quantum phases are possible.

The basic prediction of TGD is that the sign of energy depends on the time orientation of the spacetime surface so that energy can be also negative as opposed to situation in standard physics. For instance, pairs of spacetime sheets with opposite energies can be generated from vacuum. This makes possible an effective overunity production of energy, a mechanism of coherent locomotion, classical signalling to the direction of the geometric past and many other exotic effects which could be important in living matter.

Absolute minimization of so called Kähler action is the fundamental variational principle of TGD and assigns to a given 3-surface X^3 a classical spacetime surface $X^4(X^3)$ which is much like Bohr orbit going through a fixed point in wave mechanics. Another useful analogy is four-dimensional soap film spanned by a 3-dimensional frame which minimizes instead of its area a non-linear counterpart of Maxwell action. The variational principle is characterized by classical non-determinism caused by enormous vacuum degeneracy and this forces a generalization of the notion of 3-surfaces in order to achieve classical determinism in a more general sense. 3-surfaces are in general unions of disjoint 3-surfaces with timelike separations ('association sequences') rather than single time=constant snapshots of the spacetime surface. In particular, spacetime sheets with finite time duration, 'mind-like' spacetime sheets, are possible and are good candidates for the geometric correlates of selves in TGD inspired theory of consciousness (see Fig. 3).

Perhaps the most plausible identification for the classical non-determinism is as a physical correlate of language understood in a very general sense: the sequences of spacelike three-surfaces with timelike separations ('association sequences') are like sequences of the basic units of language. The identification of the 'association sequences' as classical correlates of thoughts has been also considered. It seems however that p-adic spacetime regions are more natural in this respect, and that association sequeces are symbolic representations of thoughts rather than thoughts: cognition transformed to sensory experience. Also the identification of the classical determinism as a prequisite and correlate of volition has been considered.

2.3 Quantum TGD

The basic manifesto behind quantum TGD is the geometrization of not only classical physics but also of quantum theory. Only the notion of quantum jump remains outside the geometrization program.

a) The arena of quantum dynamics is the infinite-dimensional space CH of all possible 3-surfaces of $H = M_+^4 \times CP_2$. Since one can assign to a given 3-surface X^2 a unique spacetime surface $X^4(X^3)$, one could equivalently speak of the space of four-surfaces satisfying the field equations defined by the fundamental variational principle. This space is geometrized by providing it with a metric and spinor structure crucial providing geometrization of distance measurement and spin. The infinite-dimensionality of the space CH has dramatic implications: the mere requirement that the metric exists and allows Riemann geometry fixes the metric essentially uniquely. Also the choice of the imbedding space H is fixed to $H = M_+^4 \times CP_2$ since maximal symmetries are required in order that the configuration space geometry exists mathematically.

b) There is no quantization involved: physical states correspond to classical spinor fields in the configuration space of 3-surfaces and fermionic oscillator operators have purely geometric interpretation. Configuration space spinors (as opposed to spinor field) correspond to the states of ordinary quantum field theories. The limit when 3-surfaces are reduced to points gives ordinary quantum field theory.

As far as theory of consciousness is considered, the fundamental feature of the configuration space is that it has two kinds of degrees of freedom.

a) The degrees of freedom in which metric is nonvanishing correspond to quantum fluctuating, non-classical degrees of freedom.

b) The degrees of freedom in which metric vanishes correspond to what I call zero modes and are purely TGD based prediction basically due to the non-point like character of particles identified as 3-surfaces. Zero modes are the counterparts of the classical macroscopic variables and in every quantum jump a localization in zero modes occurs: this process mathematisizes the phenomenological notion of state function reduction. For instance, particle spin corresponds to a quantum variable whereas the configuration of the needle of the measurement apparatus representing spin direction corresponds to a zero mode.

The replacement of point like particle with 3-surface means giving up the locality of the physics at spacetime level: physics is however local at the level of configuration space containing 3-surfaces as its points. For instance, classical EPR nonlocality is purely local phenomenon at the level of configuration space. Besides allowing to get rid of the standard infinities of the interacting local field theories, the non-locality explains topologically the generation of structures, in particular biological structures which correspond to spacetime sheets behaving as autonomous units.

Quite recently a considerably more general view about quantum TGD as a generalized number theory has emerged: this view is also relevant from the point of view of consciousness theory and the interested reader can consult the chapter "TGD as a Generalized Number Theory" of [cbook] for this approach.

2.4 p-Adic physics as physics of cognition, intention, and anticipation

p-Adic number fields R_p are labelled by primes $p = 2, 3, 5, ...$ and, just like real numbers, they can be regarded as completions of rational numbers $q = m/n$, m, n integers to contain the p-adic counterparts of algebraic and transcendental numbers. p-Adic numbers emerged to TGD first only as an effective mathematical tool but it has turned out that p-adic physics is fundamental element of TGD.

TGD spacetime decomposes into regions obeying real and p-adic topologies (see Fig. 4). p-Adic 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 appearing as integration constants of differential equations are pseudo constants which are piecewise constant functions. Therefore one cannot fix the solutions of field equations or of equations of motion by giving the initial values of dynamical variables for fixed value of time (for instance, initial positions and velocities are integration constants for Newton's equations and fix the solution). Pseudo constant depends on a finite number of positive pinary digits of its arguments ($x = \sum x_n p^n$ in $f(x)$ is replaced by $x_N = \sum_{n<N} x_n p^n$). This means that p-adic spacetime regions are obtained by glueing together regions for which integration constants are genuine constants.

The natural interpretation of the p-adic regions is as cognitive representations of the real physics occurring in real regions. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. In this vision real/p-adic mindlike spacetime sheets are interpreted as geometric correlates of sensory/imagined experiences. p-Adic regions provide also geometric correlates for intentionality.

3 TGD inspired theory of consciousness

The basic notions of TGD inspired theory of consciousness are quantum jump between quantum histories identified as a moment of consciousness and the notion of self as a subsystem able to remain unentangled during subsequent quantum jumps. Self hierarchy with the entire Universe at the top is the basic prediction and subselves of self are identified as mental images of self.

3.1 New elements

The basic new elements as compared to standard physics based theories of consciousness are the new view about time and quantum state allowing to resolve the basic paradoxes of modern physics, the notion of manysheeted spacetime; the non-determinism of the fundamental variational principle determining the dynamics of the spacetime surfaces; and p-adic numbers.

a) General coordinate invariance forces to replace quantum state as time=constant snapshot with entire quantum history with can be regarded as a generalization for the solution of Schrödinger equation describing entire universe. Classical histories correspond to spacetime surfaces.

b) Since quantum jumps occur between quantum histories, the non-determinism of quantum jump is outside the spacetime and the space of quantum states. This solves the basic paradox of quantum measurement theory. Time evolution by quantum jumps,

subjective time development, corresponds to hopping in the space of solutions of the field equations.

c) This view forces to differentiate between subjective time and geometric time. Geometric time is the fourth coordinate for spacetime surfaces whereas subjective time corresponds to a sequence of quantum jumps identified as moments of consciousness. The complete space-time democracy has most profound implications concerning the interpretation of the theory.

d) The generalization of the spacetime concept involving in an essential manner also the classical non-determinism of the basic variational principle defining spacetime surface $X^4(X^3)$ associated with a given 3-surface X^3, allows to understand how the correspondence between geometric and subjective time emerges. The point is that mindlike spacetime sheets with a finite geometric time duration and a well defined temporal center of mass coordinate become possible. These mindlike spacetime sheets serve as geometric correlates for conscious selves and one can understand the emergence of psychological time and its arrow. One can achieve determinism in generalized sense, if one generalizes the notion of 3-surface by allowing sequences of spacelike 3-surfaces with timelike separations. These 'association sequences' were originally identified as geometric correlates of thoughts: its seems that they more naturally correspond to linguistic representations for contents of consciousness at spacetime level.

e) The generalization of spacetime concept allowing imbedding space to be a union of real and p-adic imbedding spaces identified along common rational points and assuming that spacetime surfaces decompose to real and p-adic regions glued together along common rational boundaries. p-Adic regions allow inherent p-adic nondeterminism identified as nondeterminism of cognition and p-adic regions provide cognitive representations for sequences of quantum jumps defining contets of consciousness.

3.2 Quantum jump between quantum histories as a generalization of quantum measurement theory

T(opological)G(eometro)D(ynamics) inspired theory of consciousness can be regarded also as a generalization of quantum measurement theory. The connection comes from the identification of quantum jump as a moment of consciousness and replacement of the notion of the external observer with the concept of 'self' identified as a subsystem able to remain unentangled during subsequent quantum jumps.

The quantum jump has turned out to have a complex anatomy: the counterpart of the unitary U process of Penrose is followed by the TGD counterpart of state function reduction which in turn is followed by the TGD counterpart of state preparation resulting from a cascade of self measurements. This generalization of quantum measurement theory opens the black boxes of state function reduction and preparation by combining them in the notion of quantum jump between quantum histories.

First of all, quantum jump decomposes into informational time development

$$\Psi_i \to U\Psi_i$$

followed by the TGD counterpart of state function reduction realized as a localization in zero modes which correspond to non-quantum fluctuating degrees of freedom of configuration space of 3-surfaces (see the first part of [TGD] and of [cbook]):

$$U\Psi_i \rightarrow \Psi_f^0 \quad .$$

The assumption that the localization occurs in the zero modes of the configuration space poses a very important consistency condition on U. U must effectively correspond to a flow in zero modes such that there is one-one correlation between the quantum numbers α in quantum fluctuating degrees of freedom in some state basis and the values z of the zero modes in state $U\Psi_i$:

$$\alpha \leftrightarrow z(\alpha) \quad .$$

This together with the fact that zero modes are effectively classical variables, implies that the localization in zero modes can be identified as the TGD counterpart for the state function reduction.

The state function reduction is followed by a cascade of self measurements in quantum fluctuating degrees of freedom (the values of the zero modes do not change during this stage)

$$\Psi_f^0 \rightarrow .... \rightarrow \Psi_f \quad ,$$

whose dynamics is governed by the Negentropy Maximization Principle (NMP, see the chapter "NMP" of [cbook]). At least formally, this process is analogous to analysis at level of cognition leads to a completely unentangled state (apart from entanglement present in bound states) identifiable as a prepared state. It must be emphasized that self measurement is microtemporal aspect of consciousness and does not directly relate to our conscious experience.

A good metaphor for quantum jump is as Djinn leaving the bottle (informational time development), fulfilling the wish (quantum jump involving choice) and returning to, possibly new, bottle (localization in zero modes and subsequent state preparation process). One could formally regard each quantum jump as a TGD counterpart of a quantum computation lasting infinitely long time $t \rightarrow \infty$ followed by a state preparation of the initial state of the next quantum computation.

3.3   Negentropy Maximization Principle

State preparation corresponds to a sequence of self measurements leading gradually to a maximally unentangled state. The dynamics of self measurements is governed by Negentropy Maximization Principle (NMP, see the chapter "Negentropy Maximization Principle" of [cbook]), which specifies which subsystems of given unetangled subsystem are subject to quantum measurement in a given self measurement. NMP can be regarded as a basic law for the dynamics state preparation and states that the information content of the conscious experience is maximized. In p-adic context NMP dictates the dynamics of cognition.

a) NMP applies to each unentangled subsystem with fixed values of zero modes separately and is therefore in a well-defined sense a local principle. Every unentangled subsystem in Ψ_f^0 participates in self measurement sequence $\Psi_f^0 \rightarrow ...\Psi_f$.

b) The self measurement for a given unentangled subsystem X corresponds to a measurement of the density matrix for some subsystem Y of X. In this measurement subsystem

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.

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

3.4   Quantum self

The notion of self was originally forced by the paradoxes resulting in the attempt to understand consciousness in terms of quantum jumps alone (regarded at that time essentially as single self measurement). The concept of self has developed gradually during years and the recent view is probably not yet the final one. The connection with quantum measurement theory, statistical physics and self-organization theory however encourage to think that basic ideas are sound.

The problems relate to the precise definition of the spacetime correlates of self and to what it really means that self identity is preserved in quantum jump. A further challenge is to understand precisely what the sharing of mental images, which is made possible by entanglement of subselves of different selves, means quantum mechanically and at the spacetime level.

3.4.1   Self as a subsystem able to remain unentangled

A natural identification of self is as a sub-Universe behaving autonomously. Thus subsystems able to remain un-entangled during subsequent quantum jumps are natural candidates for selves. In the limit that self lives only a single quantum jump, one has a self consisting of a single moment of consciousness only and for mathematical generality one must allow also this case.

For Schrödinger time evolution the generation of an even slightest entanglement kills the self so that the notion does not make sense. In TGD context the situation is different: subjective time evolution is a sequence of quantum jumps in each of which quantum entanglement is minimized to bound state entanglement in the state preparation phase of the quantum jump. $\Psi_i \to U\Psi_i$ quantum entangles with everything and the quantum average classical spacetime characterized by the values of the zero modes is replaced by a new one in each quantum jump. It is not however obvious what the statement that the subsystem associated with self is preserved in quantum jump means. This problem will be discussed later.

The basic prediction is the existence of infinite hierarchy of selves and this has rather dramatic consequences. At the top of the infinite hierarchy is entire Universe, which might be called God. This structure cannot entangled with any larger structure of same kind so

that this self can be said to live eternal life. God abstracts all experiences in the infinite hierarchy of subselves to single experience. If infinite primes are allowed, as required by simple physical arguments, God corresponds to infinite p-adic prime characterizing entire universe and since this prime grows, also God evolves.

3.4.2 The notion of self and p-adic physics

As alredy noticed, the inherent non-determinism of the p-adic field equations is identified as non-determinism of imagination which is an essential element of cognition and intention. Although p-adic spacetime regions represent the 'mind stuff', geometric correlate for cognition, they are however not conscious. The transformations of intentions to actions occur in quantum jumps in which p-adic spacetime region is replaced with a real one whereas sensory input transforms to thought in the reverse transition. This mechanism should apply not only to the ordinary volitional acts but also to various forms of psychokinesis. p-Adic spacetime regions are obviously the TGD counterpart for the mind stuff of Descartes and dualism relates material world and cognitive representations which both are Zombies.

The great challenge is to build concrete models for p-adic physics of cognition and intention at brain level and for the dynamics of p-adic–real transitions as dynamics of volition and formation of cognitive representations. Considerable progress has occurred in this respect quite recently (see the chapters "Quantum model of cognition" of [cbook] and "Spectroscopy of consciousness" of [cbook2]).

3.4.3 How the contents of consciousness of self are determined

In the following basic aspects about how the contents of consciousness of self are determined are discussed.

1. Summation hypothesis, binding, and statistical averaging of experiences

Subsystem X possessing self behaves essentially as a separate sub-Universe with respect to NMP. Also the subselves 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.

a) X experiences the subselves X_i as separate mental images superposed to the pure self experience of X: this is natural since subselves are unentangled and hence behave like separate sub-Universes. These subselves are bound in the sense that self experiences them simultaneously.

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

When self has no subselves, the experience of self reduces to pure awareness without any mental images. In case of real selves these mental images are p-adic and thus represent thoughts: thus the empty mind in a state of Oneness means getting rid of thoughts. An interesting question is what kind of experience self decomposing to several subselves, each

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in state of whole-body consciousness, has: there is no averaging involved so that the mental images of self could be identical with the experiences of subselves.

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 16-18 Hz is consistent with the hypothesis that sensory subselves (mental images) have a duration of order .1 seconds and that temporal averaging indeed occurs. Our self can 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. The subjecto-temporal sequence of subselves of a finite duration is experienced as a sequence of separate mental images: this makes possible to remember the digits of a phone number despite the presence of the temporal averaging.

Summation hypothesis and temporal binding with averaging imply a hierarchy of conscious experiences with increasingly richer but abstracted contents. Also we are mental images of some higher level self.

I ended up with p-adic physics originally as a successful model of elementary particle masses (see the fourth part of "p-Adic TGD" [padTGD]). The only possible interpretation for this success is that this model is a model of a cognitive model so that p-adic physics and cognition are present already at elementary particle level. This also explains the selection of p-adic primes corresponding to p-adic length scale hypothesis as a a result of fight for survival at elementary particle level. Without this selection electron would have practically continuous mass spectrum.

2. Binding of the experiencers by entanglement

The binding of experiencers is also possible and this process gives rise to what is usually understood with binding in neuroscience context.

a) The simplest assumption is that the binding of selves by quantum entanglement means that they lose their consciousness. In the case of subselves entanglement means binding of separate mental images to single mental image. This process naturally corresponds to the formation of wholes from their parts at the level of conscious experiences. The formation of a mental image (subself) representing word from the mental images representing letters is example of this process. The information about various areas of brain (there are about separate visual areas) could bind by entanglement mechanism. Also the fusion of the left and right visual fields to a single visual field could occur via the entanglement of the corresponding subselves. Right–left entanglement might occur already at the neuronal level.

b) Quantum entanglement could make possible communication between selves belonging to different levels of the self hierarchy: for instance, part of brain representing subself could entangle with a higher level self and mediate communications to those parts of brain which are awake (the semitrance mechanism discussed in the last part of [cbook2]).

c) It seems that also subselves of separate selves could entangle. This could make possible shared experiences. Telepathy could be based on this mechanism. Communications might involve entanglement between subselves: classically communication would involve generation of spacetime sheet containing ME serving as a join along boundaries bond connecting the regions representing the subselves of sender and receiver. In the final

state this ME would disappear but leave subself which has received the message (during communication stage subself would become unconscious).

d) The non-determinism of Kähler action makes possible timelike entanglement. Long term memories could be seen as shared experiences in which the self at geometric now shares the experience of self in the geometric past. Laser mirrors defined by parallel MEs accompanying magnetic flux tubes could be the realization of this mechanism and present at all levels of the self hierarchy, even at DNA level.

The synchronous neuronal firing with the amazing precision of order millisecond [Engel *et al*] could be the neural correlate of entanglement between different areas of brain where subselves representing mental images could be located. Z^0 MEs giving rise to ZEG could provide the needed synchronizer at frequency of about one kHz, which corresponds to the duration of the bit of the memetic codeword. In p-adic state they would define cognitive representations and be passive whereas in the real state they would become active and synchronize neuronal firing (the coupling to Z^0 fields is strongest in cellular length scale). p-Adic Z^0 MEs would mimic the neuronal activity and transform to real MEs resonantly when the oscillation frequency is about kHz. Thus synchrony would be generated in phase transition like manner with a neuronal oscillation at kHz frequency serving as a seed. This vision is described in more detail in the chapter "Spectroscopy of consciousness" of [cbook2].

3.4.4   Selves self-organize

Subjective time development by quantum jumps implies quantum self-organization which can be regarded as a sequence of quantum jumps between quantum histories (see the chapter "Quantum Theory of Self-Organization" of [cbook]). This evolution corresponds to a sequence of macroscopic spacetime surfaces associated with the final state quantum histories. Quantum jumps imply dissipation at fundamental level. Dissipation serves as a Darwinian selector of self-organization patterns, which can represent both genes and memes. In particular, one can understand how habits, skills and behavioural patterns are gradually learned. Protein folding occurring to very few final state patterns suggests itself as resulting from self-organization process (proteins would be thus conscious selves).

3.4.5   Self hierarchy

The notion of self hierarchy, starting from elementary particle level and having entire Universe at the top, is a highly nontrivial prediction of TGD inspired theory of consciousness. Self hierarchy is very much analogous to the hierarchy of subprograms of a computer program and defines a hierarchy of increasingly abstract experiences. Self hierarchy allows to understand computational aspects of brain functioning although connectionistic picture realized as quantum association network seems to work at various levels of the hierarchy (see the chapter "Quantum Model for Intelligent Systems" of [cbook]). Topological field quanta of em fields (MEs and magnetic flux tube structures) are a part of the self hierarchy and this encourages to give up the view that consciousness is a purely brain centered phenomenon (wavelength of 10 Hz EEG wave has size scale of Earth). Self hierarchy is also crucial for the models of the sensory qualia and sensory representations.

3.4.6 Self as a statistical ensemble and qualia

The notion of self means possible fundamental identification of two kinds of ensembles: the subjecto-temporal ensemble defined by the quantum jumps occurred after the last 'wake-up' and spatial ensembles defined by the subselves of self defining mental images of self as statistical averages over experiences of subselves of subselves. This leads to the hypothesis that qualia correspond to average increments of quantum numbers and zero modes in quantum jumps. The sharpness of a given quale is determined by the entropy of the distribution for the quantum number increments of given type. At the statistical level qualia correspond to average rates of the change of quantum numbers and zero modes. The rates of change for entropy type variables associated with subselves are assumed to define emotional qualia. This picture is consistent with the assignment of qualia to quantum phase transitions.

The sequence of quantum jumps defining self defines also a sequence of maximally unentangled quantum states resulting in the state preparation process governed by NMP. This set of states, which grows in size quantum jump by quantum jump, defines in a natural manner a statistical ensemble identifiable as the fundamental realization of the otherwise fictive notion of statistical ensemble fundamental in the formulation of statistical physics. There are actually two statistical ensembles: the first one being associated with the final states of quantum jump and the second one being associated with the values of zero modes resulting in quantum jump. As far as conscious experience is involved, it however seems that it is the increments of quantum numbers and zero modes which are the relevant statistical variables.

This observation anchors the theory of conscious experience to statistical physics (see the chapter "General Theory of Qualia" of [cbook2]). For instance, the increments of zero modes *resp.* quantum numbers are responsible for geometric *resp.* non-geometric qualia. More precisely, the gradients with respect to subjective time for the zero modes and for the net quantum numbers associated with selves correspond to qualia. One can classify non-geometric qualia to entropy gradients associated with various increments (emotions in accordance with the fact that peptides are both informational molecules and molecules of emotion); kinestetic qualia (sense of pressure and force and, more generally, gradient of any conserved (with respect to geometric time) quantity associated with self with respect to subjective time); and generalized chemical qualia (rates for the changes of numbers of particles with various quantum numbers). Various entropies associated with self and subselves in turn characterize the sharpness of the mental images, and one can relate concepts like attentiveness, alertness and the level of arousal to these variables.

It must be however emphasized that quantum number increments alone need not determine entirely the contents of conscious experience. There is an infinite number of possible quantum jump sequences between two states Ψ_i and Ψ_f. This is also the case for diagonal quantum jumps $\Psi_i \rightarrow .....\Psi_i$. The idea that diagonal quantum jumps, and more generally, quantum jump sequences leading from Ψ_i back to Ψ_i, could give all possible conscious information about given quantum history Ψ_i is attractive. The requirement that diagonal quantum jumps give information about Ψ_i suggests that quantum jumps give also other conscious information than the information coded to the quantum number and zero mode increments. For instance, the average over the cascade of self measurements might have interpretation as a counterpart of conscious analysis.

3.4.7 Self as a moral agent

One could argue that the randomness of the quantum jump means that moral choices are impossible. Volition can however be associated with the quantum jumps in which p-adic spacetime sheet representing intention is transformed to real spacetime sheet representing real action.

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. The p-adic prime associated with entire universe is literally infinite (for the theory of infinite primes, see the chapter "Infinite primes and consciousness" of [cbook2] was originally motivated by consciousness theory). Infinite primes have however decomposition into finite primes in a well-defined sense and the increase of the infinite prime in a statistical sense implies the increase of finite composite primes and the appearence of new spacetime regions characterized by finite primes. A physical correlate for the increase of finite p-adic prime is the gradual growth of say cell or biological organism whereas the creation of new organism is a correlate for generation of a spacetime region characterized by p-adic prime.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* spacetime 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). Intentions, plans and anticipations are represented by p-adic spacetime regions simulating real regions. Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps. Thus selves are genuine moral agents if they can experience directly that increase of p is good and decrease of p is bad.

3.4.8 Sharing and fusion of mental images by quantum entanglement

When subselves of self are entangled, they lose consciousness, and a more complex mental image of self is formed. For instance, the fusion of right and left visual fields gives rise to a stereo vision. It took relatively long time to realize that the fusing subselves could also belong to separate selves. In this case the fusion of the mental images is accompanied by the sharing of the resulting common mental image. Conscious experience is perhaps not so private as has been thought. This mechanism makes possible genuine communications and should be crucial for the development of social structures. It is also the basic mechanism of remote mental interactions. At the molecular level this mechanism makes possible conscious molecular recognition mechanism and miracles like the assembly of a tobacco mosaic virus.

Since only bound state entanglement is stable against state preparation part of the quantum jump, fusion of two selves means the formation of a bound state. The liberation of binding energy as a usable energy accompanies the generation of quantum entanglement and could explain why synesthetes whose left brain contains large synchronous regions during synesthesia are able to survive although brain metabolism is 18 per cent lower than normally. Quantum metabolism could also explain why the oxidative metabolism is very low during intense synchronous neuronal firing. The notion of quantum metabolism could

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also be tested. Bound state formation also explains why generation of brain synchrony means reduction in the number of degrees of freedom.

3.5 Tripartistic world view

The new tripartistic view about existence differs from monistic and dualitic theories. There is 'holy trinity' of existences and dynamics.

a) The dynamics defined by the absolute minimization of the so called Kähler action corresponds to the dynamics of material existence, with matter defined as "res extensa", three-surfaces in 8-dimensional space $H = M_+^4 \times CP_2$. Because of classical and p-adic non-determinism, this dynamics can mimic the subjective time evolution by quantum jumps.

b) The dynamics defined by the action of the unitary process U in the space of quantum histories (configuration space spinor fields), is the counterpart of U process of Penrose and of the ordinary Schrödinger time evolution $U \equiv U(-t,)$, $t \to \infty$ and can be regarded as 'informational time development' occurring at the level of objective existence. It is however impossible to assign real Schrödinger time evolution with U.

c) The dynamics of quantum jumps between quantum histories corresponds to the dynamics of subjective existence.

The holy trinity implies that the basic problems of monistic and dualistic theories of consciousness (in particular so called hard problem) are circumvented. The classical and p-adic non-determinisms of the Kähler action are however crucial for understanding the notion of psychological time.

3.6 How to translate the notion of self to mathematics?

One of the basic challenges is to translate the notion of self hierarchy to precise mathematical structure and it has become clear that the standard mathematical structures of quantum physics are not quite enough for this. Quantum-classical correspondence and basic ideas about causality serve as valuable guidelines in this task.

3.6.1 Quantum-classical correspondence as basic guide line

The basic principle of quantum TGD is that quantum level should be mapped to the spacetime level. In particular, the self hierarchy should have counterparts at both quantum level and spacetime level.

a) At quantum level self hierarchy means following: quantum jump generates totally entangled state $U\Psi_i$ representing the entire Universe. State reduction process decomposes $U\Psi_i$ to subselves, which correspond to a fixed number field each, and thus the possible rational entanglement between different number fields is reduced. State preparation by self measurements decomposes these selves further into maximally unentangled subsystems and only bound state entanglement remains. The resulting irreducible selves allow no further decomposition into subselves. Interestingly, state reduction and preparation could be interpreted as a conscious analysis at given level of self hierarchy.

b) We experience sensory world as 3-dimensional so that the geometric correlates of selves ought to be 3-dimensional. At the spacetime level selves should act as causal determinants, 3-surfaces fixing the spacetime surface completely when absolute minimization of Kähler action serves as a dynamical principle. In the real context the previously mentioned

'association sequences' are excellent candidates for the geometric correlates of selves. In the p-adic context p-adic non-determinism allows even larger variety of 'association sequences' with given pinary cutoff and they serve as cognitive representations of the final state of the quantum jump.

Any $Diff^4$ diffeomorph of a 3-surface belonging to an association sequence is as good representation of subself as any other. This suggests that self identity corresponds to topological identity and very dramatic deformations of the quantum average spacetime surface would thus preserve self identity. In particular, the variation for the values of zero modes respects self hierarchy. The fusion of two causal determinants by join along boundaries bond would however lead to a loss of consciousness and formation of a more complex self. Three-surfaces representing causal determinants could also simply disappear.

Intuition suggests that association sequences have always the geometro-temporally first 3-surface such that there is large number of association sequences possessing this common 3-surface serving as a root of a bifurcation tree (non-determinism could correspond to a sequence of bifurcations). The bound state quantum entanglement giving rise to a fusion of subselves (mental images) should have as its geometric counterpart a join along boundaries bond connecting two 3-surfaces acting as causal determinants.

3.6.2 Manysheeted spacetime and generalization of the notion of subsystem

With the standard quantum physics notion of subsystem the self hierarchy assigned by a state preparation to a given self is simple tree and the trees associated with separate selves are disjoint. In TGD framework one must however consider the possibility that subselves of two separate selves quantum entangle so that fusion and sharing of mental images becomes possible. This process indeed seems to be of utmost importance for understanding TGD inspired theory of consciousness and the challenge is to understand its precise mathematical description.

1. Geometric correlate for the fusion of mental images

The hierarchy of spacetime sheets labelled by p-adic primes suggests the following geometric correlate for the fusion of mental images. Selves correspond to two spacetime sheets corresponding to p-adic length scale L_p to which spacetime sheets corresponding to the p-adic prime $q < p$ have topologically condensed. These spacetime sheets are connected by join along boundaries bonds quantum entangling the corresponding subsystems. Hence there are hierarchies of the state spaces $H_{p_i,1}$ and $H_{p_i,2}$ such that $H_{p,1}$ and $H_{p,2}$ can be unentangled although the spaces $H_{q,1}$ and $H_{q,2}$ entangle. This means a generalization of the standard quantum physics view according to which any subsystem of system corresponds to a tensor factor of state space: now the subsystem corresponding to a topologically condensed spacetime sheet cannot correspond to tensor factor but separate state space. This can be interpreted as saying that H_q degrees of freedom are not included in H_p for $q < p$: 'there is a hole' in H_p'.

2. Hierarchy of state spaces and hierarchy of number fields

A possible identification for the hierarchy of the state spaces is as a hierarchy of state spaces corresponding to various number fields. On this case the identification of a subsystem as an ordinary tensor factor is certainly impossible. Various levels in the hierarchy would be labelled by the primes characterizing p-adic number fields. One, but

not the only, possibility is that the real state space could be at the top of hierarchy of the finite-p p-adic state spaces. In this case only the sharing of thoughts would be possible.

3. Causal nonconnectendess and sharing of mental images

The notion of manysheeted spacetime forces to consider also the possibility that similar hierarchies are possible for a fixed number field, at least for reals. Paradoxes of type subself having self as subself are avoided if the graphs describing interacting self hierarchies does not contain loops. This requires that there is a hierarchy tree of state spaces such that entanglement is possible only between the systems at the same level after state function reduction. p-Adic length scale hypothesis suggests that p-adic primes label this hierarchy even when the spacetime sheets and corresponding state spaces are real.

If the standard description of the subsystem as a tensor factor applies only to systems which are causally connected (totally spacelike), one can understand the need for a more general notion of subsystem even in the real context. Consider a system consisting of two real spacetime sheets with a Minkowski signature of metric such that the smaller spacetime sheet is glued to the larger spacetime sheet by wormhole contacts. Wormhole contacts must have induced metric with Euclidian signature and are therefore surrounded by lightlike elementary particle horizons at which the induced metric becomes degenerate. At this 3-surface initial values can be given freely and this surface can be regarded as a correlate of self also. By the presence of this causal horizon, the entire system is not causally connected anymore. The 'hole' in H_p corresponds to the elementary particle horizons.

The entanglement mediated by join along boundaries bonds is possible between real spacetime sheets at different levels of the hierarchy but internal consistency requires that this entanglement is reduced in the state preparation process.

What about p-adic case? In p-adic context it is not possible to say whether p-adic number is negative or positive and the notions of spacelikeness and timelikeness do not seem to differ. The notion of lightlikeness makes still sense. It is not clear whether the generalized notion of subsystem is needed for a given value of p-adic prime p.

3.7   New view about time

Perhaps the most profound implications of TGD inspired theory of consciousness relate to the concept of time. There are two times and two causalities. The geometric time appearing in the field equations defining the spacetime surfaces and the subjective time defined by the sequence of quantum jumps. The causality associated with the geometric time is the causality of the classical laws of Nature related to passive events whereas the causality of the subjective time is the causality of deeds.

This distinction solves the paradox resulting from the non-determinism of state function collapse contra determinism of Schrödinger equation when one erranously identifies subjective time with geometric time. The two times have quite different properties. The dynamics with respect to subjective time is dissipative and irreversible whereas the dynamics with respect to geometric time is non-dissipative and reversible. Subjective future does not exist whereas geometric future exists and is in same position as the geometric past. These differences solve an impressive collection of paradoxes of modern physics.

3.7.1 The simplest view about psychological time

The contents of our sensory experience is localized around a definite value of geometric time. This seems to be in conflict with the hypothesis that quantum jumps occur between entire quantum histories suggesting that this kind of localization cannot occur. The solution is based on the non-determinism of the fundamental variational principle of the theory predicting the existence of spacetime surfaces differing only in a finite spacetime volume which means that the non-determinism of quantum jump and therefore also contents of conscious experience can be localized in a finite time interval. The so called mindlike spacetime sheets having a finite time duration and serving as correlates of selves realize this idea concretely. Psychological time can be defined as a center of mass time coordinate for the mindlike spacetime sheet and since spacetime surfaces are located inside future lightcone it is plausible that mindlike spacetime sheets drift gradually to the direction of the geometric future so that the arrow of psychological time results (see Fig. 3).

Psychological time becomes a local concept. This means that the entire spacetime surface must be regarded as a living system. This picture leads to the paradigms of the four-dimensional society and four-dimensional brain (see the chapter 'Time and Consciousness' of [cbook]). The civilizations of the geometric future and past exist subjectively now. My own body is lived through again and again and p-adic evolution implies that the quality of these relived lives improves in a statistical sense. Also classical and quantum communications between civilizations of past and future are in principle possible: there are even claims for the observations of this kind of signalling to the direction of past [Lavrentiev *et al*]. The hitherto most convinging TGD inspired model of long term memories relies on quantum communication between the brain of the geometric past and geometric now. What happens that the self at geometric now quantum entangles with the self of the geometric past and the experience is shared. Precognition is in principle also possible.

In quantum jump also our geometric past changes. This predicts various kinds of causal anomalies in which cause apparently occurs before effect. This kind of effects has been documented in brain science by Libet and in parapsychology by various experimenters [Deeke,Grötchinger and Kornhuber, Bierman & Radin (1997), Bierman&Radin (1998)]. What is fascinating is that the geometric past could change even in a time scale of years: even this is a testable prediction and there is indeed support for this effect [Peoch].

3.7.2 p-Adic-to-real phase transition transforms intentions to actions

One can represent objections against the proposed view about psychological time.

a) It does not explain the sharp difference between memories and intentions.

b) The assumption that the me of geometric past can make choises affecting the world in macroscopic scales should have dramatic effects to my life now. This is not the case and one should understand why the volition in my geometric past is so restricted that it perhaps affects only sensory and cognitive representations (our long term memories are indeed unstable).

c) It seems that at least the organisms able to communicate with each other must have common psychological time. Otherwise strange paradoxes result.

d) Both intentions and anticipations, memories, and sensory input from the geometric now contribute to my conscious experience: why the geometric now dominates so strongly

that it has led to the illusory identification of the geometric and subjective times?

A natural resolution of the problems related to the preferred role of single moment of time for conscious experience is based on the idea that biological growth and self-organization is a 4-dimensional phase transition proceeding in the direction of the geometric future quantum jump by quantum jump. And, in particular, that the dominating contribution to the conscious experience comes from the front of the phase transition where the volition is.

What is then this fundamental phase transition giving rise to what we call life? We know that the front of phase transition corresponds to volitional consciousness. We also know that volition as a transformation of intention to action in TGD universe corresponds to the p-adic-to-real phase transitions of spacetime spacetime sheets taking place in quantum jumps. Thus the natural conclusion is that p-adic-to-real phase transition is the fundamental phase transition inducing the biological self-organization. The difference betwen memories and intentions would be the difference between real and p-adic physics. This phase transition could occur for massless extremals (MEs) and perhaps also for the flux tubes of wormhole magnetic fields (and thus for magnetic mirrors) representing the plan for the evolution of the biological system and induce biological self-organization of matter around the resulting electromagnetic hologram like templates.

At least the selves at the same level of self hierarchy possess same value of psychological time. It might even be that the entire living biosphere (with magnetosphere included) could be seen as a phase transition front proceeding to the direction of the geometric future. This conclusion is of utmost importance since it leaves no other possibility that to accept that even biosphere defines conscious self and we correspond to only single level in the self hierarchy. In particular, the notion of collective consciousness is more or less 'a must' in this framework.

The fractality of TGD Universe suggests that there are phase transition fronts inside phase transition fronts each with their characteristic span with respect to the geometric time and age with respect to subjective time suffering the 4-dimensional analogs of cell decay and regeneration. One can imagine a fractal hierarchy of phase transition fronts in which subselves experience a common psychological time and experience the systems, whose psychological time is in the geometric future, more or less as dead because the degree of non-determinism in the geometric past of the four-dimensional body is low. Perhaps what we call non-living matter corresponds to life for which self-organization front is in the distant geometric future. Also the idea about gradual build-up of four-dimensional sculptures by 4-D phase transitions and their reversals at all levels of the self hierarchy looks attractive.

4 Biosystems as macroscopic quantum systems

The crucial elements in the theory of biosystems as macroscopic quantum systems are quantum criticality of TGD Universe and the notion of manysheeted spacetime.

4.1 Basic new physics effects

Concerning concrete application of the theory at level of biosystems and brain, the notion of manysheeted spacetime is of crucial importance since it makes possible to understand

how biosystems manage to be macroscopic quantum systems.

1. Generation of structures and topological field quantization

Manysheeted spacetime allows to understand topologically the generation of structures. Even the macroscopic objects of every day world correspond to spacetime sheets. The replacement of pointlike particles with 3-surfaces of arbitrarily large implies the crucial non-locality at spacetime level. Concerning the undestanding of bio-superconductivity the basic observation is that the space sheets which are much larger than atomic spacetime sheets contain very low densities of ordinary particles so that the temperature can be extremely low and macroscopic quantum phases are possible.

Topological field quantization implied both by topological reasons and by the absolute minimization of the Kähler action implies that spacetime surfaces are counterparts of Bohr orbits and have complex topology. This means that topologically relatively featureless linear Maxwell fields are replaced by extremely complex topological structures. The requirement that classical spacetime physics provides classical correlates for various quantum aspects of physical system leads to the view that the topological field quanta accompanying a given material system provide a representation for its quantum structure, kind of a manual. This topological self referentiality generalizes further to the idea that the inherent nondeterminism of the p-adic dynamics makes possible spacetime representation of quantum jump sequences and classical nondeterminism of Kähler action the nondeterminism inherent to the linguistic representations for the contents of consciousness of self. This in turn implies feedback loop to the configuration space level: configuration space spinor fields can represent (not faithfully) quantum jump sequences and thus the contents of consciousness associated with a sequence of quantum jumps (self), so that the ability to become conscious about being conscious about something can be understood. One can also speak about 'field body' (or actually hierarchy of them) as being associated with the material system. This field body, which is much larger than material system, serves as a sensory canvas at which sensory representations are realized and performs motor control.

2. Magnetic flux tubes and MEs as basic topological field quanta

Magnetic flux tubes are the simplest topological field quanta of magnetic fields and familiar already from superconductivity. By the quantization of the magnetic flux the thickness of the magnetic flux tubes of Earth's magnetic field is of order cell size (few microns) and the superconducting magnetic flux tubes are ideal seats for one-dimensional ionic and atomic superconductors. Magnetic flux tube structures define what might be called magnetic body in TGD based model for brain consciousness. Plasmons consisting of closed toruslike flux tube structures accompanied by ionized matter represent the simplest magnetic lifeforms and should serve as templates for various biostructures from DNA to neural circuits to blood circulation and also the field body associated with living system. The flow of ions between atomic spacetime sheet and magnetic flux tubes represents the fundamental realization of metabolism (see the chapter "Macroscopic quantum coherence and quantum metabolism as different sides of the same coin" of [cbook2]).

The so called massless extremals (MEs) define an extremely general class of solutions of field equantions. MEs can be regarded as topological field quanta of radiation fields and are in a key role in TGD. MEs are ideal for classical communications for several reasons. They carry lightlike vacuum em and/or Z^0 currents propagating with light velocity without dispersion. MEs with a cylindrical geometry represent high precision classical signalling possible over arbitrary long distances. The lightlike vacuum current at given transversal

section of ME is non-deterministic and thus optimal for coding classical information. MEs are also ideal for quantum communication and the lightlike boundaries of MEs act in a well-defined sense as quantum holograms. The lightlike em current associated with ME generates also patterns of coherent photons. MEs carry also so called supercanonical representations which are genuinely quantum gravitational states: state functionals in the set of 3-surfaces ('world of worlds') and thus represent higher abstraction level than ordinary matter. For these reasons MEs have taken the main role in TGD inspired theory of consciousness. MEs and magnetic flux serve also as field bridges acting as correlates of bound state entanglement making possible the fusion of subselves of different selves to form more complex shared mental images.

3. Also classical color and Z^0 fields are important

Also the classical color force and Z^0 force, which becomes strong in cellular length scale, play a key role in the new physics associated with the living matter. For instance, the classical Z^0 force explains the chiral selection occuring in living matter: in the standard model this phenonenon is a mystery since the weak interactions mediated by the quanta of Z^0 field are extremely weak. EEG MEs responsible for sensory representations at magnetic sensory canvas should be able to penetrate the Faraday cage defined by the ionosphere (and any Faraday cage) somehow. It is not clear whether em MEs can penetrate Faraday cages as such whereas Z^0 MEs certainly can. The transformation of Z^0 ME to em ME by a color rotation after it have penetrated through the Faraday cage defined by Earth's ionosphere could be a key element of the sensory representations. The simplest model consistent with this view is that Z^0 MEs (ZEG) mediate motor control from magnetic sensory canvas and the em MEs (EEG) obtained from them by color rotation mediate sensory input as a feedback.

4.2   Applications at the level of biocontrol and coordination

Some examples of application at the level biosystems are following.

1. Biological self hierarchy and p-adic length scale hypothesis

A model for biological self hierarchy which becomes quantitative by the application of the p-adic length scale hypothesis predicting a hierarchy of physically preferred length scales [padTGD]. For instance, p-adic length scale hypothesis allows to understand the special role of cell membrane length scale and cellular length scale as well as the resonance frequencies of EEG. What is perhaps most remarkable is that all four p-adic length scales between cell membrane thickness and bacterium size correspond to so called Gaussian Mersennes. Since very many elementary particle length scales correspond to Mersenne primes, one might expect that the miracle of life is closely related to this number theoretical miracle.

2. Homeostasis as manysheeted ionic flow equilibrium

A model for the biocontrol and coordination boiling down to a symbiosis of MEs with superconducting magnetic flux tube structures and ordinary matter at atomic spacetime sheets (see the chapter "Quantum Control and Coordination" of [cbook]). Manysheeted ionic flow equilibrium is a mechanism by which very small densities of superconducting matter can control ordinary matter effectively. MEs in turn control supra currents at magnetic flux tube structures by magnetic induction, by acting as Josephson junctions, and by inducing magnetic quantum phase transitions at multiples of magnetic transition frequencies which are in ELF range for Earth's magnetic field. The model explains the

anomalous effects of ELF em fields on biomatter [Cherry, Blackman (1994)] and strange findings challenging the notions of ionic pumps and channels [Pollack].

The effects [Smith] related to the imprinting and entraintment of frequencies representing homeopathic potency molecule, in particular the appearence of the frequencies as pairs (f_h, f_{ELF}) having homeostatically invariant ratio $f_h/f_{ELF} \simeq 2 \times 10^{11}$, provide further guidelines. There are two structures involved.

i) MEs parallel to magnetic flux tubes which are scaled down versions for those associated with our sensory representations and with long term memory mechanism. Thus water memory would be conscious and based on the same mechanism as ours. ME have length equal to wavelength associated with f_h and have this frequency as a fundamental frequency. MEs are identifiable as classical geometric correlates for the quantum transitions of the potency molecule. Remarkably, TGD predicts correctly the value of f_h/f_{ELF} ratio if f_h corresponds to the zero point kinetic energy liberated when an ion drops from an atomic spacetime sheet to the magnetic flux tube of Earth's magnetic field and f_{ELF} to the cyclotron frequency of ion in this field.

ii) Spacetime sheets associated with the blobs of liquid crystal water. f_{ELF} corresponds to the cyclotron frequency of the charged LC water blob in Earth's magnetic field. LC water blob provides a representation for the relevant rotational and possibly also vibrational levels of the molecule and amplifies resonantly f_h. LC water blobs can represent various biomolecules and amplify the frequencies f_h serving as their signatures. This makes possible a recognition mechanism based on common MEs giving rise to a resonant interaction ('alike likes alike' or 'singing in tune'). The mechanism might explain the generation of DNA conjugate strand, the ability of the aminoacid to find the corresponding RNA triplet, and the self assembly of the tobacco mosaic virus. Also the recognition of the invader molecules by the immune system might rely on the same mechanism.

3. Possible realizations of genetic and memetic codes

The simplest possible model for abstraction process predicts genetic code correctly and also what might be called memetic code (see the chapter "Genes and Memes" of [cbook2]). There are good reasons to assume that these codes are realized in many manners in living matter. A simple model for the laser mirror structure proposed on basis of experimental observations by Gariaev [Gariaev *et al*, Marcer] in terms of pairs of orthogonal ME-magnetic flux pairs associated with nucleotides could realize genetic code electromagnetically. These MEs presumably form a hierarchy with lengths varying *up to body size* (endogenous frequency f_h in GHz range). ME-magnetic flux tube pairs would not provide a mere copy of the chemical information but would define the genuinely electromagnetic part of the genetic information and guide morphogenesis in the length scales determined by their lengths. DNA thread would chemically code longitudinal degrees of freedom for a part of organism whereas MEs transversal to it would code for the transversal degrees of freedom (see chapters "Homeopathy in Manysheeted Spacetime", "Genes and Memes" and "Manysheeted DNA" of [cbook2]. The homeopathic effects observed by Cyril Smith [Smith] suggest a second realization of the genetic code discussed in the chapter "Quantum Model for Cognition" of [cbook2].

The model for the mesoscopic EEG patterns associated with 1-2 cm regions inside brain observed by Freeman [Freeman] suggest a further realization for genetic code (understood here simply as a code with 64 code words) resulting when 126 bit codewords of the memetic code at neuronal level are compressed to 6-bit codewords of the genetic code

at the mesoscopic level. p-Adic length scale hypothesis suggests that for the fundamental realization of memetic code the duration of codewords is .1 seconds and duration of single bit is about one millisecond. These are fundamental time scales in brain functioning. TGD based model for hearing leads to a realization for memetic code is in terms of cognitive neutrino pairs and predicts correctly the upper limit for audible frequencies.

4. Quantum model for EEG and nerve pulse

Quantum model for EEG and nerve pulse was one of the first applications of quantum TGD. The idea is that cell interior and exterior form weakly coupled superconductors connected by Josephson junctions. The simplest solutions of the model are soliton sequences depending only on time or on the longitudinal coordinate of axon. The first solution type is associated with standing EEG waves whereas the latter corresponds to a soliton sequence propagating along axon and could be associated with propagating EEG waves. It is tempting to identify nerve pulse sequences as being induced by the axonal soliton sequences. Stochastic resonance allows to amplify weak periodic input to a bistable system if noise with a suitable intensity is present. The signatures of stochastic resonance have been established in the time interval distribution for spikes [Gammaitoni *et al*]. The problem is that cell membrane is an excitable medium rather than bistable system. Josephson junction however represents bistable system and there is a strong tendency to assume that stochastic resonance occurs at the quantum control level.

5 Application at level of brain consciousness

5.1 Development of ideas

The understanding of brain consciousness is the challenge and test bed for the general theory of consciousness and vision about biosystems as macroscopic quantum systems.

a) The vision about universe as quantum critical quantum spin glass provides the general philosophy. Brain as a quantum spin glass paradigm allows to develop general visions and understanding about brain functioning but also mechanisms are needed.

b) The quantum model for nerve pulse and EEG based on weakly coupled superconductors formed by neuronal interior and exterior was the first attempt to understand brain at the quantum level. This model has gradually developed during years and is still developing.

c) The breakthrough came when I learned about the anomalous effects of ELF em fields on living matter [Cherry, Blackman (1994)] and led to realization that ELF MEs might be behind EEG in TGD framework and act as an electromagnetic lifeform controlling biomatter. It became clear that EEG is the most interesting signature of consciousness at our level of hierarchy whereas neurochemistry is a lower level phenomenon not so crucial when one wants to understand conscious experience at our level. The model of sensory qualia led to the notion of spectroscopy of consciousness according to which EEG is like spectrogram allowing to deduce huge amounts of information about contents of consciousness. The findings related to homeopathy have provided further valuable guidelines.

d) The model for sensory representations realized at magnetic sensory canvas; the model for mesoscopic EEG patterns representing 'features' based on ME and genetic code; and the identification of Z^0 MEs as the agent behind neuronal synchronization represent important steps in process binding the ideas about quantum brain to single coherent whole.

e) The real justification for the notion of magnetic sensory canvas came from the realization that any material system is accompanied by a field body serving in a well defined sense as a manual of the system (topological self referentiality). A further important realization was the observation that the entanglement of subselves of two separate selves generates more complex mental images shared by the selves. In case of sensory representations field body and material body share the mental image resulting as a fusion of a feature subself inside brain and a mental image representing simple 'feeling of existence' at the field body (this means assigment of a feature to given point of perceptive field).

5.2 A possible vision about quantum brain

TGD framework encourages strongly to give up the cherished belief about brain as a seat of consciousness. The following working vision seems to be plausible at least to me just now.

1. Brain and body as sensory organs of electromagnetic selves

In TGD framework life is self-organization phenomenon involving in essential manner Earth's magnetic field serving as template for the condensation of biomatter. In TGD universe our selves involve in essential manner electromagnetic field structures (topological field quanta) having size measured using Earth size as a natural unit. Our physical bodies can be seen as kind of sensory and motor organs of these electromagnetic selves. My personal magnetic (or field) body is one particular self of this kind. In particular, physical death can be seen only as a death of a mental image about the physical body. Besides my personal magnetic body there are also other field bodies: these higher levels selves are multibrained organism analogous to multicellulars and use our brains (in particular during sleep) for their own purposes. The entire magnetosphere forms can be regarded as a magnetic organism of this kind and we play the role of sensory receptors and motor organs of this magnetic Mother Gaia. It is quite possible that during sleep our selves entangle to form larger subselves (mental images) of the magnetic Mother Gaia: this fusion of mental images is much like the fusion of the left and right visual fields to a single visual field giving rise to stereovision.

2. Model of sensory representations

The model for sensory representations on magnetic sensory canvas is based on some very simple counter arguments against standard view. First, any computer scientist would argue that the processing of data and its representation must be separated completely: this requires that sensory representations are realized outside brain. Secondly, if head rotates also sensory representations inside brain should rotate and we should experience this rotation. We however do not experience this rotation which suggests that the sensory representations occur in a fixed inertial frame, perhaps outside brain. Thirdly, EEG frequencies correspond to wavelengths or order Earth size, which suggest that sensory representations are realized on structures of this size (our field bodies).

'Me as a computer sitting at is own terminal' metaphor leads to the idea that magnetic flux tube structures associated with brain serve as the personal sensory canvas to which 'sensory data files' in brain are projected. This sensory canvas is outside of brain and has size which can be as large as Earth's size and even larger (lightlife seems to provide a reasonable estimate for the size). MEs serve as projectors and frequency-place coding induces magnetic quantum phase transition at some distance along magnetic flux tube having slowly varying thickness: the distance is determined by the frequency. In this

manner it is possible to assign, not only simple sensory qualia (presumably at 40 Hz frequency band) to the points of the perceptive field but also more complex features. At quantum level sharing of mental images (feature in brain and 'feeling of existence' at some point of magnetic body) by entanglement is in question and EEG ME is a necessary prequisite for the generation of entanglement.

Also the projection of data at EEG frequencies to manybrained magnetospheric selves (magnetic flux tubes of Earth's magnetic field) representing higher collective levels of consciousness must be considered seriously. This idea has obviously far-reaching implications concerning various paranormal phenomena.

The simplest assumption is that MEs and magnetic flux tubes form parellel pairs acting effectively as laser mirrors: in this manner two amplification mechanism can be utilized since ME acts as resonant wave cavities interacting resonantly with the Alfven waves representing oscillations of magnetic flux tubes. Resonance condition fixes the distance at which a feature associated with a given frequency is assigned, and the requirement that magnetic transition frequency corresponds to this frequency leads to very stringent constraints on the representation and a close correspondence between EEG bands, brain structures, and magnetospheric structures emerges (see the chapters "Magnetic sensory canvas hypothesis" and "Magnetospheric sensory representations" of [cbook2]). Cavity resonances (in particular Schumann resonances) associated with spacetime sheet complex of Earth make possible horizontal communications between personal magnetic sensory canvases by sharing of mental images and could be responsible for the strange experiences associated with hypnagogy (experiencing directly what it is to be quite another person, say).

3. EEG patterns as correlates for features

Sensory canvas model splits sensory representations nicely from their production (the same occurs in computers!) and one of the remaining big challenges is to understand something about the general principles involved with the construction of the features assigned to the points of the sensory canvas. The idea that mesoscopic EEG patters associated with the 1-2 cm sized regions of cortex and having average duration of order .1 seconds, might correspond to MEs providing electromagnetic representation of memetic code by rapid amplitude modulations of waves in alpha band by multiples of alpha frequency, is very attractive. This kind of patters could be associated with other larger regions and EEG rhytms in theta and delta range and represent information usually not conscious-to-us.

4. p-Adic physics as physics of cognition and Z^0 MEs as synchronizers

A further basic challenge is to understand how p-adic physics as physics of cognition is realized in brain. Syncronized regions of brain define excellent candidates for subselves representing mental images: different sychronized brain areas could represent entangled subselves. Neuronal synchrony occurs in millisecond time scale. It is difficult to understand how this could occur if only neural circuits are involved. Rather, Z^0 MEs which are not visible in EEG directly should provide kHz rhytm serving as a pacemaker (note that kHz corresponds to the duration of the bit of the memetic code!).

The idea is natural since classical Z^0 force is strongest in cell length scale. Z^0 MEs are in passive and active states and passive state would be most be represented by p-adic Z^0 MEs representing thought/intention/plan.... When syncronization occurs seed stimulus at resonant frequency generates p-adic ME as a simulation of the oscillation and p-adic ME is resonantly transformed to real ME re-inforcing the seed of resonant oscillation so that

syncronous regions are generated in phase transition like manner when syncronized region syncronizes region to which it send excitatory nerve pulse patterns. This same mechanism could be quite general and also behind some psychokinetic phenomena.

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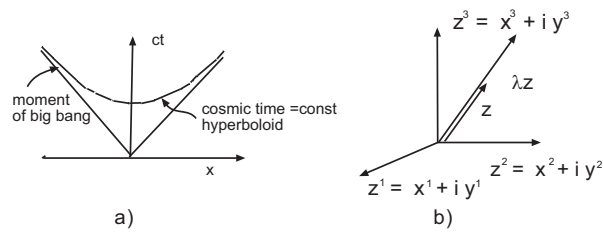
6 Figures

Figure 1: a) Future light cone of Minkowski space. b) CP_2 is obtained by identifying all points of C^3, space having 3 complex dimensions, which differ by a complex scaling Λ: z is identified with $\Lambda \times z$.
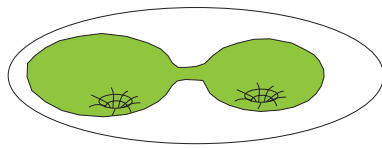

Figure 2: Wormhole contacts and join along boundaries bonds make possible transfer of energy, momentum, electric, magnetic and gravitational fluxes between spacetime sheets.
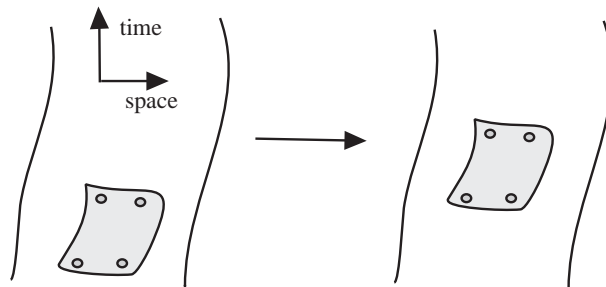

Figure 3: The mechanism giving rise to the arrow of psychological time. What happens is that gradually drifts in the direction of geometric future. Note that mindlike spacetime sheet has finite time duration.
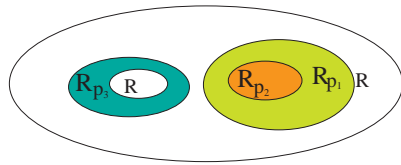
Figure 4: Spacetime surface decomposes into real and p-adic regions serving as geometric correlates for matter and cognition