p-Adic Physics as Physics of Cognition and Intention

M. Pitkänen,

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Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Recent postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland.

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Abstract

TGD as a generalized number theory vision supports the interpretation of the p-adic physics in terms of physical correlates of cognition and intentionality so that matter-mind dichotomy would correspond to real–p-adic dichotomy at the level of the geometric correlates of mind. This interpretation has far reaching implications for both TGD inspired theory of consciousness and for the general world view provided by TGD. Cognition is predicted to be present in all length scales and the success of the p-adic physics in elementary particle length scales forces to conclude that cognition and intention are present even at this level.

The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is the key guiding principle also in TGD inspired quantum biology. The very fact that the notion of conscious information makes sense only in this intersection supports the proposed interpretation of p-adic physics. Zero energy ontology (ZEO) and the notion of causal diamond (CD) with zero energy states having interpretation as memes in very general sense is also of central importance, and allows a quantitative formulation reducing the fundamental bio-rhythms to fundamental elementary particle time scales. The hierarchy of Planck constants as an explanation of dark matter and energy as macroscopic quantum phases even in astrophysical scales and implying that dark matter is a key actor in the drama of life is the third key element.

In this chapter the implications of this vision are studied from the point of view of cognitive consciousness. The basic ideas behind the proposed vision about intentionality and cognition are following.

1. p-Adic space-time sheets are identified as the correlates of cognition and intention. The possibility to identify the inherent non-determinism of the p-adic field equations as the non-determinism of imagination makes this identification attractive. Only the p-adic space-time sheets in the intersection of real and p-adic worlds allow the transformation of intentions to actions and sensory input to cognitions. Cognitions and intentions are related by time reversal in zero energy ontology. The common algebraic points of real and p-adic partonic 2-surfaces in the algebraic extension or rationals guaranteing that the representation of 2-surface makes sense both in real and p-adic senses define fundamental cognitive representations as finite point sets.
2. The "phase transition" of a p-adic space-time sheet to a real space-time sheet taking place in quantum jump between quantum histories corresponds to the transformation of a thought into action or sensory experience (during dreams and hallucinations) whereas the reverse transformation corresponds to the transformation of the sensory input into cognition. This transition can be thought to occur in the intersection of real and p-adic worlds where the mathematical representations of partonic 2-surface make sense both in real and p-adic sense. Motor action would correspond to the transformation of p-adic space-time sheets to their real counterparts and during sensory experience the reversal of this transformation would take place. In zero energy ontology these transformations could reduce to quark and lepton level as is suggested by the fact that the time scales assignable to quarks and leptons correspond to 1 ms and .1 s defining fundamental time scales of nerve pulse activity and EEG.
3. The obvious question is how to test p-adic physics empirically. First of all, thinking could be interpreted as p-adic sensory experiencing. Hence the reduction of theories–experimental science dichotomy to p-adic–real dichotomy seems natural: just like experimental science is an extension of everyday real sensory experience, theories represent an extension of everyday p-adic sensory experience (common sense thinking). Thus the basic test is how well p-adic physics based theories describe cognition. Secondly, the p-adic models for physical systems are strictly speaking models for cognitive models for real physics. The successes of these highly predictive models (consider only p-adic elementary particle mass calculations involving only very few integer valued parameters) supports the vision about p-adic physics as physics of cognition. p-Adic–real phase transitions as models for how thought is transformed to action and sensory input to thought provide a further testing ground for the new paradigm.

The following topics are discussed in the chapter.

1. The relationship between p-adic physics, intentionality, and cognition are discussed on general level. Basic cognitive functions such as imagination, hallucinations, formation of cognitive representations, Boolean mind, and learning are discussed in this conceptual framework.

2. Possible - necessarily indirect - evidence for p-adic cognition is considered.
3. In the mathematical sections the relationship between intentionality, cognition and number theory is discussed. Also the relation between p-adic and real physics is discussed at general level with basic vision being that the intersection of real and p-adic space-time sheets in the intersection of real and p-adic worlds consists of points belonging to the algebraic extension of rational needed to guarantee that the mathematical representation of the partonic 2-surface makes sense both in real and p-adic sense.
4. Frontal lobes are known to be the seat of the higher level intentional action and are discussed from p-adic point of view.
5. A generalization of the memetic code to cognitive codes is discussed and some proposals about codes are made. This generalization is based on p-adic length scale hypothesis. If the time scales involved correspond to time scales assignable to the CDs of the known elementary particles, the generalization is not favored. On the other hand, dark matter sector could allow entire fractal hierarchy of elementary particle physics whose existence is reflected as fundamental bio-rhytms and cognitive codes.
6. The intersection of real and p-adic partonic 2-surfaces defining space-like cognitive representations consist of algebraic points. The hypothesis that these intersections obey various kind of symmetries identifiable as molecular symmetries is discussed.

1 Introduction

TGD as a generalized number theory vision stimulates the hypothesis about p-adic physics provides the physical correlates of cognition and imagination. This interpretation has far reaching implications for both TGD inspired theory of consciousness and for the general world view provided by TGD. cognition is predicted to be present in all length scales and the success of the p-adic physics in elementary particle length scales forces to conclude that cognition is present even at this level. In this chapter these implications are studied from the point of view of cognitive consciousness.

The view about cognition relies also heavily on the developents that have occurred during the last ten years in the understanding of TGD. The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is certainly the most important aspect in this respect and the very fact that the notion of conscious information makes sense only in this intersection supports the proposed interpretation of p-adic physics. Zero energy ontology and the notion of causal diamond (CD) with zero energy states having interpretation as memes in very general sense is also of central importance. The hierarchy of Planck constants assigned with a hierarchy of quantum criticalities as an explanation of dark matter and energy as macroscopic quantum phases even in astrophysical scales and implying that dark matter is a key actor in the drama of life is the third key element.

1.1 Clarifying Some Basic Concepts

Before continuing it is could to clarify basic conceps.

The earlier view was that p-adic space-time surfaces are correlates for both cognition and intentionaity. The recent view is that p-adic space-time sheets correspond only to cognition and that their intersections with real space-time sheets in the intersection of real and p-adic worlds (intersection briefly) define cognitive representations. These representations are defined in terms of the data coming from the rational and algebraic points common to real and partonic 2-surfaces with the algebraic extension in question characterized by the mathematical representation of the partonic 2-surfaces making sense for both real and p-adic 2-surfaces simultaneously. The immediate powerful implication is that the algebraic extensions of rationals define a cognitive hierarchy. One can also understand preferred p-adic primes as so called ramified primes of the extension and NMP suggests strongly an extension of p-adic length scale hypothesis.

The original view was that cognitive representations as p-adic space-time surfaces are built and define images of real space-time surface [K34]: the problems with symmetries forced to challenge this view. The recent view is adelic. Space-time surfaces are adeles with a book-like structure with pages representing preferred extremals of Kähler action in various number fields, and real and p-adic space-time sheets serve as correlates of sensory experience and cognition are present in all

length scales and for all systems, even elementary particles. The success of p-adic mass calculations conforms with this assumption.

TGD must be number theoretically universal in order to have a first principle description of conscious intelligence and cognition and the algebraic continuation from the intersection to various number fields from the back of Big Book allows to realize this idea.

The earlier view about discretization was that space-time surfaces are replaced with discrete point sets defined by points of surface for which imbedding space coordinates are in an extension of rationals. This led to problems with symmetries and general coordinate invariance. Discretization is more abstract than originally believed and occurs at the level of "world of classical worlds" (WCW). Co-dimension two rule holds true. n-dimensional object is discretized as a collection of $n-2$-dimensional objects. In the case of space-time surfaces the lower-dimensional objects are string world sheets and partonic 2-surfaces: co-dimension 2 rule is equivalent with the strong form of holography. The discretization is physically: physics itself defines its representation with finite resolution. Discretization occurs for the parameters (conformal moduli) characterizing these 2-surfaces and the parameters - naturally conformal moduli - are in some algebraic extension of rationals so that the space-time surfaces themselves are not discretized. This allows to get of rid of difficulties as one tries to map real and p-adic space-time surfaces to each other locally.

The classical non-determinism of Kähler action quite generally implies that space-time surfaces define what might be called symbolic representations realizing quantum classical correspondence. This applies irrespective of the number field used and in p-adic context p-adic non-determinism is an additional ingredient. For instance, nerve pulse patterns define symbolic real physics representations of the sensory input but do not give rise to sensory qualia which reside at the level of the primary sensory organs (contrary to the expectations raised by various findings of neuro-science). Sensory experience is always a multiverse experience since sensory qualia have quantum number increments as quantum correlates, and is thus not reducible to the level of space-time.

I have use also the notions of meme and morphic field. One could defend the identification of the geometric correlates of memes and morphic fields as p-adic space-time sheets. On the other, all negentropic quantum states in zero energy ontology have the character of a rule A→B, where quantum superposition represents various instances $a \to b$ of the rule and one could say that every negentropic zero energy state can be seen as a meme. I leave the choice between these interpretations for the reader.

1.2 Basic Vision

It is useful to summarize the recent TGD inspired view about quantum biology and conscious intelligence since it serves as background for the chapter.

1.2.1 Magnetic body as intentional agent and experiencer

The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism [K3].

The magnetic body of Earth - magnetic Mother Gaia - could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

Magnetic flux tubes and flux sheets are basic building bricks of the magnetic body and DNA as topological quantum computer hypothesis assumes that DNA nucleotides are connected to cell membrane by flux tubes defining braids playing a key role in topological quantum computation [K5]. Therefore magnetic body is essential for realizing the software of biological intelligence. The essential assumption is that magnetic body carries dark matter consisting of ordinary with a non-standard value of Planck constant. The phase transition changing the value of Planck constant change the size scale of the flux tube and this process together with reconnection of the flux tubes would define mechanisms of bio-catalysis.

1.2.2 Zero energy ontology, causal diamonds, and identification of memes

In zero energy ontology (ZEO) physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds (CDs) defined as pairs of future and past directed light-cones ($\delta M^4_{\pm} \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology.

Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in zero energy ontology. ZEO leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II_1 [K28]. The space-time correlate for the finite resolution is discretization in terms of string world sheets and partonic 2-surfaces forced also by the well-definedness of em charge for Kähler-Dirac action [K29].

At the imbedding space-level CD serves as a correlate of self whereas space-time sheets having their ends at the light-like boundaries of CD - more precisely, partonic 2-surfaces and the distributions of the 4-D tangent spaces of space-time sheet associated with them - are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves. Zero energy ontology leads also to an argument explaining why the arrow of subjective time induces an apparent arrow of geometric time as a result if intentional action and why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD) [K26, K1].

The original interpretation of the space-time correlates of mental images was as "mind-like" space-time sheets identified as space-time sheets with a finite temporal size. In zero energy ontology all space-time sheets have a finite size and serve as correlates for zero energy states, which could be interpreted as representations of laws of physics as superpositions of pairs of initial and final states given by M-matrix. In state function reduction process these states are reduced to states for which only negentropic time-like entanglement is possible and one might say that the negentropy measures the conscious information associated with the final state of the reduction process. One can interpret negentropic quantum states as memes or morphogenetic fields [K20]. [I7] These negentropic quantum states are possible only in the intersection of real and p-adic worlds so that living systems are the systems carrying information and intelligence.

1.2.3 Boolean mind and fermions

The connection of fermionic Fock space basis with Boolean algebra was one of the first ideas related to the quantum modelling of intelligent systems. The state basis for the fermionic Fock space has a natural interpretation as Boolean algebra (fermion number $=1/0 \leftrightarrow$ yes/no). In this manner ordinary Boolean algebra is extended to a vector space spanned by fermionic states. Fermion number conservation poses an obvious problem for this scenario in positive energy ontology. Zero energy ontology resolves this problem quite generally and zero energy states resulting as an outcome of state function reduction process represent Boolean statements of type A$\rightarrow$ B in terms of time-like negentropic entanglement in fermionic degreees of freedom.

The original proposal was to use cognitive fermion pairs instead of fermions with fermion and anti-fermion located at the opposite throats of wormhole contact. In the recent formulation of quantum TGD bosons and their super counterparts correspond to wormhole contacts. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for

the complex quantum logic and whether our logical mind could have something to do with Boolean algebra. For instance, could primary "this is true" experiences correspond to Boolean qualia having increments of fermionic quantum numbers as physical correlates. Boolean truth values could also correspond to spin directions of fermions. In this case fermion number conservation does not pose any constraints and the macroscopic realization replaing single spin as a representative of bit with a magnetized ensemble of fermions, makes the realization robust.

Negentropic entanglement (NE) means that qubits are always fuzzy and the fuzziness depends on the situation. The positive aspect is that the quantum superposition gives rise to an abstraction, rule about pairing of say initial and final states represented as positive and negative energy parts of zero energy state with the pairs of superposition representing the instances of the rule. p-Adic-real entanglement with positive definite number theoretical entanglement entropy in the intersection could give rise the experience of understanding and makes possible cognitive quantum computation like processes. Interestingly, negentropic entanglement corresponds to an entanglement matrix characterized by a unitary matrix encountered in quantum computation.

1.2.4 p-Adic physics as physics of cognition and imagination

The vision about p-adic physics as physics of cognition has gradually established itself as one of the key idea of TGD inspired theory of consciousness. There are several motivations for this idea.

The strongest motivation is the vision about living matter as something residing in the intersection of real and p-adic worlds. One of the earliest motivations was p-adic non-determinism identified tentatively as a space-time correlate for the non-determinism of imagination. 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 pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the 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 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 pinary 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. 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 looking interpretation for the solutions of the p-adic field equations would be as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general could have p-adic space-time sheets as their geometric correlates. A deep principle could 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.

The original idea was that p-adic space-time regions can suffer topological phase transitions to real topology and vice versa in quantum jumps replacing space-time surface with a new one is given up as mathematically awkward: quantum jumps between different number fields do not make sense. The new adelic view states that both real and p-adic space-time sheets are obtained by continuation of string world sheets and partonic 2-surfaces to various number fields by strong form of holography.

The idea about p-adic pseudo constants as correlates of imagination is however too nice to be thrown away without trying to find an alternative interpretation consistent with strong form of holography. Could the following argument allow to save p-adic view about imagination in a mathematically respectable manner?

1. Construction of preferred extremals from data at 2-surfaces is like boundary value problem. Integration constants are replaced with pseudo-constants depending on finite number pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces.

2. Preferred extremal property in real context implies strong correlations between string world sheets and partonic 2-surfaces by boundary conditions a them. One cannot choose these

2- surfaces completely independently. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets and partonic 2-surfaces not allowed in real context and realizing imagination.

3. Could imagination be realized as a larger size of the p-adic sectors of WCW? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could the modes of WCW spinor fields for which 2-surfaces are extandable to space-time surfaces only in some p-adic sectors make sense? The real space-time surface for them be somehow degenerate, for instance, consisting of string world sheets only. Could imagination be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real preferred extremals? p-Adic physics would be there as an independent aspect of existence and this is just the original idea. Imagination could be realized in state function reduction, which always selects only those 2-surfaces which allow continuation to real space-time surfaces. The distinction between only imaginable and also realizable would be the extendability by using strong form of holography.

Although p-adic space-time sheets as such are not conscious, p-adic physics would provide a beautiful mathematical realization for the intuitions of Descartes. The formidable challenge is to develop experimental tests for p-adic physics. The basic problem is that we can perceive p-adic reality only as "thoughts" unlike the "real" reality, which represents itself to us as sensory experiences. Thus it would seem that we should be able generalize the physics of sensory experiences to physics of cognitive experiences.

1.2.5 Life as something in the intersection of real and p-adic worlds and negentropic entanglement

In the p-adic context one must modify Shannon's definition of entropy by replacing the ordinary logarithm based on p-adic norm. This definition gives rise to a real valued entropy in both real and p-adic contexts if entanglement coefficients are rational/algebraic numbers. For irrational/non-algebraic entanglement standard Shannon formula and its p-adic variant must be used and gives rise to non-negative entropy. Unlike Shannon entropy, the p-adic entropies (one for each p) can be also negative so that the entanglement entropy defines a genuine information measure whose sign tells whether the system contains information or dis-information. For the p-adic entropies Negentropy Maximization Principle (NMP) [K13] tends to preserve the quantum coherence if p divides the common denominator of the entanglement probabilities. The states with rational/algebraic entanglement can be regarded as new kind of states analogous to bound, which are not at all fragile like the states with non-algebraic entanglement are. In particular, these states need not be bound due to the binding energy.

For instance, the problematic notion of high energy phosphate bond might be understood in terms of negentropic entanglement making possible correlations without binding energy so that the ATP→ADP process defining fundamental step of metabolism could be interpreted in terms of negentropy transfer. Negentropic entanglement is highly stable in state function reduction process so that the randomness of quantum jump does not apply to it. Weak form of NMP [K13, K37] supports this view and allows also to derive a generalization of p-adic length scale hypothesis.

Although the entropy of second law is ensemble entropy and one cannot expect second law to be in conflict with NMP, breakdown of the second law of thermodynamics might be implied by NMP in the scale defined by the size of CD involved: consider only transformation of thermal ensemble to single dark particle for which original particles are negentropically entangled. Certainly it requires a generalization to take into account the possibility that the arrow of geometric time changes in volitional acts meaning death of self at some level of self hierarchy.

I have proposed that sub-selves lose consciousness as ordinary entropic bound state entanglement is generated but experience expansion of consciousness when negentropic entanglement is generated. Positive emotions like love, experience of understanding would naturally accompany the generation of negentropic entanglement.

These observations suggest a purely number-theoretic characterization of life: life is in the intersection of real and p-adic worlds: life corresponds to islands of rational/algebraic numbers in the seas of real and p-adic continua. This vision have rapidly become the most important source of insight in attempts to develop TGD based vision about conscious intelligence and cognition.

As explained, strong form of holography following from strong form of GCI allows to identify the intersection of reality and p-adicities as string world sheets and partonic 2-surfaces for which defining parameters (relevant WCW coordinates characterizing them physically) are in some algebraic extension of rationals defining also algebraic extension of p-adic numbers. Parameters correspond to conformal moduli, which are GCI invariants.

These surfaces define space-time surfaces by holography, and general space-time surfaces in various number fields are obtained by algebraic continuation of parameters to reals and various p-adic number fields. Also adelic scattering amplitudes are obtained in the similar manner from those in the intersection. Induced spinor fields are localized to these 2-surfaces - this guarantees the well-definedness of em charge - and fermions can be interpreted as correlates for Boolean cognition. The hierarchy of algebraic extensions of rationals becomes the characterizer of the fundamental cognitive hierarchy. So called ramified primes define preferred p-adic primes and NMP allows to deduced generalization of p-adic length scale hypothesis. Hence rather concrete view about number theoretical aspects of cognition emerges.

1.3 Topics Of The Chapter

The topics of the chapter is as follows.

1. The relationship between p-adic physics of cognition is discussed on general level. Possible evidence for p-adic cognition is considered.

2. In the mathematical sections the relationship between cognition and number theory is discussed. Also the relationship between p-adic and real physics is discussed at general level with basic vision being that the intersection of real and p-adic space-time sheets in the intersection of real and p-adic worlds consists of points belonging to the algebraic extension of rational needed to guarantee that the mathematical representation of the partonic 2-surface makes sense both in real and p-adic sense.

3. Frontal lobes are known to be the seat of the higher level cognition and also responsible for intentional action and are discussed from p-adic point of view.

4. A generalization of the memetic code to cognitive codes is discussed and some proposals about codes are made. This generalization is based on p-adic length scale hypothesis and the condition that the time scales involved correspond to time scales assignable to the CDs of the known elementary particles does not favor the generalization. On the other hand, the dark matter sector could allow entire fractal hierarchy of elementary particle physics whose existence is reflected as fundamental bio-rhythms and cognitive codes.

5. The intersection of real and p-adic partonic 2-surfaces defining space-like cognitive representations consist of algebraic points. The hypothesis that these intersections obey various kind of symmetries identifiable as molecular symmetries is discussed.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L2].

2 P-Adic Physics And Cognition

The basic vision based on adelic TGD is that p-adic space-time sheets serve as correlates for cognition. The original idea that that the transformation if intention to action is realized as a quantum jump replacing p-adic space-time region with a real one is given up for both mathematical difficulties and the fact that there is no need for this in Zero Energy Ontology (ZEO), where development of intentions and volitional action can be understood differently.

2.1 The Three Non-Determinisms

TGD Universe is characterized by a "holy trinity" of non-determinisms. The first non-determinism is associated with quantum jumps between quantum histories and is what makes possible subjective existence and consciousness. One achieve determinism by giving up the assumption that initial values at fixed time define the time evolution and replaces 3-dimensional sections of space-time surface with what I have called mind-like space-time sheets. The attempt to realize this picture geometrically led to ZEO.

Second non-determinism is classical non-determinism of Kähler action and is closely related to quantum criticality. It is also relevant for symbolic representations and perhaps serves as a correlate for macroscopic volition. The third non-determinism is inherent to all p-adic field equations and might relate to the non-determinism of imagination and thus makes possible cognition and intentionality. There is no conscious experience associated with classical nor with p-adic non-determinism as dualist might think. These three non-determinisms have are candidates for be basic building bricks of TGD inspired theory of consciousness.

The original identification of the geometric correlates of selves was as "mind-like" space-time sheets. In zero energy ontology (ZEO) all space-time sheets satisfy the criterion for mind-likeness and therefore serve as correlates for selves.

Classical and p-adic non-determinisms inspired the the notion of association sequence defined as a sequence of space like 3-surfaces with time like separations determining uniquely the preferred extremal going through these 3-surfaces. In the case of CP_2 vacuum type extremals discrete association sequences become in principle continuous sequences of 3-surfaces but topological condensation is expected to reduce this non-determinism to its discrete version. It has however turned out that the notion of association sequence is redundant. The hierarchy of causal diamonds (CDs) defining kind of spot-lights of consciousness and serving as correlates of selves is the natural notion. Mind-like space-time sheets correspond to space-time surfaces inside CDs.

2.2 Classical Non-Determinism And Symbolic Representations

In the special case that classical non-determinism gives rise to macroscopic multi-furcations of the time development of 3-surface, it is tempting to identify the branches of the multi-furcations as alternative choices involved with volitional acts. Contrary to the long held beliefs, it however seems that classical non-determinism is most naturally associated with symbolic representations understood in a very general sense (one could even understand classical space-time surfaces as symbolic representations of quantum dynamics). The assignment of sensory experiences with real mind like space-time sheets explains why the contents of sensory experiences are localized with respect to geometric time.

The book "Gödel, Escher, Bach" by Douglas Hofstadter about self-reference has been perhaps the most fascinating of my intellectual arm chair adventures and it stimulated the dream about the identification of the physical counterpart of self-reference. The physics as a generalized number theory vision stimulated concrete ideas about how this self-reference might be realized in terms of quantum universe repeatedly re-creating itself. The quantum jump building sensory and cognitive representations about the Universe means the replacement of the Universe with a new one containing these representations. Hence the paradoxical infinite regress resulting from the assumption that it is possible to be conscious about what one is conscious of is avoided with a simple modification of this assumption by replacing "is" with "was". By quantum classical correspondence this vision requires also the failure of classical determinism in the conventional sense of the word.

In accordance with the crossing symmetry of standard quantum field theories, one can interpret the elements of M-matrix (generalization of S-matrix in TGD framework) as time-like entanglement coefficients between positive and negative energy parts of the zero energy state with incoming and outgoing particles having positive and negative energies respectively. Thus the classical non-determinism and zero energy ontology make possible for the TGD Universe according to represent the laws of physics in the structure of the zero energy physical states. That all possible vacua provide representation for physics is very much akin to the ideas of Eastern philosophies, and is bound to have deep implications from the point of view of TGD inspired theory of consciousness.

2.3 Basic Vision About Qualia

Before proceeding it is useful to summarize the basic view about sensory qualia [K8].

1. Geometric qualia correspond to the increments of WCW zero modes in quantum jump and are cognitive qualia. Shape, size, length duration, ... etc. are good examples of geometric qualia. Real geometric qualia could be also called symbolic qualia. The universe of symbolic representations is completely classical if a complete localization in the zero modes occurs in each quantum jump. It is not completely clear whether this must be the case also in the real WCW degrees of freedom. In p-adic WCW degrees (WCW, "the world of classical worlds") of freedom it must take place so that cognition would be completely classical. The moduli space for CDs is an excellent candidate for the fundamental geometric qualia [K21, K19].

2. Sensory qualia correspond to the increments of quantum numbers related to the quantum fluctuating degrees of freedom, non-zero modes. They are genuine multi-verse qualia since the final states of quantum jumps are superpositions of space-time surfaces with varying values of non-zero modes. One cannot understand color red in terms of space-time geometry.

3. The trinity sensory-symbolic-cognitive is central for understanding consciousness in TGD framework. Also the division to fermionic (WCW spinor) and WCW degrees of freedom at the level of qualia is important. Fermionic qualia correspond to Boolean qualia and are number theoretical universal. WCW qualia correspond to geometric and sensory qualia. If cognition and sensory experience is restricted to the intersection also these qualia would be number theoretically universal. The original idea was that sensory qualia could be assigned with real physics. One can also speak about geometric qualia having both real and p-adic counterparts. These would be abstact qualia like position, velocity, etc...

2.4 The New View About Intentional Actions

The original rather naive view that volitional acts involve a quantum jump transforming p-adic space-time sheet to a real one has turned out to be mathematically unfeasible. The new adelic view about the fusion of real and p-adic physics makes this idea also un-necessary. Cognition is present always and everywhere and ZEO based view about quantum jump allows to understand volitional act as initiated by the first state function reduction at the opposite boundary of CD in which self dies and re-incarnates. Intention develops during the sequence of repeated state function reductions and is how NMP forcing this reduction to eventually occur is experienced consciously. It has both cognitive and sensory components (plan and desire). One can say that sensory perceptions and motor actions are time reversals of each other and correspond to opposite boundaries of CD.

2.4.1 Volitional act as a quantum jump transforming p-adic space-time sheet to a real one?

If one accepts the idea that real and p-adic space-time regions are correlates for matter and cognition, one encounters the question how matter and mind interact. As already noticed, the first guess for this interaction was the quantum jump replacing real space-time regions with p-adic ones and vice versa. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or intention to an action. The reverse phase transition would relate to the transformation of the sensory experience to cognition.

It turned out that this idea raises mathematical challenges, which are probably too heavy. Instead, one can assume that the Universe is adelic. Real and p-adic existences form a Cartesian product so that an adele is obtained. Cognitive aspects of existence correspond to various p-adic variants of the space-time surface.

p-Adic space-time sheets would indeed define a theory about real space-time sheets. The interaction between real and p-adic number fields would mean that p-adic space-time surfaces define cognitive representations of real space-time surfaces (preferred extremals). One could also say that real space-time surface represents sensory aspects of conscious experience and p-adic space-time surfaces its cognitive aspects. Both real and p-adics rather than real or p-adics.

Strong form of holography implied by strong form of General Coordinate Invariance (GCI) leads to the suggestion that partonic 2-surfaces and string world sheets at which the induced spinor

fields are localized in order to have a well-defined em charge (this is only one of the many reasons) and having having discrete set as intersection points with partonic 2-surfaces define what might called "space-time genes". Space-time surfaces would be obtained as preferred extremals satisfying certain boundary conditions at string world sheets and carrying vanishing super-symplectic Noether charges in a sub-algebra for which conformal weights are n-multiples of those for the entire algebra. Space-time surfaces are defined only modulo transformations of this algebra acting as conformal gauge transformations so that one can talk about conformal gauge equivalences classes of space-time surfaces.

The map assigning to real space-time surface a cognitive representation would be replaced by a correspondence assigning to the string world sheets preferred extremals of Kähler action in various number fields: string world sheets would be "space-time genes". String world sheets would be in the intersection of realities and p-adicities in the sense that the parameters characterizing them would be algebraic numbers associated with the algebraic extension of p-adic numbers in question. It is not clear whether the preferred extremal is possible for all p-adic primes but this would fit nicely with the vision that elementary particles are characterized by p-adic primes. It could be also that the classical non-determinism of Kähler action responsible for the conformal gauge symmetry corresponds to p-adic non-determinism for some particular prime so that the cognitive map is especially good for this prime.

2.4.2 Volitional actions as first state function reductions to the opposite boundary of CD

Adelic vision forces to modify the original view about intentional action. Ontology (ZEO) volitional action begins with the first state function reduction to the opposite boundary of causal diamond (CD) involving "death" of corresponding self and re-incarnation at opposite boundary [K27, K1]. Intention develops during the sequence of state function reductions at same boundary of CD as a mental state of self. Basically NMP gradually forces self to make the first state function reduction to the opposite boundary and this is experienced as gradually maturing decition to realize the act of volition. In this profess self dies and re-incarnates at opposite boundary. We experience these deaths as disappearances of mental images.

A more concrete picture about the acts of volition would rely on generation of negative energy MEs representing signals propagating backwards in geometric time when the first state function reduction at the opposite boundary of CD changes the arrow of geometric time.

1. Although ZEO in principle allows a creation of zero energy states with arbitrarily large energies of positive energy part of the state as analogs of quantum fluctuations, the condition that the entanglement is negentropic poses energetic constraints. The interpretation of metabolic energy transfer as transfer of negentropic entanglement (NE) allows to understand the somewhat foggy concept of energetic phosphate bond central for ATP-ADP process [K7]. What is transferred in this process would be negentropy rather than mere energy.

2. Em fields, in particular ELF em fields, are crucial for TGD inspired model of brain and a natural question. I have proposed the generation MEs as a mechanism of coherent locomotion made possible by the maximally coherent momentum carried by ME and resulting as a recoil momentum of material system absorbing second ME. In fact, the mechanism is optimal since the momentum of ME is completely coherent. Thus a possible interpretation is as a transformation of intention to real motion. Of course, it is difficult to say whether this mechanism occurs in cellular or micro-tubular length scales or perhaps even in macroscopic lengths scales. And there are certainly also other mechanisms.

A more refined picture about the realization of volitional action emerges, when one asks how a precisely targeted intention could be realized at the atomic or molecular level.

1. The change must involve energetic changes in the scale of the entire system so that the quantum numbers characterizing the positive energy part of the state change. This includes energy and momentum. It seems safe to assume that zero energy states are created in rather small length scales and that macroscopic systems cannot transform between real and p-adic states. Hence the bottle neck step of the process would be the generation of zero energy states

from vacuum as sub-CD with a rather short characteristic time scale and their subsequent interaction with the existing state inducing the desired action.

2. This favors the generation of zero energy states representing elementary particles and electrons and quarks are excellent candidates in this respect for reasons that should be already clear. The sub-CD created from vacuum could be p-adic and transform to a real one and interact with the background to induce the transition. Protons and electrons are key actors in bio-catalysis and TGD forces to consider the possibility that at least electron and quarks exist only in the sense of zero energy ontology.

3. The creation of sub-CD can be interpreted direction of attention of CD to a particular spatiotemporal region inside it. If this region is near vacuum extremal it is critical and the subsequent interaction of sub-CD with 4-D environment can induce a large change of the entire system.

Another view about motor action is as negative energy signal sent to the geometric past and inducing a neural activity leading to the motor action as a consequence. This view conforms with the findings of Libet and others [J3]. It should be possible to fuse these two views together.

1. The intention can be realized in a precisely targeted manner only for the transitions which do not occur spontaneously, and thus involve the emission of negative energy MEs. For a transition involving emission of positive energy, the direction of ME is random so that targeted intentional action is not possible.

2. The emission of negative energy ME translates to a quantum jump in which the energy of the positive energy part of zero energy state increases in the interaction with sub-CD or some other CD. The generation of negative energy MEs would utilize the quantum credit card mechanism of metabolism implying extreme flexibility.

3. Quantum credit card mechanism requires the existence of a system analogous to a population reversed laser. The TGD based model for metabolism assumes that electrons or protons kicked to a small space-time sheet provide this system and that their dropping to a larger space-time liberates zero point kinetic energy as metabolic energy. Hence sensory, cognitive and memory representations would be realized in terms of positive energy MEs spontaneously whereas intentionality and motor actions would be much like time reversed sensory representations and realized in terms of negative energy MEs.

2.4.3 Motor actions as time reversed perceptions

ZEO view about self allows to see motor actions as time reversed perceptions. This allows a simple view about imagined motor activities. Imagined motor actions would be sensory percepts with stimulus generated at some level above muscles - rather than at brain! - and proceed to the cortex as time reversed activities as far as the MEs controlling these activities are considered. If looked in standard time direction they would start from brain and end at some level before ending to the muscles. In a symmetric manner, imagination would correspond to virtual percepts with sensory input generated at level of neural pathways above sensory organs involving perhaps virtual sensory input from higher level.

Negative energies make possible precisely targeted intention. There is no need to stop the imagined motor action so that it is not a safety risk. It is possible to learn motor actions by initiating them from a level above the muscles. Time reversal means negative energies for MEs and buy now-let others pay mechanism implies extreme flexibility. Time reversed dissipation can be interpreted as a healing mechanism since entropy decreases in the standard direction of the geometric time. ZEO view about self organization allows to see motor action as a carving of a four-dimensional statue by a gradual refinement and error corrections using dissipation as a Darwinian selector. No detailed planning is needed: only a rough sketch is enough in the time scale of the motor action and Nature takes care of the rest.

p-Adic fractality suggests that cognitive representations realized in the intersection of realities and p-adicities and reducing by strong form of holography to string world sheets and partonic

2-surfaces plus fermions at them are present at all length scales. In particular, MEs in the intersection are excellent candidates for defining cognitive representations. Nothing forbids a repertoire of simple MEs serving as symbols, typically frequencies or field patterns, and generating neural activities in turn amplified to macroscopic actions.

2.5 P-Adic Physics As Correlate For Cognition

The original vision was that p-adic non-determinism could serve as a correlate for imagination. The recent view is much more cautious. Certainly imagination does not reduce to p-adic non-determinism since it has also real physics correlates. Real and p-adic space-time surfaces are also extensions of same basic objects (string world sheets and partonic 2-surfaces) to 4-D surfaces and therefore highly correlated rather than almost independent. One might however consider that the classical non-determinism and p-adic non-determinism serve as correlates for quantum non-determinism which makes possible both volition and imagination.

2.5.1 Could p-adic non-determinism serve as a correlate for imagination?

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context.

1. p-Adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the 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 unique solution of field equations results. Since the fundamental formulation of quantum TGD [K28] indeed relies on the notion of finite measurement resolution, a highly attractive interpretation of this cutoff is in terms of measurement resolution of some kind.

2. Solution can be fixed in a discrete subset of rational (algebraic) points of the imbedding space. In the case of space-time surfaces this set is expected to have inherent cutoff since the condition of rationality (or algebraicity in the extension of p-adic numbers used) posed separately for all imbedding space coordinates is very strong. Note that preferred imbedding space coordinates are required and this kind of coordinate systems indeed existence thanks to the isometries of the imbedding space.

Clearly, 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. 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.

A possible interpretation for the solutions of the p-adic field equations would be as geometric correlates of cognition and perhaps even intentionality. Plans, intentions, expectations, dreams, and possibly also cognition as imagination in general could have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is the 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. The original candidate for this interaction was as a phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations would 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.

It turned out that this interpretation leads to grave mathematical difficulties: one should construct U-matrix and M-matrix for transitions between different number fields, and this makes

sense only if all the parameters involved are rational or algebraic. A more realistic view is that the interaction between real and p-adic number fields is that p-adic space-time surfaces define cognitive representations of real space-time surfaces (preferred extremals). One could also say that real space-time surface represents sensory aspects of conscious experience and p-adic space-time surfaces its cognitive aspects. Both real and p-adics rather than real or p-adics. The notion of p-adic manifold [K34] tries to catch this idea mathematically.

Strong form of holography implied by strong form of General Coordinate Invariance leads to the suggestion that partonic 2-surfaces and string world sheets at which the induced spinor fields are localized in order to have a well-defined em charge (this is only one of the reasons) and having having discrete set as intersection points with partonic 2-surfaces define what might called "space-time genes". Space-time surfaces would be obtained as preferred extremals satisfying certain boundary conditions at string world sheets. Space-time surfaces are defined only modulo transformations of super-symplectic algebra defining its sub-algebra and acting as conformal gauge transformations so that one can talk about conformal gauge equivalences classes of space-time surfaces.

The map assigning to real space-time surface cognitive representation would be replaced by a correspondence assigning to the string world sheets preferred extremals of Kähler action in various number fields: string world sheets would be indeed like genes. Mathematically this formulation is much more elegant that that based on p-adic manifold since discretization seems to be un-necessary at space-time level and applies only to the parameters characterizing string world sheet.

String world sheets and partonic 2-surfaces would be in the intersection of realities and p-adicities in the sense that the parameters characterizing them would be algebraic numbers associated with the algebraic extension of p-adic numbers in question. It is not clear whether the preferred extremal is possible for all p-adic primes but this would fit nicely with the vision that elementary particles are characterized by p-adic primes. It could be also that the classical non-determinism of Kähler action responsible for the conformal gauge symmetry corresponds to p-adic non-determinism for some particular prime so that the cognitive map is especially good for this prime.

The idea about p-adic pseudo constants as correlates of imagination is however too nice to be thrown away without trying to find an alternative interpretation consistent with the strong form of holography. Could the following argument allow to save p-adic view about imagination in a mathematically respectable manner?

1. The construction of preferred extremals from data at 2-surfaces is like boundary value problem. Integration constants are replaced with pseudo-constants depending on finite number pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces.

2. Preferred extremal property in real context implies strong correlations between string world sheets and partonic 2-surfaces by boundary conditions a them. One cannot choose these 2- surfaces completely independently. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets and partonic 2-surfaces not allowed in real context and realizing imagination.

3. Could imagination be realized as a larger size of the p-adic sectors of WCW? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could the modes of WCW spinor fields for which 2-surfaces are extendable to space-time surfaces only in some p-adic sectors make sense? The real space-time surface for them be somehow degenerate, for instance, consisting of string world sheets only.

   Could imagination be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real preferred extremals? p-Adic physics would be there as an independent aspect of existence and this is just the original idea. Imagination could be realized in state function reduction, which always selects only those 2-surfaces which allow continuation to real space-time surfaces. The distinction between only imaginable and also realizable would be the extendability by using strong form of holography.

I have the feeling that this view allows respectable mathematical realization of imagination in terms of adelic quantum physics. It is remarkable that strong form of holography derivable

from - you can guess, strong form of General Coordinate Invariance (the Big E again!), plays an absolutely central role in it.

2.5.2 Cognition at elementary particle length scales?

The success of p-adic mass calculations [K12, K2, K14] does not leave much room for the interpretations if one identifies p-adic physics as a physics of cognition: cognitive representations must be present already at elementary particle level. The adelic vision is the most elegant manner to describe the situation mathematically.

This means that the creation of zero energy states representing photons and perhaps even electrons and quarks could occur routinely in living matter. In the standard physics framework the interpretation would be as quantum fluctuations generating fermion pairs from vacuum. In TGD framework these quantum fluctuations become quantum states with precisely defined characteristics.

Intentional action could be present also in elementary particle length scales if the adelic vision makes sense. Time reversals should occur so often that the effects related to the arrow of time disappear on the average. The extreme situation is the each state function reduction occurs at opposite boundary of CD so that the life time of self is vanishingly short. In this case one cannot speak of any kind of intentional action or volition but already a sequence of few state function reductions generates self and can give rise to intentions.

What makes this hypothesis testable is the prediction that the time scales of CDs assignable to electron and quarks should define fundamental time scales of living matter. This seems to be the case. kHz neuronal synchrony is only one example. kHz frequency and 10 Hz frequency would be associated also with "dead" matter if cognition is present at elementary particle level. A particular prediction is the failure of second law below these time scales. This kind of failure has been indeed observed [D1] and the effect indeed involves millisecond and.1 second time scales [K13].

The experience has taught that physical system can be understood throughly only after the characteristic time and length scales have been understood. In case of biology the prevailing reductionistic attitude has led to the belief that living matter is a basic example of a "non-tidy" system so that the time and length scales associated with living matter are more or less accidental as also genetic code and the miracles of bio-chemistry. My own belief is that this attitude is wrong and explains why the progress in the theoretical understanding of living matter has been so slow.

2.5.3 Cognitive degeneracy and the survival of the fittest

Physical systems with large degeneracy would be favored since intuitively one expects this to give a high representational power. 4-D spin glass degeneracy suggests that these systems correspond to small deformations of vacuum extremals. If the final states of quantum jumps have roughly the same probabilities, this means that quantum jumps lead with highest probability to those states for which cognitive degeneracy is highest. The mere ability to imagine would mean winning in the fight for survival.

The hierarchy of Planck constants associated with the hierarchy of quantum criticalities involves degeneracy and its connection with conscious information in much more concrete manner. The density matrices for the outcomes of state function reductions are higher-dimensional projection operators and one can can assign to them negentropy and conscious information. The interpretation is as a consciously experienced abstraction or rule with its instances represented as state pairs in the superposition.

2.5.4 The emergence of symbols

p-Adic non-determinism gives rise to cognitive representations whereas the non-determinism of the real Kähler action gives rise to symbolic representations in terms of association sequences consisting of space like 3-surfaces with time like separations: the individual space like 3-surfaces play the role of words of sentence.

Conscious activities are indeed highly symbolic: a push of button can initiate a nuclear war. The reduction of the p-adic-to-real phase transitions to some fundamental level, perhaps to the level of nerve pulse transmission, indeed makes possible a build-up of very complex actions by using a repertoire of very simple basic actions serving p-adic memes translatable to symbols in case that

system is initial value sensitive. Dark MEs with preferred frequencies inducing transitions provide an excellent candidate for the buttons.

This idea is developed concretely in the model of bio-photons as decay products of dark photons at flux tubes having $\hbar_{eff} = \hbar_{gr} = Gmm/v_0$ [K33, K35]. The cyclotron energies of charged particles are proportional to h_{gr}/m and thus independent of the mass of the particle. Therefore the cyclotron energy spectrum of emitted dark photons and bio-photons resulting from them is universal and in the range of visible and UV photons where also molecular transition energies are. Hence bio-photons define an optimal control too. This leads to a vision in which each biomolecule is symbolically represented by a collection of cyclotron frequencies characterizing its magnetic body and directed attention between molecules corresponds to a resonance interaction involving emission and absorption of cyclotron photons. This idea have been develop further in the geometric model of harmony leading to a proposal that genetic code is realized in terms of triplets of cyclotron frequencies for dark photons [K17]. Molecules - at least DNA and proteins- would be symbolically represented by "music pieces" consisting of sequence of 3-chords- somewhat like characters in Wagner's operas correspond to themes.

2.5.5 What cognitive representations are and how they develop?

It is far from clear what cognitive representations are and how they develop. The recent vision about generalized imbedding space and about life as something in the intersection of real and p-adic worlds provides one possible answer to the question based on adelic physics supported also by p-adic mass calculations.

For a long time I believed that discretization of space-time by a subset of algebraic points and with cutoff makes sense at space-time and imbedding space level: this vision was concretized in the proposal what p-adic manifolds as cognitive charges of real manifolds - now preferred extremals- could be [K34]. The intersection of realities and p-adic world was at the space-time level identified as discretized space-time surfaces with points having coordinates which are numbers in some algebraic extension of rationals. These discrete point sets were assumed to be continuable to preferred extremals of Kähler action containing them. This introduces a lot of non-uniqueness interpreted in terms of a finite measurement resolution.

The first problem is that this discretization is highly non-unique and one is forced to introduce preferred coordinates. Second problem was that there is a tension between symmetries and continuity. The identification via common rationals (or numbers in algebraic extension of rationals defining an extension of p-adic number fields) would respect symmetries represented by rational matrices but would be totally discontinuous. The canonical identification is continuous but does not respect symmetries. The proposal was a compromise involving pinary cutoffs.

The discretization at space-time level is abstracted to a discretization at the level of WCW reducing by strong form of holography to a discretization for the parameters characterizing partonic 2-surfaces and string world sheets. By conformal and modular invariances these parameters should corresponds to finite-dimensional space of conformal moduli (Teichmueller parameters and punctures representing intersections of string world sheets with partonic 2-surface [K2, K12]). As far as scattering amplitudes are considered, all calculations could be carried out at this level without continuation to 4-D space-time surfaces. p-Adic variant of Teichmueller space was actually used in p-adic mass calculations already two decades ago [K12].

The correspondence between real and p-adic space-time sheets would be induced by the continuation of string world sheets and partonic 2-surfaces to preferred extremals so that canonical identification is not needed. The tension between symmetries and continuity would disappear since there is no map from reals to p-adics or vice versa but only algebraic continuation from the intersection. Space-time discretization is not present except for partonic 2-surfaces but has purely physical meaning since the discrete points correspond physically to the ends of boundaries of string world sheets carrying fermions. Also measurement resolution can be formulated elegantly in terms of pinary cutoffs at this level.

The partonic 2-surfaces are in the intersection of realities and p-adicities in the sense that the parameters appearing in their mathematical representations are in extension of rationals so that they make sense both in real sense and p-adically. Restriction to algebraic points, which is clumsy at the level of space-time, occurs now at the level of "world of classical worlds" (WCW). These 2-dimensional objects would define the fundamental cognitive and symbolic representations at the

same time.

One should answer several questions.

1. What are the basic types of cognitive representations? One can imagine two basic correspondences between reals and p-adics induced by common rationals and canonical identification or some map akin to it. One can ask whether self-representations could be induced by common rationals whereas representations of the external world could be induced by a proper generalization of canonical identification mapping rationals to themselves up to some power of p. In both cases there is some pinary cutoff determining the goodness of the representation. For the identification based on common rationals or algebraics the geometry of the surfaces would dictate the resolution inherently.

   More than decade after writing the above lines adelic view has replaced the original vision and the situation looks much simpler. Both real and p-adic space-time sheets are obtained as preferred extremals by strong form of holography from the partonic 2-surfaces and string world sheets in the intersection of reality and various p-adicities. Thus the representations are fixed to a high degree and provide kind of kaleidoscopic view about existence. How refined these representations are, depends on how complex the algebraic extension of rationals is. Evolution indeed corresponds to a gradual increase of the complexity of extension [K37].

2. How do cognitive representations in p-adic sectors relate to sensory representations in real sector? In the adelic view [K37] there is no step of this kind since p-adic and real sectors accompany automatically each other. p-Adic non-determinism might mean that p-adic preferred extremals depend on pseudo constants so that strong form of holography would not be highly non-unique in p-adic sectors. There could be large number of space-time surfaces associated with a given string world sheets and partonic 2-surfaces distinguished by different pseudo constants. This would mean that cognitive representations are not so trustworthy but does not seem to relate naturally to imagination.

3. Cognitive representations evolve in the sense that they become gradually more precise. What does this mean in the adelic vision? The complexity of the algebraic extension of rationals for the 2-surfaces in the intersection is the natural measure for a level of cognitive and symbolic representation. Evolution would involve a gradual increase of the complexity of the extension [K37] leading to the emergence of new preferred p-adic primes as ramified primes of the extension.

   In strong form of holography p-adic continuations of 2-surfaces to preferred extrmals identifiable as imaginations would be easy due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K16]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes. Whether the preferred primes satisfy p-adic length scale hypothesis or its generalization from $p = 2$ to small primes remains an open question.

   The value of effective Planck constant $h_{eff}/h = n$ corresponds to the number of sheets of some kind of covering space defined by the space-time surface. The discretization of the space-time surface identified as a monadic manifold [L5] with imbedding space preferred coordinates in extension of rationals defining the adele has Galois group of extension as a group of symmetries permuting the sheets of the covering group. Therefore $n = h_{eff}/h$ would naturally correspondto the dimension of the extension dividing the order of its Galois group.

   Weak form of NMP would allow the emergence of highly negentropic entanglement, when the dimension of the projector for the outcome of projection is power of large prime. The phase transitions reducing quantum criticality and increasing h_{eff} would generate NE and extend the scale of macroscopic quantum coherence. The evolution would also involve the emergence of new strings connecting partonic 2-surfaces. These strings would carry super-symplectic Noether charges creating many-fermion states, which in turn would provide representation of Boolean algebra bringing in Boolean cognition.

4. What is the relationship to the memetics of Susan Blackmore [J15]? Susan Blackmore sees memes as independent objects using brain as a tool of replication.

   Memes could be identified as mental images able to utilize the metabolic energy resources associated with brains and to replicate themselves in communications. They must correspond to self-organization patterns able to induce the birth of their almost copies in communications. Selves have magnetic bodies and also memes should have them.

   The replication of magnetic body - analogous to what happens in 3-vertex of Feynman diagram - is what induces the replication of biological sense in TGD inspired biology [K32]. The replication vertex is indeed the generalization of fundamental 3-vertex in TGD context. There is strong temptation to assume that also memes are magnetic bodies replicating in this concrete sense. Thus magnetic bodies serving as analogs of the morphic fields of Rubert Sheldrake [K32] would be the physical correlates for memes: this makes sense since they carry dark matter and NE, and can be said to act as an intentional agents using biological bodies as motor instruments and sensory receptors.

   The original idea that p-adic cognitive representations could serve as the physical realization of memes is not feasible in the adelic framework. In the adelic picture p-adic cognitive representations are not independent elements but determined to a high extent by the string world sheets and partonic 2-surfaces as real sensory representations. One cannot say that p-adic representations use brain as at tool for the materialization and replication.

2.6 Quantization Phenomena In Psychophysics

p-Adicity might provide understanding of some phenomena of psychophysics related to the discrimination between different intensities of stimuli and to threshold phenomena of sensory perception.

When over-learning occurs in tasks involving temporal discrimination, the memory images about the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [J10] such that the plateaus where response remains constant are octaves of each other. This suggests that the memory image about the sensation depends only on the 2-adic norm of the 2-adic image of the ratio I/I_0 of the intensity of the stimulus to the threshold stimulus under canonical identification.

This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jump-wise replacement of the n: th harmonic by n+1: th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of over-learning or neurons involved act unisono and the underlying 2-adicity is not masked anymore. At the level of ELF selves this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier.

3 Various Aspects Of Cognition

In the following various aspects of cognition are discussed further. The representation differs from the earlier one in some important aspects. Adelic view about sensory-cognitive representations replace the idea about weakly dependent sensory and cognitive representations: in the new view real and p-adic space-time sheets are determined by strong form of holography from string world sheets and partonic 2-surfaces - "space-time genes". ZEO allows a precise formulation of various ideas related to time reversed cognition. The replication of magnetic bodies suggests itself as a counterpart for the replication of memes. The idea about quantum jumps transforming p-adic space-time sheets to real ones or vice versa is given as mathematically awkward one.

3.1 P-Adic Physics And Imagination

p-Adic non-determinism makes it natural to interpret p-adic space-time sheets as geometric correlates of cognitions. A natural guess is that p-adic physics is also physics of imagination but one must very carefully define what this means and whether it can make sense. The original idea that imagination corresponds to building of p-adic variants of the action transformed to real ones. This idea meets however grave mathematical difficulties and is un-necessary.

In the adelic picture the p-adic representations automatically accompany all physical systems, even elementary particles: this is consistent with the success of p-adic mass calculations.

One can also ask whether p-adic nondeterminism really plays any important role in imagination. One can of course imagine that the assignment of space-time surfaces to 2-D space-time genes is not unique due to the presence of pseudo-constants. But what this non-uniqueness could mean?

If sensory organs are the seats of the primary sensory qualia, one can understand imagined sensory experience as a perception, which does not start from the level of sensory organs but some higher level and gives rise only to cognitive representations. Dreaming and hallucinations would involve a feedback to the primary sensory organs "qualiafying" the cognitive representations. If motor action can be identified as a time reversal of the sensory perception in a relevant time scale for MEs then imagined motor actions would differ from real ones only in that they would be initiated from some higher level than muscles and proceed to brain and from brain to magnetic body. Imagined would be almost realized.

3.2 How Dreams And Hallucinations Relate To Sensory Experiences?

If primary sensory qualia are realized at the level of sensory organs, then dreams and hallucinations would be virtual sensory experiences with sensory input from magnetic body and brain instead of external world. Rapid eye movements and oto-acoustic sounds would be a signature of this process. Spontaneous movements during dreaming would in turn be the signature of the imagined motor activities. I have proposed this view about dreams already earlier and explains nicely the observations of Claude Rifat about lucid dreaming [J4]. The strange piecewise logical consistency of dreams is consistent with smaller value of Planck constant $h_{eff} = n \times h$ implying shorter time scale of memories and planned actions. The original interpretation was that it reflects p-adic non-determinism.

This view about dreaming is in accordance with the observations (reviewed in [J12]) that dreaming is not produced by random inputs from brain stem to cortex but is cognitive skill learned gradually during infancy. The most primitive dreams represent static pictures, then these pictures become dynamical, and at the age of about eight the dreamer becomes a participant of the dream. In lucid dreaming the dreamer has taken active role in transforming cognitive representations to sensory experiences.

One must actually distinguish between two kinds of "hallucinations": a genuine sharing of sensory mental images involving no "qualiafication" and interpretable as telepathy, and the receival of cognitive information, which is then qualiafied by the receiver like during dreaming. The presence/absence of a feedback to the sensory organs allows to discriminate between these options. The semitrance model for the bicameral mind [K22] relies on the idea that these experiences are communicated by higher levels of the self hierarchy during semitrance. This communication could be purely telepathic.

3.3 Cognition, Sensory Experience, And Boolean Mind

Thoughts have not color and pure thoughts seem to be free of emotions, with aesthetic experiences induced by abstract ideas being perhaps an exception. Pure thoughts involve often the experience that something is true or false but not beautiful or ugly or right or wrong. These simple observations provide tests for the identification of the p-adic physics as physics of cognition and for the model of sensory qualia, Boolean qualia, and emotions. These observations also suggest a concrete identification of the physical correlates for the Boolean algebras of ethics, aesthetics, and logics.

3.3.1 Are qualia number theoretically universal?

Sensory qualia were originally identified as averages of quantum number increments associated with the quantum jump sequence defining the sub-self representing sensory mental image. The recent view inspired first by the sensory capacitor model of qualia [K8, K3] and then suggested strongly by ZEO based definition of self reducing to the TGD inspired quantum measurement theory leads to a somewhat different view.

Qualia correspond to quantum number flows between subsystem defining sub-self and environment continuing as long as the mental image representing the qualia defined by quantum numbers of flowing particles. Quantum numbers of flowing particles instead of quantum number increments define qualia. There is high temptation to assume that qualia involve a transfer of negentropic entanglement. Also the flow of metabolic energy is proposed to involved it. This raises the question whether fundamental qualia are associated with metabolites- not only metabolic energy but also important bio-molecules carrying NE: certainly this would be very natural.

In the recent view all qualia related to fermions are number theoretically universal so that one cannot regard them a p-adic or real: this at least in the intersection of reality and p-adicities. Strong form of holography in any case demands that fermionic qualia can be assigned with string world sheets and partonic 2-surfaces at the fundamental level. The strong form of holography suggests that the qualia associated with quantum numbers in bosonic WCW degrees of freedom can be also localized to these 2-surfaces.

What about geometric qualia carrying geometric information? Do they make sense as it would seem? It is not at all clear whether sensory capacitor model applies to them. Rather, it would seem that string world sheets and partonic 2-surface define kind of conscious skeleton of space-time surface allowing conscious localization of various qualia. Does this mean that one can assign even geometric qualia to the 2-D objects - say their positions and velocities.

What is then the role of the space-time surfaces? How do they contribute to conscious experience? The answer to this question should be based on quantum classical correspondence realized as the analog of AdS/CFT correspondence in TGD. The zero modes of space-time surfaces provide a dual classical representation of quantum states necessary to interpret quantum measurements. The space-time surface generates correlations between the 2-surfaces otherwise absent and could bind the experiences to a coherent whole. Here quantum gravitational quantum coherence could play crucial role as the model for bio-photons as decay products of dark photons suggests. Could it be that cognition builds the 4-D representation from the 2-D representation as theoretical physicist might argue?

Here the question about uniqueness of the holographic correspondence becomes important. In particular, in p-adic case this could give rise to additional degeneracy which might however have interpretation as gauge degeneracy.

3.3.2 Does cognition involve emotions?

It is a fact of neuroscience that emotions and information are closely related [J5]. I have considered two views trying to mathematisize this finding.

1. Emotions could correlate with the rates of change for the negentropies associated with various quantum number increments in quantum jump sequence determining self. It seems that it is not possible to classify emotions or qualia to real and p-adic ones: number theoretical universality holds true.

2. Emotions could also correlate directly with the negentropy of the entanglement. Negentropic sub-selves would define mental images with positively colored emotions and entropic ones those with negatively colored emotions.

3.3.3 A naive view about three dichotomies

Beautiful/ugly, right/wrong, and true/false dichotomies relate to the comparison of experience with some standard. Beautiful/ugly relates to sensory experience, right/wrong characterizes deeds, and true/false logical statements. What comes in mind that these dichotomies could be interpreted as Boolean qualia assignable to quantum jumps in purely fermionic degrees of freedom. The first guess is that these dichotomies could reduce to negentropic/entropic dichotomy.

1. Right/wrong relates to intentional actions - deeds - and therefore to the first quantum jump to the opposite boundary of CD in which old sub-self disappears and new one is born. This dichotomy could be understood in terms of weak form of NMP allowing free will and possible quantum correlates for ethics and moral [K26]. Strong form NMP would state that the reduction is always such that negentropy gain is maximal: the final state sub-space has a dimension for which the negentropic entanglement gain is maximal. Weak form of NMP allows also to choose some sub-space of any eigen-space of density matrix. Weak NMP can also allow in some situations larger negentropy gain than the strong form of NMP and explains the generalized p-adic length scale hypothesis. The higher the negentropy gain, the more right the choice would be.

2. Beautiful-ugly dichotomy relates to sensory experience and should accompany the sequence of state function reductions at the same boundary of CD giving rise to self. What is interesting that the weak form of NMP impies that for a *fixed* fermionic Fock basis there are $2^n - 1$ sub-spaces, which can be selected in the reduction if the eigen-space is n-dimensional. This corresponds to a Boolean algebra with the physically non-realizable element (having empty set as set theoretic counterpart) thrown away. Could this give an emotional realization of Boolean algebra so that various choices would each give rise to some negentropy gain allowing to order them with respect to negentropy. Could this correspond to the aesthetic dimension? How to map this representation to a fermionic representation. Could the n-sheets of the singular covering of the space-time surface for which both ends collapse to single 3-surface carry the fermions and negative energy antifermions at the ends?

3. One should explain also the true-false aspect. Fermionic Fock states define Boolean basis and one can decompose it to independent states and their conjugates. True statements should correspond to some preferred basis with preferred direction of say fermion spin defining quantization axis.

3.4 Replication Of Memes, And Morphic Fields

What are the counterparts of memes in TGD framework? The identification of memes as zero energy states assignable to string world sheets and partonic 2-surfaces is one possible identification at fundamental level but so general that it does not say much. At the space-time level the magnetic bodies assignable to physical systems are a very natural candidates. String world sheets and partonic 2-surfaces accompany them and define the intersection of reality and p-adicities. The original idea was that p-adic space-time sheets could correspond to memes but it seems that memes corresponds to an entire adelic structure for which sensory-cognitive representations reside in the intersection.

3.4.1 Replication of sensory-cognitive representations

Memes are in central role in the theory of Susan Blackmore [J15] and magnetic bodies are excellent candidates for the space-time correlates memes understood in a more general sense. The replication of memes would reduce to a replication of 3-surfaces occurring at partonic 2-vertices and would be completely analogous to what happens in 3-vertex of Feynman diagram. This replication would also induce ordinary biological replication as visible matter self-organizes around the replicas of the magnetic body. This leads to a new view about genetic code as something realized at the level of dark magnetic bodies and becoming visible via this self-organization [K10].

Contrary to the vision of Susan Blackmore, memes would be conscious selves rather than unconscious deterministically behaving objects, and brain would not be an un-conscious machine used by memes but serving as a vehicle making possible for meme replication.

Although the notions of the meme and meme replication are very attractive, the mechanism of imitation is only partially known. The so called mirror neutrons are certainly an important of it. Learning by imitation could be understood as a process in which a sensory-cognitive representation as in sensory perception is formed as particular magnetic body and then replicates.

3.4.2 Time reversed cognition and reverse speech

Time reversed cognition and reverse speech are interesting phenomena allowing possibility to test these ideas.

1. Time reversed cognition

Time reflection yields time reversed and spatially reflected sensory-cognitive representations. When mental image dies it is replaced with its time-reversal at opposite boundary of its CD. The observation of these representations could serve as a test of the theory.

There is indeed some evidence for this rather weird looking time and spatially reversed cognition.

1. I have a personal experience supporting the idea about time reversed cognition. During the last psychotic episodes of my "great experience" I was fighting to establish the normal direction of the experienced time flow. Could this mean that for some sub-CDs the standard arrow of time had reversed as some very high level mental images representing bodily me died and was re-incarnated?

2. The passive boundary of CD corresponds to static observing self - kind of background - and active boundary the dynamical - kind of figure. Figure-background division of mental image in this sense would change as sub-self dies and re-incarnates since figure and background change their roles. Figure-background illusion could be understood in this manner.

3. The occurrence of [J11] is a well known phemonenon [J11] (my younger daughter was a reverse writer). Spatial reflections of MEs are also possible and the arrow of geometric time might determine the direction in mirror writing.

4. Reverse speech would be also a possible form of reversed cognition. Time reversed speech has the same power spectrum as ordinary speech and the fact that it sounds usually gibberish means that phase information is crucial for storing the meaning of speech. Therefore the hypothesis is testable.

2. Reverse speech

Interestingly, the Australian David Oates claims that so called reverse speech is a real phenomenon [J2], and he has developed entire technology and therapy (and business) around this phenomenon. What is frustrating that it seems impossible to find comments of professional linguistics or neuro-scientists about the claims of Oates. I managed only to find comments by a person calling himself a skeptic believer but it became clear that the comments of this highly rhetoric and highly arrogant commentator did not contain any information. This skeptic even taught poor Mr. Oates in an aggressive tone that serious scientists are not so naive that they would even consider the possibility of taking seriously what some Mr. Oates is saying. The development of science can often depend on ridiculously small things: in this case one should find a shielded place (no ridiculing skeptics around) to wind tape recorder backwards and spend few weeks or months to learn to recognize reverse speech if it really is there! Also computerized pattern recognition could be used to make speech recognition attempts objective since it is a well-known fact that brain does feature recognition by completing the data into something which is familiar.

The basic claims of Oates are following.

1. Reverse speech contains temporal mirror images of ordinary words and even metaphorical statements, that these words can be also identified from Fourier spectrum, that brain responds in unconscious manner to these words and that this response can be detected in EEG. Oates classifies these worlds to several categories. These claims could be tested and pity that no professional linguist nor neuroscientist (as suggested by web search) has not seen the trouble of finding whether the basic claims of Oates are correct or not.

2. Reverse speech is complementary communication mode to ordinary speech and gives rise to a unconscious (to us) communication mechanism making lying very difficult. If person consciously lies, the honest alter ego can tell the truth to a sub-self understanding the reverse speech. Reverse speech relies on metaphors and Oates claims that there is general vocabulary.

> Could this taken to suggest that reverse speech is communication of right brain whereas left brain uses ordinary speech? The notion of semitrance used to model bicameral mind suggests that reverse speech could be communication of higher levels of self hierarchy dispersed inside the ordinary speech. There are also other claims relating the therapy using reverse speech, which sound rather far-fetched but one should not confuse these claims to those which are directly testable.

Physically reverse speech corresponds to phase conjugate sound waves which together with their electromagnetic counterparts can be produced in laboratory [D2, D4]. Phase conjugate waves have rather weird properties due the fact that second law applies in a reversed direction of geometric time. For this reason phase conjugate waves are applied in error correction. TGD based description of both electromagnetic and sound wave phase conjugation is based on negative energy space-time sheets representing classically electromagnetic fields and Z^0 fields [K4].

Negative energy topological light rays are in a fundamental role in the TGD based model for living matter and brain. The basic mechanism of intentional action would rely on time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) utilizing the TGD counterparts of phase conjugate waves producing also the nerve pulse patterns generating ordinary speech. If the language regions of brain contain regions in which the the arrow of psychological time is not always the standard one, they would induce phase conjugates of the sound wave patterns associated with the ordinary speech and thus reverse speech.

ZEO based quantum measurement theory, which is behind the recent form of TGD inspired theory of consciousness, provides a rigorous basis for this picture. Negative energy signals can be assigned with sub-CDs representing selves with non-standard direction of geometric time and every time when mental image dies, a mental images with opposite arrow of time is generated. It would be not surprising if the reverse speech would be associated with these time reversed mental images.

3.4.3 A connection with the ideas of Sheldrake

In [K20, K31] I have discussed a possible TGD based justification of Sheldrake's ideas about learning at the level of species.

If one assumes that memes correspond to magnetic bodies, that the replication of memes by topological replication of magnetic bodies is possible [K31], and that MEs involved can have even sizes of order Earth size and are associated with cyclotron transitions at magnetic bodies, it is not too difficult to imagine how species memory could be realized. Magnetic bodies cold take the role of the morphic fields in TGD framework and represent habits, skills, ideas, ... Susan Blackmore would call these morphic fields memes but basically only a naming convention and generalization is in question (amusingly, skeptics regard Sheldrake as a pseudoscientist but Blackmore as a serious scientist, perhaps because she has emphasized her skepticism in the publicity!).

The meme associated with the development of a particular skill could be realized in a particular brain and replicate itself. When the magnetic replicas would encounter other brains of the same species, the skill could be manifested as a real action and lead to learning without direct sensory communication.

Sheldrake's theory thus generalizes memetics and would thus make Sheldrake pseudo scientist! Labels are dangerous: needless to add that certainly Blackmore has not been using them. That a given meme could be realized only in brains of the same species might be understood in this framework by using resonance argument: morphic resonance is the notion used by Sheldrake which could reduce to cyclotron resonance for dark photons with frequencies in say EEG range but energies in the range of bio-photons and therefore maximally bio-active. The precise cyclotron frequencies - that is precise values of magnetic fields associated with the parts of magnetic body- would characterize species and make possible resonant communication restricted within species.

It is also possible that stochastic resonance [D3] to be discussed later in more detail could be involved with the morphic resonance. The individuals that learned the habit first, need not even live anymore since c memes remain and replicate even when the physical body dies.

4 Frontal Lobes And TGD

Negentropic entanglement (NE) is possible and is stable against self measurement if NMP holds true. Even weak form of NMP is enough and strongly favoured. This very encouraging finding suggests that cognition involves the p-adic aspects in an essential manner. For instance, number theoretic entanglement entropy would make it possible to understand what it is to understand! To have an experience of understanding is to have a sub-self (cognitive mental image) with a positive entanglement negentropy.

Frontal lobes are regarded as seats of the highest mental functions such as cognition, intention, volition, attention, evaluation of actions, self model, and perception of and reaction to social situations. Long term memory and language are largely independent of frontal lobes whereas working memory can be located to the dorsolateral parts of prefrontal lobes. Thus the concrete model both the p-adic aspects of the physics of sensory experience, intention, and cognition might boil down to a model of frontal lobe function. Of course, also the notions of field body and magnetic body are needed to understand the highest levels of the control. In particular, social control could be performed basically by the multi-brained collective selves by activation of social habit routines as suggested by the fact that the persons who have lost these routines are able to deduce the correct social behaviour.

4.1 Basic Functional Anatomy Of Frontal Lobes

Frontal lobes involve the most complex association networks of brain. In fact so complex, that the diagnostics based on simple reflex schema and the idea about exact locations of mental functions applied to subjects having serious frontal lobe damage suggested that frontal lobes have no function at all! Only a view in which brain is regarded as self-regulating and self-organizing system allowed to develop diagnostic tools revealing the effects of frontal lobe damage.

Dorsolateral frontal lobes seem to be specialized with various aspects of cognition such as problem solving, judgement, reasoning, and discrimination. In particular, what is identified usually as working memory is located here. These areas are also involved with imagination and corresponding loops extend to sensory areas. In TGD framework dreams can be seen as a particular kind of imagination in which imagined sensory features are mapped to the magnetic sensory canvas.

The medial and ventral frontal lobes are involved with intention, planning, volition, and attention. These regions are also crucial for the routine perception of and reaction to social situations. Affect and motivation are crucial concepts here and the complex circuits connecting frontal lobes, amygdala/brain stem and cortex are essential for planning and decision making. Salience detection or rather, selective amplification of those aspects of percepts which are significant seems to be basic function of these loops. The lesion for these loops implies effective loss of volition as well as emotional flatness.

Phineas P. Gage is a classic example of a person with serious damage for the circuits. He did not lose either his intellectual abilities nor memory but lost the ability of planning and the access the previously acquired social conventions and rules, and became childish and irresponsible. Gage was also well aware that he did was not anymore able to react emotionally. Gage was also able to use to theoretically deduce what would be the appropriate behaviour in social situations but in everyday life this was impossible.

These findings suggest that frontal lobes perform high level control and habit routines are the basic tools of cognition and planning, and that frontal lobes both active, generate, modify and replace these habit routines by new ones. Using brain as computer metaphor one might say that working memory provides the initial values of the parameters of the habit routines.

4.2 Some Neurophysiological Findings Related To The Functioning Of Frontal Lobes

The notion of cortical tone characterizes the state of cortex and is maintained by CNS. In so called inhibitory phase state the tone is low and brain responds with similar response to both strong and weak stimuli. This phase is also called equalization phase. In paradoxal phase weak stimuli can give rise to strong responses and vice versa. In this state no organized thought appears and selective associations are replaced by non-selective and more or less random associations. REM

sleep is regarded as an example of paradoxal phase. The interaction between medial frontal lobes, reticular activating system and cortex controls the cortical tone.

Gray Walter found that any expectation elicits characteristic slow waves emanating from frontal lobes and spreading to other regions. Expectancy wave diminishes if the probability of expected signal diminishes. When the instruction that elicited the expectation states is negated, the wave ceases. Similar wave phenomenon is detected during concentration, say during an attempt to solve a complex mathematical problem. The interpretation as a correlate for binding by quantum entanglement suggests itself.

Orienting reaction is a vegetative and electrophysiological reaction to stimulus. Constriction of the vascular system to the arms, dilation of the vascular system to the head, galvanic skin changes and alpha wave amplitude reduction are involved. Habituation to the stimulus reduces orienting reaction. Orienting reaction can be however increased and stabilized by verbal instruction that links meaning to the stimulus. If frontal lobe lesion affects attention, the orienting reaction fails to be stabilized by this mechanism. The interpretation is that for polar, medial and mediobasal section of the frontal lobe, the physiological tools for the regulation of attention are deranged.

4.3 TGD Based View About Frontal Lobes

The TGD based model for how frontal lobes cognize forces some new interpretations of classic experiments. Also a new view about working memory is unavoidable.

4.3.1 Paper, pencil, and eraser metaphor

The inability to modify existing routines or replace them with new ones rather than loss of these routines seems to accompany the lesions of ventromedial frontal lobes. Or more precisely, new routines can be acquired but instantaneous replacement of active routines with new ones is not possible. In a classic experiment already performed by Pavlovian school a person having a frontal lobe lesion in the ventromedial area started to plane a plank and continued until there was no plank anymore and continued to plane of the bench. In the so called Wisconsin card sorting test the subject is presented with a series of stimulus cards and a deck of response cards. The cards bear coloured geometric patterns and can be matched by categories such as colour, form or number. The experimenter selects category but does not inform subject person who guesses rapidly the category by trial and error. After ten cards experimenter changes the category without informing the subject person about the change. Patient is not able to revise his strategy and continues to make wrong guesses.

These persons can adopt strategy but cannot change it. This is something very essential. The proposed interpretation is however that these persons do not have motor imagination and therefore cannot construct new habit routine. This seems to be wrong since in the beginning card experiment the subject was able to achieve this. Something more delicate is involved: patient is not able to replace an activated strategy with a new one instantaneously The activated strategy however becomes deactivated spontaneously sooner or later.

This leads to pencil, paper, and eraser metaphor as a model for what frontal lobes are doing. Creation of habit routines is creation of symbolic representations and frontal lobes both create and erase habit routines just as we do when we do our calculations or type text to computer file. The patient with dorsolateral frontal lobe lesion must wait until the erasure happens spontaneously to establish a new habit routine. Of course, sticking into habit routines seems to a part of human condition, in particular at the old age.

Interestingly, during psychedelic experiences frontal lobes are very active. Habit routines are what one gets rid in these experiences and also during meditation. The interpretation would thus be that a very intense erasure of old and generation of new habit routines is going on.

4.3.2 Working memory quantum mechanically

The notion of working memory does not seem to be an appropriate concept in TGD framework. The proper interpretation seems to be as erasure and replacement mechanism for habit routines. Short term geometric and subjective memories are automatic side products. Mirror mechanism is also now the natural mechanism for geometric memories but one cannot exclude the interpretation

of working memory as subjective memory. Note that it does not make sense to construct long term memory representations of all intermediate stages of habit routine construction (just as it does not make sense to publish all intermediate and often erratic stages of a long mathematical calculation).

Erasure and replacement mechanism corresponds in spin glass metaphor to the kicking of the system out from the bottom of a potential well. In quantum framework this means a formation of a de-localized state in zero modes followed by a localization to the bottom of some other potential well representing the new habit routine. Delocalized states in zero modes are however not possible. Rather, a generation of a bound state implying a temporary transformation of the zero modes in question to quantum fluctuating macroscopic quantum degrees of freedom is required. This is the TGD counterpart of Penrose-Hameroff mechanism. State of oneness, quantum computing macro-temporally quantum coherent system, moment of consciousness effectively lasting very many quantum jumps: all these characterizations apply to the resulting state.

The creation of new habit routine might even mean the changing synaptic connections. This would mean a multiverse state of multineuron system with different synaptic strengths such that one of these states is selected when the bound state decays. Interestingly, it is known that the synaptic connections related to the somatosensory representations of rat's whiskers change in an incredibly short millisecond time scale. The explanation as a macroscopic quantum effect strongly suggests itself.

Also quantum superposition of entangled axons with varying membrane potentials near axonal hillock and thus with a varying firing probability could be considered. Also the ends of axons might be in entangled quantum superposition: Ca^{++} waves and sol-gel transition might be involved.

4.3.3 Cognitive quantum computation like processes at neurolevel

If one assumes that an eigenstate of the density matrix or of the negentropy operator results in self measurement, the system must end up to an entangled state corresponding to some eigenspace of the density matrix. The requirement that the increase of entanglement negentropy is maximal, fixes this eigenspace uniquely. For the resulting state density matrix is proportional to unit matrix and entanglement negentropy is maximal $N_R = Nlog(p)$, when the number of states is $n = p^N n_0$, n_0 not divisible by p, $N > 0$: otherwise it vanishes. Quantum computers indeed operate with systems for which entanglement probabilities are identical. A very strong prediction is that the dimension of the state space should be divisible by p^N.

A possible neurolevel realization of a cognitive quantum computation is following.

1. Information is represented as a sequence of p-adic and real memetic qupits along axon. If the effective phase velocity ofME is sufficiently low quite high number of qupits can be realized as already found. Incoming p-adic and real memetic codewords can be taken to be identical unentangled sequences of p-adic and real memetic codewords. The unitary time development is discrete with a time step of 1/1270 seconds and lasts an integer multiple of $T_2(127) = .1$ seconds (127 steps). Thus the minimal quantum computation involves $2^{127} - 1$ quantum jumps effectively glued to a single quantum jump by macro-temporal quantum coherence. The outcome of the cognitive self-measurement is a pair of memetic codewords representing the initial memetic codeword and the result of the cognitive quantum computation.

2. A conscious experience results, when the spin directions of the real oddball qubits flip to the direction of the external magnetic field at the cell membrane space-time sheet. The spatial sequences of qubits in the direction of the magnetic field are excluded because these states do not give rise to any spin flips. In this manner a quantum computer with $p = 2^{127} - 1$ results. The spin flips of the real qubits induce MEs which in turn induce membrane oscillations and perhaps even nerve pulses.

4.4 Goal Structures And Emotions

Daniel Pouzzner has proposed quite an interesting theory of emotions relating most emotions to cognitive models and goal structures [J6]. Goal structures are also cognitive models assumed to have correlates at the level of neurophysiology.

Quite many emotions originate basically from comparisons of expectations or goals with reality and Pouzzner's model of emotions relates emotions to the dynamics of the goal structure. The failure to reach a goal or giving up a goal is accompanied by a disappointment or sadness; realization of a goal is accompanied by a feeling of success; fear or rage is experienced when the achievement of a goal is threatened. The failure of a model is accompanied by a surprise; the success of a model, which has been questioned by experience involves a feeling of relief; etc..

There are of course exceptions: for instance, physical pain and pleasure, excitement, love and perhaps also pure rage without any object. The basic question is whether the comparison type emotion accompanies inherently comparison or whether emotions as such have nothing to do with comparisons and brain has only evolved to associated emotions to comparison results to guide the behaviour. In the model of Pouzzner the latter view is adopted and various neurotransmitters are identified as correlates of emotions. The problem is to understand how cognitive models and goals could be represented in real physics.

In TGD framework negative emotions relate to the increase of the entropies associated with various quantum number and zero mode increments defining qualia and are automatically generated in state function reductions in which sub-self representing mental image dies and re-incarnates at opposite boundary of CD. Contrary to the original believes one cannot assign emotions to any specific number field since they are number theoretically universal. Positively colored emotions relate to the increasing negentropies. The formation of negentropic generating sub-selves are obviously excellent candidates for quantum correlates of positive emotions. The challenge is two-fold.

1. Construct a concrete model for intentions and goal structures analogous to the model of long term memories. In fact, the two structures might differ only by time orientation and be represented by the active boundary of CD whereas the passive boundary would represent the self, kind of background to a figure.

2. Develop a model for the comparison process explaining why a quantum coherent sub-self results if the mental images about the predicted and actual states of the world are nearly identical and de-cohering sub-self results if these mental images are too different. Fractality of TGD Universe basically to quantum criticality allows to have scaled variants of sub-selves. The intelligent system must be able build scaled variants of its sub-selves having basically similar goal structures, and test statistically the average outcome of reduction to the opposite boundary from them. If the outcome of the real reduction is very different from that for the simulated reduction in shorter time scale, the outcome is disappointment or joy. In the simplest situation the goal is to yield negentropy and in this case the comparison between predicted and real events is simple.

4.4.1 A model of goal structures

The models for geometric memories and intentions should be very symmetrical the basic difference being that geometric past is replaced with the geometric future in the model for intentions: intentions are memories about geometric future in very precise sense. The new elements of the model are due to ZEO based notion of self. The static background contribution to self consciousness comes from the passive boundary of CD and the rest - such as intentions and memories - comes from the changing active boundary of CD.

Intention does not have p-adic space-time sheet as its correlate as the original idea went but something assignable to the evolution of sub-self by repeated state function reductions at passive boundary and involves both emotional and cognitive (real and p-adic) aspects. NMP forces the state function reduction to the opposite boundary to occur eventually and NMP must in some sense force the development of intention. Weak form of NMP however allows free choice. The one who chooses is the higher level self possessing the sub-self for which the state function reduction to opposite boundary occurs. We are gods of our mental images.

1. The content of intention or goal corresponds to the second member for the pair formed by the positive and negative energy parts of the zero energy state. Intentions and goals might also involve time like NE between the opposite boundaries of CD say that between the brain of the geometric now with the brain of the geometric future: in this case the intention involves

abstraction. Whether the time like NE is necessary aspect of intention is not clear. NE between opposite boundaries of CD is would reflect finite measurement resolution and the degeneracy would be related to quantum criticality. M-matrix defined as a product of square root of S-matrix and real diagonal density matrix decomposing to a sum projection operators of various dimensions multiplied by real numbers would realize time-like NE.

2. It should be possible to speak about intention fields as analogs of perceptive fields and memory fields - characterizing various brain cells according to how long is the temporal distance T to the event of the geometric future representing the intention. The cells corresponding to the highest values of T should be found in frontal lobes. The value of T would correlate with quantum criticality and the value of $h_{eff} = n \times h$ and would be highest for frontal lobes defining kind of intelligence quotient. Large h_{eff} means that the size of the super-symplectic algebra represented as gauge symmetries is smaller so that the resolution of sensory and cognitive experience is better. It would seem that large value of h_{eff} must be assigned with the magnetic bodies of the cells, rather than cells and could be achieved by a large number of "deaths" and re-incarnations for the self assignable to he magnetic body.

In TGD cognitions and intentions should appear also at brain level and have definite correlates. A good guess is that cognitive representations are realized using memetic code in terms of MEs (of course, also em MEs might be involved). The model of music harmony and of genetic code provides a very concrete realization of this idea [K17].

4.4.2 How comparison type emotions could result?

What is needed is a concrete model for the comparison proces? One must answer several subquestions. What characterizes typical goals? What comparison means? What generates the positive or negative emotion in the comparison process? What is the fundamental quantum correlate of emotional coloring?

The challenge is to understand how comparison type emotions could result from the comparison of a sensory-cognitive model of reality with the reality. The model could be for a sub-self representing goal or ensemble of sub-selves representing scaled down variants of the sub-self. Fundamental goal helps self to say alive. Hence the death of goal sub-self must generate maximal negentropy gain to make NMP happy. Primary goal is expected to be such that its realization by a state function reduction at opposite boundary generates maximal negentropy gain meaning that it gives for self good changes to continue before the fatal state function reduction forced eventually by NMP, who wants NE by any means. There are also secondary goals formulated as concrete outcomes of state function reduction. There are hopes to achieve this if the achieved goal corresponds to a large negentropy gain.

1. The the mental image representing is sub-self whereas the prediction of the model is represented by scaled down variants sub-selves in shorter time scales. p-Adic length scale hierarchy and hierarchy of Planck constants allow to realize the scaling. Contrary to the original expectations p-adic space-time sheets are not in special role although they are essential part in adelic picture.

2. The members of the modelling ensemble of sub-selves are born and die and generate some average negentropy. If this average negentropy is large, there are good hopes that the goal assigned with sub-self can be realized. If this is not the case, self can modify the sub-self representing the goal to make it more realistic. Eventually the goal sub-self dies and generates the attempt to realize the goal. It the negentropy gain is smaller than expected, disappointment results. If its is higher, self has reasons to be happy. A more precise comparison would require a more precise characterization of the contents of goal.

4.5 Figure-Background Rivalry

The classical demonstration of figure-background rivalry (`http://tinyurl.com/y7nojvey`) is a pattern experienced either as a vase or two opposite faces. This phenomenon is not the same thing as bi-ocular rivalry in which the percepts associated with left and right eyes produced by

different sensory inputs are rivalling. This phenomenon is not the same thing as bi-ocular rivalry in which the percepts associated with left and right eyes produced by different sensory inputs are rivalling. There is also an illusion in which one perceives the dancer to make a pirouette in either counter-clockwise or clockwise direction although the figure is static. The direction of pirouette can change. In this case time-reversal would naturally change the direction of rotation.

Figure-background rivalry gives a direct support for the TGD based of self relying on ZEO if the following argument is accepted.

1. In ZEO the state function reduction to the opposite boundary of CD means the death of the sensory mental image and birth of new one, possibly the rivalling mental image. During the sequence of state function reductions to the passive boundary of CD defining the mental image a boundary quantum superposition of rivalling mental images associated with the active boundary of CD is generated.

   In the state function reduction to the opposite boundary the previous mental image dies and is replaced with new one. In the case of bin-ocular rivalry this might be the either of the sensory mental images generated by the sensory inputs to eyes. This might happen also now but also different interpretation is possible.

2. The basic questions concern the time reversed mental image. Does the subject person as a higher level self experience also the time reversed sensory mental image as sensory mental image as one might expect. If so, how the time reversed mental image differs from the mental image? Passive boundary of CD define quite generally the background - the static observer - and active boundary the figure so that their roles should change in the reduction to the opposite boundary. In sensory rivalry situation this happens at least in the example considered (vase and two faces).

   I have also identified motor action as time reversal of sensory percept. What this identification could mean in the case of sensory percepts? Could sensory and motor be interpreted as an exchange of experiencer (or sub-self) and environment as figure and background?

If this interpretation is correct, figure-background rivalry would tell something very important about consciousness and would also support ZEO. Time reversal would permute figure and background. This might happen at very abstract level. Even subjective-objective duality and first - and third person aspects of conscious experience might relate to the time reversal of mental images. In near death experiences person sees himself as an outsider: could this be interpreted as the change of the roles of figure and background identified as first and third person perspectives? Could the first moments of the next life be seeing the world from the third person perspective?

An interesting question is whether right- and left hemispheres tend to have opposite directions of geometric time. This would make possible metabolic energy transfer between them making possible kind of flip-flop mechanism. The time-reversed hemisphere would receive negative energy serving as metabolic energy resource for it and the hemisphere sending negative energy would get in this manner positive metabolic energy. Deeper interpretation would be in terms of periodic transfer of negentropic entanglement. This would also mean that hemispheres would provide two views about the world in which figure and background would be permuted.

A further interesting question relates to near death experiences (NDEs). In biological death the roles of boundaries of CD are changed and figure becomes background and vice versa. This could also mean that third person perspective becomes first person perspective and vice versa. In NDEs one indeed sees ones's own body from outside. Could this mean that in the beginning of reincarnation third person perspective dominates. One can go even further and ask whether the habit of children to talk about themselves as third person could relate to the dominance of third person perspective.

Quantum TGD brings in also other new elements.

1. In the conceptual framework of the standard quantum mechanics there is no known mechanism making possible macroscopic quantum coherence in the time scales involved. If dark matter with large h_{eff} is involved with the formation of conscious percept there is no problem in understanding the time scales in question. Actually a hierarchy of rivalries of various kinds in various time scales is predicted corresponding to the p-adic time scale hierarchy and hierarchy of Planck constants.

2. Another ingredient which is new from the point of view of standard quantum mechanics is that the hierarchy of Planck constants implies self hierarchy. The fractal structure of state function reduction process means that it is possible have macroscopic quantum behavior in given time scale but dissipative self-organization in shorter time scales.

   This is actually not new: in hadron physics hadrons are described as quantum systems whereas parton dynamics in the shorter time scales is assumed to be dissipative. In the recent case this means the possibility of quantum superposition of dissipative self-organization processes involved with the formation of neuronal correlates of percepts and proceeding in time scales of order milliseconds considerably shorter than the time scale of binocular rivalry.

4.6 Experimental Support For Binocular Rivalry As A Quantum Phenomenon

For years ago I constructed a quantum model for binocular rivalry and generalized it to a general model of volitional act as a quantum jump selecting not only between alternative motor actions but also between percepts. In this model different alternatives were represented as superpositions of neural firing patterns. The model allows to see sensory perception as an active volitional process (at some level of hierarchy of selves) and explains sensory rivalry as a quantum phenomenon.

4.6.1 The work of Efstratios Manaosakis

I learned from New Scientist [J16] that physicist Efstratios Manousakis has now published an interesting work [J8] about binocular rivalry providing experimental support for this model.

Recall that the classical demonstration of binocular rivalry [J1] is using different sensory inputs to left and right eye: figures can have different color or shape or be just different. Subject person does not see a superposition of figures but either or them. The two percepts alternate with some frequency and it is not possible to consciously experience both patterns simultaneously. This has led Manousakis to consider the idea that binocular rivalry could provide direct evidence for the notion of quantum consciousness. The obvious idea is that either of the percepts results by a state function reduction from the superposition of both percepts. As already explained this phenomenon need not have anything to do with figure-background rivalry.

The model predicts that the flip rate correlates with neuronal firing rate. The prediction is confirmed by using as subjects persons who have a reduced firing rate due to the use of LSD. The work of Manousakis might turn out to be an important step of progress in the development of theories of quantum consciousness and might help also main stream physicists to get rid of their atavistic fears relating quantum consciousness.

4.6.2 Justification for the model in TGD framework

4.6.3 TGD based model for rivalry and its generalization

The TGD based quantum model for binocular rivalry relies on the idea that the formation of quantum superposition of competing percepts is somewhat analogous to quantum computing in which large number of quantum parallel computations are carried out and one computation is selected as the computation halts. TGD however brings in also some new elements.

1. In ZEO the state function reduction in question means the death of the sensory mental image and birth of new one, possibly the rivalling mental image. During the sequence of state function reductions to the passive boundary of CD defining the mental image a boundary quantum superposition of rivalling mental images associated with the active boundary of CD is generated. In the state function reduction to the opposite boundary the previous mental image dies and is replaced with itself or with rivalling mental images and is assignable to the opposite boundary.

2. One could think that the two percepts correspond to two different quantum stats at active boundary of CD: the attention of self is directed to either left or right sensory input and

superposition of these states is possible at active boundary of CD whereas at passive boundary either one is selected. This would make possible considerable metabolic economy since metabolic costs would be halved.

The proposal for the space-time correlate of directed attention is flux tubes connecting the perceiver and perceived and involving resonant transfer of dark cyclotron photons. Different configurations of connecting and active flux tubes would serve as a concrete correlate for left and right-attention.

3. As proposed the opposite boundaries of CD would naturally correspond to figure and background. What could this mean in the case of sensory mental images in the case of bin-ocular rivalry?

The formation of quantum superposition of right and left percepts has evolutionary advantages which suggest also a generalization to a model of volitional action as a selection between neural firing patterns leading to alternative motor actions. As a matter fact, in ZEO motor actions and sensory percepts as mental images are time reversals of each other so that the suggestion is a prediction of ZEO.

1. The formation of superposition would be metabolically advantageous. In the classical world one should form both right and left percept simultaneously. The associated self-organization process requires a metabolic energy feed. When only single brain hemisphere forms the percept and one has quantum superposition of right and left percepts metabolic energy feed is reduced by factor 1/2. A highly synchronous neural firing distinguishes the perceived stimulus from non-perceived so that a quantum superposition of patterns of two neural firing patterns would be in question.

2. This picture leads naturally to a proposal that one function of sleep is to make possible quantum superposition of large number of neural firing patterns via quantum entanglement with external systems (perhaps other sleeping brains) so that sleep would be a process analogous to quantum computation.

3. The formation of alternative percepts would have an obvious evolutionary advantage in a situation in which several percepts are consistent with the sensory input. For instance, bipolar mood disorders seem to involve sticking of consciousness to either hemisphere. This generalizes also to cognition: of course, percepts actually consist of sensory input plus cognition.

4. This framework is behind TGD based model of volitional action applying to both motor actions and selection of sensory percepts. For a brain living in jungle it would be highly advantageous to develop in a difficult situation a quantum superposition of alternative motor actions and select the proper one only at the eleventh moment.

5. Sensory rivalry is analogous to an ability to move fluently between - say - skeptic and new age views about world. There is also a parallel at the level of society and in TGD framework the rivalry of various views (religions, political parties, competing scientific theories, ...) might perhaps be seen as counterpart of binocular rivalry at the level of collective consciousness. The complete dominance of only single view - be it religious or materialistic world view, market economy or communism, or super-string model or loop quantum gravity - would be something comparable to a bimodal mood disorder.

4.6.4 Alternative TGD based model for binocular rivalry

Science Alert reported an interesting result from neuroscience. The title of the popular article was"A New Brain Experiment Just Got Closer to The Origins of Consciousness" (see `http://tinyurl.com/y9n9mbjm`). The original article "Human single neuron activity precedes emergence of conscious perception" is published in Nature [J9] (see `http://tinyurl.com/y7rhklsr`).

The researchers in Tel Aviv University studied people suffering from epilepsy: the epilepsy as such is however not relevant for the research interests. During more than 20 sessions the volunteers stared at a pair of images. Each image was located in front of one eye. Because each eye saw only one image, the brains couldn't fuse the images into single picture. Instead, the brain choose one

image to deal with at a time. This process is known as binocular rivalry. The article claims that this process allows to separate visual stimulation and conscious seeing for each other. I would however argue that the outcome of the experiment relates to binocular rivalry rather than generation of conscious percept itself.

The finding was that medial-frontal lobe becomes active two seconds before the subject sees the picture. A second zone becomes active second later in medial-temporal lobe (that is 1 second before the conscious visual percept). These time scales are rather long as compared to time scale of 0.08-.1 seconds associated with sensory mental images - one might call this time scale a duration of sensory chronon.

As article explains, these experiments differ from the usual experiments studying the behavior of medio-temporal neurons in response to various modifications of the sensory input (flashing a different image to the other eye; backward masking, in which a briefly presented image is suppressed by the immediate presentation of a mask image; and the attentional blink, in which the second of two target stimuli appearing in close succession is often not perceived). Also these experiments study what happens at brain level as the visual percept changes but the change is now induced externally rather than internally as in binocular rivalry. The response of MTL neurons started about .2-.3 seconds after the external manipulation. There was no activation before the change.

If I understood correctly, the interpretation of the finding was based on computational paradigm. According to this interpretation it takes about 2 seconds to compute the new visual percept when the decision about new percept is made. One might however argue that this computation should take 2 seconds also in the case of externally induced change of percept. Actually the time for the emergence of the percept is .2-.3 seconds and there was no activation before the change.

In TGD framework this longer time scale would naturally correspond to a higher level in self hierarchy. In self hierarchy mental images correspond to sub-selves and self is sub-self of self at the higher level of the hierarchy. Each level is characterized by time scale and the higher the level in the hierarchy, the longer the time scale.

1. Could a higher level self direct its attention to alternative percepts in bio-ocular rivalry in more or less random manner? Could this re-directing of attention be seen as a motor action at some level of self hierarchy? This is the case when I turn my gaze from one object of the perceptive field to another one.

2. In TGD picture motor based on zero energy ontology (ZEO) [L8] motor actions are identified as sensory percepts in opposite time direction: a signal is sent to geometric past and initiates neural processing leading to the motor action. This explains Libet's finding that motor action is preceded by a neural activity beginning a fraction of second before the conscious decision about motor action. Could the situation be the same now except that the time scale would be now longer? The longer time scale would suggest that the decision maker is not "me" characterized by a fraction of second time scale but some higher level in the hierarchy of selves associated with my biological and magnetic body.

4.7 Quantum Cognition

The talks in the conference Towards Science of Consciousness 2015 held in Helsinki produced several pleasant surprises, which stimulated more precise views about TGD inspired theory of consciousness. Some of the pleasant surprises were related to quantum cognition. It is a pity that I lost most of the opening talk of Harald Atmanspacher (`http://tinyurl.com/pvb36jq`).

The general idea is to look whether one could take the formalism of quantum theory and look whether it might allow to construct testable formal models of cognition. Quantum superposition, entanglement, and non-commutativity, are the most obvious notions to be considered. The problems related to quantum measurement are however present also now and relate to the basic questions about consciousness.

1. For instance, non-commutativity of observables could relate to the order effects in cognitive measurements. Also the failure of classical probability to which Bell inequalities relate could have testable quantum cognitive counterpart. This requires that one should be able to speak about the analogs of quantization axis for spin in cognition. Representation of Boolean logic statements as tensor product of qubits would resolve the problem and in TGD framework

fermionic Fock state basis defines a Boolean algebra: fermions would be interpretation as quantum correlates of Boolean cognition.

2. The idea about cognitive entanglement described by density matrix was considered and the change of the state basis was suggested to have interpretation as a change of perspective. Here I was a little bit puzzled since the speakers seemed to assume that density matrix rather than only its eigenvalues has an independent meaning. This probably reflects my own assumption that density matrix is always assignable to a system and its complement regarded as subsystems of large system in pure state. The states are purifiable - as one says. This holds true in TGD but not in the general case.

3. The possibility that quantum approach might allow to describe this breaking of uniqueness in terms of entanglement - or more precisely in terms of density matrix, which in TGD framework can be diagonalized and in cognitive state function reduction reduces in the generic case to a 1-D density matrix for one of the meanings. The situation would resemble that in hemispheric rivalry or for illusions in which two percepts appear as alternatives. One must be of course very cautious with this kind of models: the spoken and written language do not obey strict rules. I must however admit that I failed to get the gist of the arguments completely.

One particular application discussed in the conference was to a problem of linguistics.

1. One builds composite words from simpler ones. The proposed rule in classical linguistics is that the composites are describable as unique functions of the building bricks. The building brick words can however have several meanings and meaning is fixed only after one tells to which category the concept to which the world refers belongs. Therefore also the composite word can have several meanings.

2. If the words have several meanings, they belong to at least $n = 2$ two categories. The category associated with the word is like spin $n = 2$ and one can formally treat the words as spins, kind of cognitive qubits. The category-word pairs - cognitive spins- serve building bricks for 2 composite worlds analogous to two-spin systems.

3. A possible connection with Bell's inequalities emerges from the idea that if word can belong to two categories it can be regarded as analogous to spin with two values. If superpositions of same word with different meanings make sense, the analogs for the choice of spin quantization axis and measurement of spin in particular quantization direction make sense. A weaker condition is that the superpositions make sense only for the representations of the words. In TGD framework the representations would be in terms of fermionic Fock states defining quantum Boolean algebra.

   (a) Consider first a situation in which one has two spin measurement apparatus A and B with given spin quantization axis and A′ and B′ with different spin quantization axis. One can construct correlation functions for the products of spins s_1 and s_2 defined as outcomes of measurements A and A′ and s_3 and s_4 defined as outcomes of B and B′. One obtains pairs 13, 14, 23, 24.

   (b) Bell inequalities give a criterion for the possibility to model the system classically. One begins from 4 CHSH inequalities (`http://tinyurl.com/y6ua44dk`) follow as averages of inequalities holding for individual measurement always (example: $-2 \leq s_1s_3 + s_1s_4 + s_2s_3 - s_2s_4 \leq 2$) outcomes by *assuming* classical probability concept implying that the probability distributions for s_is_j are simply marginal distributions for a probability distribution $P(s_1, 2_2, s_3, s_4)$. CHSH inequalities are necessary conditions for the classical behavior. Fine's theorem (`http://tinyurl.com/y8c8r22s`) states that these conditions are also sufficient. Bell inequalities follow from these and can be broken for quantum probabilities.

   (c) Does this make sense in the case of cognitive spins? Are superpositions of meanings really possible? Are conscious meanings really analogous to Schrödinger cats? Or should one distinguish between meaning and cognitive representation? Experienced meanings

are conscious experiences and consciousness identified as state function reduction makes the world look classical in standard quantum measurement theory. I allow the reader to decide but represent TGD view below.

What about quantum cognition in TGD framework? Does the notion of cognitive spin make sense? Do the notions of cognitive entanglement and cognitive measurement have sensible meaning? Does the superposition of meanings of words make sense or does it make sense for representations only?

1. In TGD quantum measurement is measurement of density matrix defining the universal observable leading to its eigenstate (or eigen space when NE is present in final state) meaning that degenerate eigenvalues of the density matrix are allowed). In the generic case the state basis is unique as eigenstates basis of density matrix and cognitive measurement leads to a classical state.

   If the density matrix has degenerate eigenvalues situation changes since state function can take place to a sub-space instead of a ray of the state space. In this sub-space there is no preferred basis. Maybe "enlightened" states of consciousness could be identified as this kind of states carrying negentropy (number theoretic Shannon entropy is negative for them and these states are fundamental for TGD inspired theory of consciousness. Note that p-adic negentropy is well-defined also for rational (or even algebraic) entanglement probabilities but the condition that quantum measurement leads to an eigenstate of density matrix allows only projector as a density matrix for the outcome of the state function reduction. In any case, in TGD Universe the outcome of quantum measurement could be enlightened Schrödinger cat which is as much dead as olive.

   Entangled states could represent concepts or rules as superpositions of their instances consisting of pairs of states. For NE generated in state function reduction density matrix would be a projector so that these pairs would appear with identical probabilities. The entanglement matrix would be unitary. This is interesting since unitary entanglement appears also in quantum computation. One can consider also the representation of associations in terms of entanglement - possibly negentropic one.

2. Mathematician inside me is impatiently raising his hand: it clearly wants to add something. The restriction to a particular extension of rationals - a central piece of the number theoretical vision about quantum TGD - implies that density matrix need not allow diagonalization. In eigen state basis one would have has algebraic extension defined by the characteristic polynomial of the density matrix and its roots define the needed extension which could be quite well larger than the original extension. This would make state stable against state function reduction.

   If this entanglement is algebraic, one can assign to it a negative number theoretic entropy. This negentropic entanglement is stable against NMP unless the algebraic extension associated with the parameters characterizing the parameters of string world sheets and partonic surfaces defining space-time genes is allowed to become larger in a state function reduction to the opposite boundary of CD generating re-incarnated self and producing eigenstates involving algebraic numbers in a larger algebraic extension of rationals. Could this kind of extension be an eureka experience meaning a step forwards in cognitive evolution?

   If this picture makes sense, one would have both the unitary NE with a density matrix, which is projector and the algebraic NE with eigen values and NE for which the eigenstates of density matrix outside the algebraic extension associated with the space-time genes. Note that the unitary entanglement is "meditative" in the sense that any state basis is possible and therefore in this state of consciousness it is not possible to make distinctions. This strongly brings in mind koans of Zen buddhism. The more general algebraic entanglement could represent abstractions as rules in which the state pairs in the superposition represent the various instances of the rule.

3. Can one really have superposition of meanings in TGD framework where Boolean cognitive spin is represented as fermion number (1,0), spin, or weak isospin in TGD, and fermion Fock state basis defines quantum Boolean algebra.

In the case of fermion number the superselection rule demanding that state is eigenstate of fermion number implies that cognitive spin has unique quantization axis.

For the weak isopin symmetry breaking occurs and superpositions of states with different em charges (weak isospins) are not possible. Remarkably, the condition that spinor modes have a well-defined em charge implies in the generic case their localization to string world sheets at which classical W fields carrying em charge vanish. This is essential also for the strong form of holography, and one can say that cognitive representations are 2-dimensional and cognition resides at string world sheets and their intersections with partonic 2-surfaces. Electroweak quantum cognitive spin would have a unique quantization axes?

But what about ordinary spin? Does the presence of Kähle magnetic field at flux tubes select a unique quantization direction for cognitive spin as ordinary spin so that it is not possible to experience superposition of meanings? Or could the rotational invariance of meaning mean SU(2) gauge invariance allowing to rotate given spin to a fixed direction by performing SU(2) gauge transformation affecting the gauge potential?

4. A rather concrete linguistic analogy from TGD inspired biology relates to the representation of DNA, mRNA, amino-acids, and even tRNA in terms of dark proton triplets. One can decompose ordinary genetic codons to letters but dark genetic codons represented by entangled states of 3 linearly order quarks and do not allow reduction to sequence of letters. It is interesting that some eastern written languages have words as basic symbols whereas western written languages tend to have as basic units letters having no meaning as such. Could Eastern cognition and languages be more holistic in this rather concrete sense?

5 P-Adic Cognition And Various Codes

I learned from Tidjani Negadi about some new ideas related to the attempt to understand the basic numbers of the genetic code [A4]. Some of these ideas stimulated some speculations about genetic code and its relationship to cognition and led to a discovery of two number theoretical miracles related to the realization of cognition at DNA and protein level. I have done a lot of work with genetic code [K9, K5, K25, K17] and the ideas below correspond to arelatively old layer in this work.

5.1 Symmetry Breaking Generates Conscious Information

What is very attractive in Negadi's approach is the interpretation of the reduction of the entropy in the symmetry breaking as information [A3]. This kind of a philosophy fits nicely with the general TGD based view about the generation of the macro-temporal quantum coherence and hierarchy of quantum criticalities and super-symplectic symmetry breakings as a source of negentropic entanglement and correlate for evolution.

The recent vision about fractal hierarchy of quantum criticalities brings the breaking of super-symplectic symmetries as gauge symmetries central element of evolution. The phase transitions reducing the sub-algebra of this algebra acting as gauge symmetries occur spontaneously and generate negentropic entanglement if weak form of NMP is accepted as the basic variational principle. The sub-algebras are characterized by an integer n telling that the conformal weights for its generators are n-ples of those for the full algebra isomorphic to the sub-algebra. A very detailed view reducing evolution to the hierarchy of algebraic extensions of rationals defining in turn those of p-adic numbers emerges from this picture. Preferred p-adic primes can be identified as so called ramified primes of the algebraic extension of rationals and also the generalization of p-adic length scale hypothesis emerges from the weak form of NMP.

In strong form of holography 2-surfaces are algebraically continued to preferred extremals. p-Adic continuations identifiable as imaginations would be due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K16]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes.

What this picture implies at space-time level is yet an open question. Certainly the representations of Galois groups are important but are realized rather abstractly at the level of conformal invariants parameterizing string world sheets and partonic 2-surfaces rather than space-time surfaces. The discretization is at the level of this space and means that common points ore reality and p-adicities are at the level of parameter space.

Co-dimension 2 rule holds true for the discretization. Space-time is discretized in terms of string world sheets and partonic 2-surfaces (this is just strong form of holography implied by strong form of General Coordinate Invariance). Partonic 2-surfaces are discretized as discrete sets of points common the real and p-adic variants of the partonic 2-surface belonging to the algebraic extension of rationals in question. This means also discretization at space-time level and one might hope that some preferred very simple discrete geometries could be dynamically favored.

Weak form of NMP generalizes p-adic length scale hypothesis. p-Adic primes, which are near but below powers of prime are favored. The original form of p-adic length scale hypothesis states that the primes $p \simeq 2^k$ are preferred. Mersenne primes are the primes nearest to power of two and in this sense unique. For odd powers of primes this criterion cannot be satisfied so accurately as for Mersennes. The model for the hierarchy of codes containing also genetic code relies on Combinatorial Hierarchy $M(n+1) = M_{M(n)}$, $M(1) = 3$, giving rise to Mersenne primes $3, 7, 127, 2^{127}-1$. The remaining numbers in the hierarchy could but need not be Mersenne primes. $M_7 = 127$ corresponds to genetic code and M_{127} to what I have called memetic code possibly assignable to electron. If cognition is fundamental aspect of TGD present already at elementary particle length scales as already p-adic mass calculations and the adelic vision about tGD [K37] suggest, one indeed expects that the Universe is full of cognitive codes - even at the level of elementary particles. They would however correspond to the "dark" aspects of matter not observable by the existing experimental methods and related to the hierarchy of Planck constants predicted by TGD.

The considerations related to codes discussed in the sequel are written much before the emergence of this picture and I cannot guarantee full consistency with the proposed picture.

5.2 Cognitive Codes As A Realization Of The Information Generated By DNA-Protein SymmetryBreaking?

One can argue that before the establishment of the genetic code the assignments of DNA triplets to amino-acids are random. This would mean that the symmetry group is a direct product of the permutation groups permuting 64 DNA triplets and 20 amino-acids. The symmetry entropy is logarithm about the number of elements of the symmetry group

$$S_{max} = log(w) \quad , \quad w = 64! \times 20! \quad . \tag{5.1}$$

One obtains $S_{max} \simeq 4 \times 61.8789$.

The work of Negadi inspired the question about whether one could interpret protein-DNA symmetry breaking as a process in which the information $I = S_{max} - S$ is generated and represented in a concrete manner as an additional conscious cognitive information associated with DNA and protein sequences.

In case of DNA sequences the symmetry breaking would be maximal so that one has $I = S_{max}$. In case of protein sequences symmetry breaking would be partial and $I = S_{max} - S$, where S corresponds to the entropy due to the fact that DNA triplets coding for the same amino-acid are equivalent from the view point of protein: DNA sequences carry more cognitive information than protein sequences.

Weak form of NMP provides additional clues.

1. Unitary entanglement between two state spaces of dimension kp^N (in the sense that entanglement matrix is proportional to a unitary matrix) gives rise to negentropic entanglement with p-adic prime p [K13]. These dimensions are favored by weak form of NMP as highly negentropic (the maximum of number theoretic negentropy corresponds to p-adic prime p).

2. If p is Mersenne prime: $p = M_k = 2^k - 1$, temporal sequences of k spin directions /qubits could provide a concrete mechanism of quantum computation (for $k = 127$ associated with the memetic code at least. This suggests that DNA triplets or amino-acids could be accompanied by $p = M_k$-fold degeneracy resulting from the assignment of a sequence of k qubits to each DNA triplet and/or amino-acid.

3. This representation of information should relate somehow to the realization of the memetic code in terms of DNA and amino-acid sequences. In the model of the memetic code sequences of 21 DNAs are a natural candidate for the realization of the memetic code words since the number of different sequences is $64^{21} = 2^{126}$, which is the number of the memetic code words representing maximal number of forming a set theoretic inclusion hierarchy and logical implication hierarchy in the Boolean algebra represented by sequences of 127 bits. These statements correspond also to all statements consistent with a fixed atomic statement fixing the value of one bit. The sequences of 21 proteins are a natural candidate for defining the memetic counterpart of the DNA-protein translation if one assumes that the translation of genetic code induces directly the translation of the memetic code to proteins. A test is to find whether sequences of 21 DNAs/proteins might appear in the tertiary structure of DNAs/proteins.

4. The argument above suggests that one should try to find a representation of the cognitive information by assigning a temporal sequence of $p = M_k$ spin directions to each DNA/protein in the the sequence of 21 DNAs/proteins. This representation makes sense if the condition

$$I = 21 \times log(M_k) \simeq 21 \times k \times log(2) \tag{5.2}$$

giving

$$k = \frac{I}{21 \times log(2)} , \tag{5.3}$$

is satisfied for k Mersenne prime. The condition is obviously extremely restrictive and a number theoretical miracle is required since k has exponential sensitivity to the value of I. Even more, this miracle is required to occur twice: for both DNA and proteins! The value of I can be calculated for both DNA and proteins and one can check whether the mircacle occurs. That it indeed occurs gives a support for the realization of memetic code in terms of sequences of 21 DNAs and proteins.

5.3 Peptides As Molecules Of Emotion

The view about peptides and proteins as cognizing and intentional entities allows to translate to TGD language often used expressions like "emotions are expressed", "blocked emotions are released", "emotions are stored to the body as traumatic body memories", "peptides are molecules of emotion and information molecules". Most importantly, a concrete code for cognition emerges in which elementary intention represents inhibition or facilitation of gene expression.

5.3.1 Unasked questions

The interactions of the information molecules involve the formation of receptor-information molecule complex either at cell surface or in the cell plasma inside cell. Receptor-information molecule complex inside cell can move to genome and induce gene transcription. In case that the complex is formed at the surface of cell, second messenger action is involved. One can also speak about N: th messenger action. There are many poorly understood aspects related to the mechanisms of information molecule action [I6].

1. There are only few second messenger pathways and relatively few receptors but large number of different functions. This phenomenon is known as pleiotropy or multi-functionality. For instance, given second messenger causes different effects depending on the hormone that activated it (the phenomenon is somewhat analogous to the phenomenon in which message can be understood in several manners depending on the state of receiver).

   At purely chemical level the problem is how second messenger knows what hormone activated it? In steroid action the complex formed by information molecule and receptor in turn activates some gene. Now the question is: How the activated RNA polymerase knows which gene

has to be activated? Pleiotropy appears also at level of hormones. Same hormone can have multiple effects and the border between hormone, neuropeptide or even neurotransmitter is unclear. For instance, a hormone which by definition transmits long distance communications, can have effects in nearby cells and thus acts like a neuropeptide. How hormone knows what function it must perform? Also drugs and treatments can have different effects and side effects.

2. There is also functional redundancy: the same function is performed by several second messenger molecules. For instance, glucagon, growth hormone, adrenaline and corticosteroids elevate glucose levels. This suggests that there is deeper level of communication involved and that second messenger molecules are more like computer passwords than subprogram calls. Now the question is: What these subprogram calls do correspond physically?

3. Biological functions can be initiated also in non-chemical manner. The phenomena of healing by touch and the effects of meditation and biofeedback are examples of biological self-organization processes are initiated in non-chemical manner. Even other treatments like massage, acupuncture or meditation can decrease or inhibit pain. These observations suggest that chemical level is not the deepest level involved with biological functions and the question is: What is this deeper control level?

Simple lock and key mechanism cannot provide answer to the questions raised above. If information molecules carry p-adic intentions about say gene level expression of emotions, situation changes since additional information transfer is involved.

5.3.2 The code of emotions

The expressions of emotions are usually symbolic. What it means that peptides are responsible for the expression of emotions? Perhaps information molecules transfer the information about the emotions to be expressed at molecular level between body parts. It is indeed known that nervous system, immune system, and endocrine system are in an intense information exchange using information molecules.

The original naive speculation was that p-adic physics might be concretely involved here. The recent view is however more mundane looking.

1. The emotional expression - in fact all signalling in biosystems - involves pairs of magnetic flux tubes connecting the sender of the control signal and the target and serving as a correlate for directed attention. The reconnection of U-shaped flux tubes emanating from sender and the receptors of the target gives rise to the connecting pair of flux tubes. The connections would be between information molecules. For instance, messenger molecules would be connected to the sender and receptor of the target in this manner. Hormones and neurotransmitters would have similar connections.

2. The signal itself is transmitted along the flux tube pair and realized as dark photons propagating along massless extremals (MEs) parallel to flux tubes. Dark photons would have frequencies selecting only special targets by resonance mechanism. Dark photons would be cyclotron photons with a universal energy spectrum assignable to bio-photons in visible and UV range resulting as dark photons transform to ordinary photons. Universal energy spectrum is obtained if the value of h_{eff} satisfies $h_{eff} = h_{gr}$, where $\hbar_{gr} = GMm/v_0$ is so called gravitational Planck constant [K35] being proportional to the mass m of the charged particle appearing in cyclotron condensate so that cyclotron energy proportional to h_{eff}/m does not depend on the mass of the charged particle. The independence of gravitational Compton length on the mass of charged particle makes possible macroscopic gravitational quantum coherence.

The model for the music harmony and genetic code [K17] leads to a more detailed model for the representation of DNA codons and amino-acids in terms of "3-chords" defined by 3 frequencies. Since music represents and generates emotions, it is natural to consider the possibility that this representation provides correlates for emotions.

1. DNA sequences and proteins correspond to sequences of 3-chords, music pieces one might say and are represented by a characteristic musical theme. An analogous dark photon representation could apply to all important biomolecules and serve as its name. What is interesting that 256 different harmonies defined by the possible 3-chords emerge. They could provide correlates for various kinds of moods at bio-molecular level and assignable to magnetic bodies carrying dark matter, which would represent completely new information processing level distinguishing biochemistry from the ordinary chemistry.

2. The model involves only 3-chords playing the role of passwords, and can be seen as a particular realization of the genetic code. Password code could be enough but the temporal patterns of the signal analogous to temporal coding of bit sequences make possible an additional message much like in the ordinary communications between computers. The signal could be sent using higher level code in a hierarchy of codes.

3. Combinatorial Hierarchy containing at least the primes $3, 7, 127, 2^{127} - 1$ could define such a sequence of codes having interpretation as a hierarchy of statements about statements. Above the genetic code with 6 bits would be memetic code with 126 bits, which could be assigned to dark electrons if the flux tube connecting the wormhole contacts involved corresponds to $h_{eff} = M_{127} \times h$. Electron could have dark side invisible using recent measurement technology but crucial for understanding biology - the size scale of electron CD is .1 seconds, the fundamental biorhythm.

4. An interesting question is whether DNA sequences consisting of 21 DNA triplets realizing memetic code could have some special role in the control part of the genome. The sequences of $10 \times n$ DNA triplets are special in that the net helical rotation along the sequence is a multiple of 2π. This suggests a connection with $p = 5$ finite geometry realized in terms of pentagon and involved also with the finite geometry defined by icosahedron characterizing genetic code. Could the sequences of 20 DNA and thus also of 20 amino-acids serve as units of genetic information? Note that the sequence of 21 DNA codons realizing memetic codon corresponds to same twist modulo 2π tetrahedron as single DNA nucleotide. 10 memetic codons correspond to full multiple of 2π twist: is there some kind of fractality involved?

   Clearly, the number 5 is the key number of genetic code and $p = 5$ finite geometries dimension 1 and 2 seem to be involved. The challenge is to undertand the full picture.

Of course, any code based on Mersenne primes and on prime near but below a power of prime p_1 might be involved. $p_1 = 2, 3, 5$ correspond to finite geometries realizable as Platonic solids and are especially interesting candidates in this respects. All primes are realizable as regular polygons. Since $h_{eff} = h_{gr}$ is proportional to the mass of charged particle, each charged particle would have its own frequency scale analogous to a user specific frequency band used in radio communications so that the communications would not interfere with each other. Temporal code could have several variations. Frequency modulation is however strongly suggested by the model for cell membrane as generalized Josephson junction [K18].

5.3.3 What could happen in information-molecule receptor complex?

I have considered at the general level the question about what might happen in receptor complex in [K24].

The general idea is that the receptor serves as a relay station. The attachment of U-shaped flux tube emanating from the sender to a receptor generates a flux tube connection between sender and target analogous to that generated by a tele-operator. The connection can be very long ranged since the size scale of the magnetic body can e very large as compared to that of biological body from the fact that time scale of .1 seconds defining universal biorhythm assignable to electrons corresponds to the size scale of the Earth.

In [K24] I have discussed a speculative model for the effect of psychedelics on consciousness considering the possibility that the claimed encounters with representatives of other civilizations might be actually real remote sensory experience involving genuine communication rather than mere hallucination. The basic objection that the finite light velocity makes these encounters impossible is circumvented in ZEO. I do not of course expect that the reader would take this kind

of speculation seriously. What however remains is the possibility that receptors would serve as kind of tele-operators at which the flux tubes can attach so that remote connection is generated.

It is known that membrane proteins serving as receptors are in a helical conformation such that the number of proteins in the portion connecting the cell exterior and interior is 20 [I3]. This is not quite 21, which is the number of DNA codons representing single memetic codon ($126 = 21 \times 6$ bits). What could this mean?

1. Could the number 20 relate somehow to the number of triangular faces of icosahedron playing a key role in the model of music harmony and genetic code?

Cell membrane receptors are especially important receptors. The active parts of the cell membrane receptors corresponds to the parts of the membrane proteins traversing the cell membrane. Often the receptors are proteins, which traverse the cell membrane many times and the interpretation would be that each portion of 20 amino-acids defines one elementary signal unit defining a portion of DNA sequence to be translated and initiating a process leading to an expression of some gene(s). 7-bit code suggests that the codeword activates control genes which promote or disfavor the expression of some gene(s).

Micro-tubular cytoskeleton which is piezoelectric structure claimed to allow 64 bit code [I2], [J7] could mediate the electric electric signal to the nucleus and activate the desired genes. Massless extremals could be involved. The generation of the second messenger would represent a standardized part (there are relatively few second messenger pathways) of the process of realizing gene expression now responsible for the transfer of the intention.

5.3.4 Failure to express emotions

The expression of emotions can fail at several levels. The intention to express emotion is not realized as action. No state function reduction to the opposite boundary of CD for the corresponding sub-self would take place so that the mental image representing emotion would become very long-lived. By NMP the death of the emotional mental image is however required in order to generate negentropic entanglement. The unexpressed emotion is stored to the body as kind of tension.

Second failure is that the information molecules are sent but fail to bind to their receptors for some reason or the transfer of information inside the receiving cell fails for some reason. In this case the emotion is expressed at the primary level but the desired effect is not achieved.

An important function of sleep and dreams might be the expression of the un-expressed emotions of the geometric past. Also meditation and various therapies might have the same effect. Neuropharmacological approach, as long as it tries to affect only the geometric now, cannot change the geometric past and would not seem therefore very useful healing method for emotional traumas. My own rather traumatic academic past provides a good testing ground for this hypothesis. As a scientific heretic I lost my academic human rights for long time ago. It became clear that if I react to this, I will be labelled as an asocial paranoid. Apart from few exceptions, when the psychic pain was simply too intolerable, I managed to avoid this. This left a lot of unexpressed emotion to my geometric past and the reward for a civilized behavior was a label of a stupid sissy. Gradually it became also clear that there is no hope: the academic decision makers have unlimited power. It is hard to imagine a more effective mechanism for generating deep frustration and long term depression! Gradually I however realized that the coin had also the other side: the role of an academic zombie gave me an unlimited intellectual freedom which those professors did not possess and I had actually ideal circumstances for carrying out my mission optimally. Besides the incredible stupidity of the academic power holders I have been wondering second strange phenomenon during these years. Why do I spend practically all my dream time in my past? Could a partial answer be that I have been busily trying to express these un-expressed emotions: during sleep it is easier to break the academic etiquette.

6 About Molecular Cognitive And Sensory Representations?

The challenge of understanding how intentions and cognitions are realized at the molecular level is a fascinating and potentially very rewarding challenge. The work with genetic and memetic codes based on the notion of Combinatorial Hierarchy [K9, K11, K17] represents first steps in

this direction but does not yet involve p-adic aspects. The ideas of preceding section provide a lot of additional insight but do not provide any general theory. This section is devoted to an attempt to say something about the general theory of cognitive and symbolic representations at the molecular level assuming that even molecular structures have intentions and cognition and are able to transform intentions to actions.

The basic hypothesis is that molecules provide both static and dynamic symbolic representations for cognitive codes. Cognitive codes would be characterized by the symmetry groups of finite geometries and their projective counterparts. The requirement that cognitive quantum computation is possible raises the primes defining Mersenne primes to a preferred position. The symmetry groups of finite geometries are assumed to act as the symmetries of the molecular structures responsible for the symbolic representations. This leads to strong predictions as some examples treated below demonstrate and one might even speak about Golden Road to the understanding of cognition and intentionality at molecular level.

6.1 Number Theoretical Ideas

The predictive power of the model to be proposed derives basically from number theoretical constraints. Mersenne primes are in a unique position as far as p-adic quantum computation is considered. One can imagine a good reason for why Gaussian Mersennes should have a unique role. Fibonacci numbers characterize often the structure of biological systems, and there are reasons to believe that they might relate very intimately also to the evolution of cognitive representations.

6.1.1 Mersenne primes an cognitive hierarchies

The findings about new cognitive codes initiated by the idea of symmetry entropy of DNA-protein system can be compressed to a generalized notion of abstraction hierarchy, which was introduced years earlier. Any Mersenne prime M_p, p prime defines an abstraction hierarchy containing at most two levels. The $2^p - 1$ elements of the finite field $G(M_p, 1)$ represent all possible statements about p basic statements except the one which is not representable for some physical reason. Hierachies start from some prime which is $2, 5, 13, 17, 19, 31, 89, 107$ in the range of p-adic time scales of interest and can have several levels.

1. Combinatorial hierarchy $p = 2, 3, 7$ (single base pair), 127 (genetic code), M_{127} (memetic code whose mutually consistent statements are realized also as sequences of 21 DNAs) is the longest hierarchy. It is not known whether $M_{M_{127}}$ is prime: Hilbert conjecture states the entire infinite hierarchy consists of Mersenne primes. This would mean that universe possesses infinite ability of cognitive abstraction.

2. The next hierarchy starts from prime 5 and contains three levels $p = 5$, M_5=31, and $M_{31} = 2^{31} - 1 \simeq 2 \times 10^9$.

3. The remaining known to me hierarchies are two-step hierarchies and any Mersenne prime defines such a hierarchy. The largest Mersenne prime hierarchy of this kind relevant for human consciousness is M_{127} which is the p-adic prime characterizing electron and memetic code. M_{521} is the next Mersenne prime and corresponds to a completely super-astrophysical time scale.
   i) The first abstraction pair (p, M_p) corresponds to $p = 13$. Micro-tubuli are excellent candidates for the realization of M_{13}^{13} representations with $13^2 = 169$ bits of information (recall that $k = 169$ characterizes the p-adic length scale associated with neutrinos!).
   ii) Next Mersenne M_p prime corresponds to $p = 17$ and was deduced by the argument relating to the information gain in complete symmetry breaking of the DNA-protein system.
   iii) Also the Mersenne primes M_p associated with $p = 19, 31, 61, 89, 107$ should be there.

The beauty of Mersenne representations is that one can construct from them product representations containing M_p^k cognitive states and bits replaced by pinary digits M_p. Furthermore, by fractality any time scale $2^{pm/2}T_{M_p}$ is possible for sufficiently small primes p so that these representation can be present in and a wide spectrum of time scales ranging from the time scales relevant for the conformational dynamics of molecules to the time scales relevant for neural activity and EEG and even time scales measured in years.

6.1.2 What about Gaussian Mersennes?

The Gaussian Mersennes $G_n = (1+i)^n - 1$, n some prime, are expected to be also of fundamental importance and one expects that they give rise to complex cognitive representations. The Gaussian Mersennes possibly relevant to life correspond to primes $n = 2, 3, 5, 7, 11,\ 19, 29, 47, 73, 79, 113, 151, 157, 163, 167,\ 239, 241, 283$. The length scale range between cell membrane thickness and size of small bacterium contains only scaled up Compton lengths of electron for Gaussian Mersennes: they are $n = 151, 157,\ 163, 167$. The norm squared of the Gaussian Mersenne $G_{n=2k+1}$ is $p_n = 2^{21+1} + 2^{k+2} + 1$ and larger than 2^n.

One might guess that the number of Gaussian integers with norm smaller than the norm squared of Gaussian prime G_n defines the number of states in this kind of representation and that this number must be prime. Some very beautiful cognitive structures might be involved with Gaussian Mersennes and it remains to be found what this structure is. Obviously the idea that one could use sequences of n bits to realize $p_n = 2^n - 1$ points as phase transitions by spontaneous magnetization to an analogous representation of $p_{n=2k+1} = 2^{2k+1} + 2^{k+1} + 1$ points. One can write p_n in a form which gives hints about what kind of physics this representation might require:

$$p_{n=2k+1} \equiv N_1 + N_2 + N_3 \ ,$$

$$N_1 = 2^{2k+1} - 1 \ , \qquad N_2 = 2 \times 2^k - 1 \ , \quad N_3 = 2 \times 2 - 1 \ .$$

p_n is sum over numbers of magnetization phase transitions for three phases of the fermion system. N_1 corresponds to a system of $2k+1$ fermions. N_2 corresponds to a system consisting of one fermion plus k Cooper pairs: by the indistinguishability of fermions the combinatorial factor k is absent from N_2. N_3 corresponds to a system consisting of one fermion and a Bose-Einstein condensate of all k Cooper pairs behaving like a single particle. Neutrinos at $k = 169$ space-time sheet suggest themselves strongly as a realization of this phase.

6.1.3 Fibonacci numbers and the evolution of cognition

Fibonacci numbers proliferate living matter (logarithmic spirals) and emerge in the simplest models of growth: living matter is full of logarithmic spirals and also micro-tubular structure involves the sequence $3, 5, 8, 13$ of Fibonacci numbers. The natural guess is that Fibonacci numbers are also involved with cognitive growth and evolution: especially so if this biological growth is basically intentional and involves growth of plans from rough sketches to more detailed ones and if this development is seen in the structure of intention. In particular, 21 DNA/protein codeword could decompose to ordered hierarchy of subsequents of $1, 2, 3, 5, 8, 13, 21$ DNAs and these sequences with increasing length gradually give better and better representation of codeword. The development of the full cognitive code word or intention, would be like an interactive growth of a population of 21 cognitive organisms, primitive intentions associated with single DNA. Older unit intentions react to the presence of new ones by generating new unit of intention each. When, say, a generation consisting of 5=2+3 unit has been established, 3 units of previous generation generate new units (5+3=8) as a response to the presence of new 2 units.

For intance, single micro-tubule would represent only the 13 first DNAs and would not give faithful coding of the codeword. The wall of a double micro-tubule with 21 tubulin strands at its wall would do it. Interestingly, triple micro-tubules seem to contain the total of 33 or 34 micro-tubules, whether the number is 34=21+13, the next Fibonacci in the micro-tubular series, is not clear on basis of material that I have seen. Because of its Fibonacci structure of micro-tubule could automatically represent 5, 8 and 13 DNA approximations to the full intention represented by a sequence of 21 DNAs.

6.2 Representations

Representations are fundamental notions in geometry and physics and, as it seems, also sensory, symbolic, and cognitive representations make sense. The basic idea is that Nature codes its mathematical cognition to various kinds of symbolic representations. The fascinating possibility is that practically every bio-structure which results in genetic expression represents some cognitive/intentional structure somehow. We have been used to think that our theories represent those

structures we see: it might be fruitful to see the situation as just the opposite! DNA and proteins would be only particular hardware realization of finite geometries associated with cognition. This view might be general enough and certainly practical: one can deduce the symmetry groups associated with various structures and look whether one can assign them to finite geometries or their projective counterparts and thus to p-adic cognition.

6.2.1 Various types of representations

One can distinguish between several kinds of representations.

1. There are cognitive representations in terms of temporal sequences of p-adic neutrinos. Sequences of 21 DNA triplets could realize any representation defined by Mersenne prime since the temporal character of the sequences means that the density of neutrinos needed does not depend on the Mersenne prime. Thus there is no really deep reason for making too restrictive assumptions at this stage.

2. The symbolic representations can transform further to dynamical representations as either nerve pulses or oscillations of membrane potential. This representation generalizes: what is needed are two-state systems in an external field which forces a process analogous to spontaneous magnetization.

3. One can also consider the possibility of static geometric representations in terms of molecular geometry. These kind of representations could be realized for any prime p and in case that M_p is Mersenne prime, the structure characterized by p parts related by a cyclic symmetry Z_p could serve as a template for dynamical representations obtained by attaching a two-state system at every unit of the system. For instance, DNA triplets realize statically the set of 64 statements consistent with an atomic statement (single bit fixed) for $M_7 = 127$ cognitive representation and single DNA triplet could realize $M_3 = 7$ representation if each basepair can be in two states. Clathrin molecule gives 12-fold product of $p = 5$ representation in terms of 12 disjoint pentagon faces whose vertices carry a two-state system (the polarization of the triskelion protein could define the two states).

6.2.2 The basic principle for realizing dynamical representations

According to TGD inspired theory qualia, primitive qualia correspond to spin flips, and more generally, to phase transitions changing the direction of spin or some other quantity characterizing the state of the two-state system. In case of neutrino representations the essential elements are the presence of magnetic field, the fact that the neutrino is a two-state system which flips in the direction of externa magnetic field, and the fact that the number of representable states is $M_n = 2^n - 1$ rather than 2^n states since the state in which all spins are parallel does not give rise to spontaneous magnetization and conscious experience.

The replacement of single particle states with say spontaneously magnetized states guarantees rigidity and robustness. Spin glass type phase is optimal for the representative purposes and TGD universe is indeed a quantum spin glass. Dynamic representations can be realized in terms of molecular conformations instead of using fields. Micro-tubule representations provide a fundamental example but there are a lot of others. If magnetic flux tubes and electrets are indeed fundamental building blocks of living systems (they represent fundamental solutions of field equations of TGD), living system should be a huge fractal collection of these representations. Also cell membrane is expected to carry representations of this kind.

What this means is that the projective finite geometry with $M_n + 1 = 2^n$ points is represented dynamically by n two state systems such that the point at infinity is not realizable as spin flip pattern since it corresponds to the spontaneous magnetization or electret state in which all n two-state systems have spin /polarization/... direction parallel to external field and nothing happens. This is indeed what is required by the realization of qualia as quantum number increments. At the level of set theoretical Boolean algebra representation the point at infinity corresponds to the empty set.

If the strength of the background field can be controlled, the representation could be generated by weakening the field temporarily so that there results either a spin glass phase at criticality

optimal for the storage of bits or a phase above criticality optimal for signal propagation. The transformation inducing "spontaneous magnetization" responsible for the conscious experience could be generated by increasing the strength of the magnetic/electric field to its original value. For instance, in case of micro-tubular conformational representations reading would result by introducing strong electric field forcing the conformations to ground state conformations.

Magnetic flux tubes and their electric duals provide these background fields. In case of magnetic flux tubes cyclotron transitions are these transitions and spins of Cooper pairs define the bits. This allows a deeper understanding of also sensory representations.

6.2.3 Fractal hierarchy of time scales

The beauty of the realization of cognitive representation in terms of Mersenne primes is that all fractal powers $T(p,n) = p^{(n-1)/2}T_p$ of p-adic time scale T_p are a priori possible and correspond in good approximation to the square roots of the octaves of the fundamental time scale. The first implication is that the entire span of biologically relevant time scales can be realized using relatively few fundamental time scales defined by small Mersenne primes. This means also that for large Mersenne primes corresponding to relatively long time scales there can be several small Mersenne representations with essentially the same time scale. The signatures for these time scales are resonance frequencies corresponding to the time scales defining the duration of the codeword and also the duration of single bit. How much the duration of the codeword can vary around the p-adic time scale is still an open and important question: the width of alpha band suggests that the variation is about $\pm$ 20 per cent.

6.2.4 Is evolution 3-adic?

I received an interesting email from Jose Diez Faixat giving a link to his blog (`http://tinyurl.com/ycesc5mq`). The title of the article in the blog is "Bye-bye Darwin" and tells something about his proposal. The sub-title "The Hidden rhythm of evolution" tells more. Darwinian view is that evolution is random and evolutionary pressures select the randomly produced mutations. Rhythm does not fit with this picture. Faixat published 1993 the first article about his observations in the journal World Futures Vol. 36, pp. 31-56, edited by Ervin Lazlo with the title "A hypothesis on the rhythm of becoming" [I4, I5].

The observation challenging Darwinian dogma is that the moments for evolutionary breakthroughs - according to Faixat's observation - seems to come in powers of 3 for some fundamental time scale. There would be precise 3-fractality and accompanying cyclicity - something totally different from Darwinian expectations.

By looking at the diagrams demonstrating the appearance of powers of 3 as time scales of evolution, it became clear that the interpretation in terms of underlying 3-adicity could make sense. I have speculated with the possibility of small-p p-adicity. In particular, p-adic length scale hypothesis stating that primes near powers of 2 are especially important physically could reflect underlying 2-adicity. One can indeed have for each p entire hierarchy of p-adic length scales coming as powers of $p^{1/2}$. $p = 2$ would give p-adic length scale hypothesis. The observations of Faixat suggest that also powers p=3 are important - at least in evolutionary time scales.

Note: The p-adic primes characterizing elementary particles are gigantic. For instance, Mersenne prime $M_{127} = 2^{127} - 1$ characterizes electron. This scale could relate to the 2-adic scale $L_2(127) = 2^{127/2} \times L_2(1)$. The hierarchy of Planck constants coming as $h_{eff} = n \times h$ also predicts that the p-adic length scale hierarchy has scaled up versions obtained by scaling it by n.

The interpretation would be in terms of p-adic topology as an effective topology in some discretization defined by the scale of resolution. In short scales there would be chaos in the sense of real topology: this would correspond to Darwinian randomness. In long scales p-adic continuity would imply fractal periodicities in powers of p and possibly its square root. The reason is that in p-adic topology system's states at t and $t + kp^n$, $k = 0, 1, ...p - 1$, would not differ much for large values of n.

A possible interpretation relies on p-adic fractality [K15] (`http://tgdtheory.fi/figu.html`). p-Adic fractals are obtained by assigning to real function its p-adic counterpart by mapping real point by canonical identification

$$\sum_n x_n p^n \to \sum_n x_n p^{-n}$$

to a p-adic number, assigning to it the value of p-adic variant of real function with a similar analytic form and mapping the value of this function to a real number by the inverse of the canonical identification, the powers of p correspond to a fractal hierarchy of discontinuities.

A possible concrete interpretation is that the moments of evolutionary breakthroughs correspond to criticality and the critical state is universal and very similar for moments which are p-adically near each other.

The amusing co-incidence was that I have been working with a model for 12-note scale [L3], [K17, K25] (`http://tinyurl.com/y7csuxaw`), which to my opinion is highly interesting from the point of view of consciousness theory. Already the mathematicians of ancient Greece speculated with a connection with the geometry of Platonic solid and music scale [J13].

The basic observation is that icosahedron is a Platonic solid containing 12 vertices. The scale is represented as a closed non-self-intersecting curve - Hamiltonian cycle - connecting all 12 vertices: octave equivalence is the motivation for closedness. The cycle consists of edges connecting two neighboring vertices identified as quints - scalings of fundamental by factor 3/2 in Platonic scale. What is amusing that scale is obtained essentially powers of 3 are in question scaled down (octave equivalence) to the basic octave by a suitable power of 2. There is of course slight discrepancy due to the fact that $(3/2)^{12} = 2^7$ is not quite true. This motivated the transition to the well temperated scale with half note corresponding to the scaling by $2^{1/12}$.

The faces of icosahedron are triangles and define naturally basic 3-chords. Triangle can contain either 0, 1, 2 edges of the cycle meaning that the 3-chords defined by faces and defining the notion of harmony contain 0, 1, or 2 quints. One obtains large number of different harmonies partially characterized by the numbers of 0-, 1-, and 2-quint icosahedral triangles since the total number of Hamiltonian cycles at icosahedron is 2^{10}. One must howe$h_{eff} = n \times h$ver notice that those related by an isometry of icosahedron are equivalent.

The connection with 3-adicity comes from the fact that Pythagorean quint cycle is nothing but scaling by powers of 3 followed by suitable downwards scaling by 2 bringing the frequency to the basic octave so that 3-adicity might be realized also at the level of music!

There is also another strange co-incidence. Icosahedron has 20 faces, which is the number of amino-acids. This suggests a connection between fundamental biology and 12-note scale. This leads to a concrete geometric model for amino-acids as 3-chords and for proteins as music consisting of sequences of 3-chords. Amino-acids can be classified into 3 classes using polarity and basic - acid/neutrality character of side chain as basic criteria. DNA codons would would define the notes of this music with 3-letter codons coding for 3-chords. One ends up also to a model of genetic code relying on symmetries of icosahedron from some intriguing observations about the symmetries of the code table.

At the level of details the icosahedral model is able to predict genetic code correctly for 60 codons only, and one must extend it by a fusion it with a tetrahedral code. The fusion of the two codes corresponds geometrically to the fusion of icosahedron with tetrahedron along common face identified as punct (punct) and coded by 2 stopping codons in icosahedral code and 1 stopping codon in tetrahedral code. Tetrahedral code brings in 2 additional amino-acids identified as so called 21st and 22nd amino-acid discovered for few years ago and coded by stopping codons. These stopping codons certainly differ somehow from the ordinary ones - it is thought that context defines somehow the difference. In TGD framework magnetic body of DNA could define the context.

The addition of tetrahedron brings one additional vertex, which correlates with the fact that rational scale does not quite closed. 12 quints gives a little bit more than 7 octaves and this forces to introduce 13 note for instance, $A_\flat$ and $G_\#$ could differ slightly. Also micro-tubular geometry involves number 13 in an essential manner.

6.3 Finite Geometries And Cognition

Finite geometries defined by Galois fields $G(p, n)$ with p^n elements and identifiable as integers in an algebraic extension of p-adic numbers modulo p and corresponding projective geometries are the natural mathematical framework for simplest cognition. The primes p defining Mersenne

primes $M_=2^p-1$ and Gaussian Mersennes and these primes themselves are preferred primes for the reasons already explained.

1. The evolution of mathematics represents the evolution of cognition if ontogeny recapitulates phylogeny also at the level of cognition. This means that ancient mathematicians constructed also models for the basic structures of cognition. The Platonic solids could represent basic cognitive structures rather than only vice versa as it is usually thought.

2. Symmetry group characterizes a given geometry. This group is cyclic group Z_p for the simplest finite geometries defined by finite fields $G(p,1)$, p prime, and finite projective group for for their projective counterparts obtained by adding the point at infinity.

3. One can interpret spatial and temporal sequences of quark magnetization directions as representing points of finite geometries or their projective counterparts defined by Mersenne primes. The point at infinity corresponds to all spins in the direction of magnetic field so that no membrane oscillation is generated: infinity is un-reachable. Operational infinity is something which one is not able to achieve or perceive. This finding generalizes to a more general representational principle using two-state systems in an external field which forces the two-state systems to the same state. The cognitive state is coded to a conscious experience resulting in the phase transition to the ground state. If there are p two-state systems such that M_p is Fermat prime this system codes the points of the finite geometry M_p to conscious experiences.

Primes $p=2,3,5$ define especially interesting finite geometries and they correspond to Platonic solids. These Platonic solids appear in the molecular physics of living matter abundantly and this suggests that the p-adic length scale hierarchies associated with this primes are of special importance. There is indeed evidence for this as will be found.

If this view is correct, the mathematicians were studying their own cognitive consciousness when they were proving theorems about Platonic and Archimedean solids or doing ruler and compass constructions. In fact, I realized for years ago that Pythagorean triangles which pop up naturally in p-adic context, represent the very early view about world as mere rational numbers. The simplest mathematical cognition relies on finger counting: amusingly, decimal code pops up already at the level of DNA: 10 DNA triplets correspond to a helical twist which is minimal multiple of 2π.

6.3.1 Finite geometries

Ordinary finite geometry understood as having a structure of number field involves only a set of p (prime) ordered points defining the finite field $G(p,1)$ and subsets of points of this geometry. The projective counterpart involves also the point at infinity and contains thus $p+1$ points. Also the algebraic extensions $G(p,n)$ of $G(p,1)$ containing p^n points are possible but not discussed here. The symmetry group of the finite geometry $G(p,1)$ is cyclic group Z_p and the sequences of magnetization directions of p quark blocks represent the subsets of $G(p,1)$ as ordered sets. In case of projective finite geometry containing also the point infinity projective transformations induced by 2×2 unimodular matrices

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \tag{6.1}$$

induce projective transformations via the formula

$$x \to \frac{ax+b}{cx+d} \ . \tag{6.2}$$

By studying the unimodularity condition $ad-bc=1$ in finite field one easily finds that the number of elements in the projective group is

$$N \ = \ (p-1)\times[(p-1)\times(p-2)+4\times(p-1)+2]/2 \ . \tag{6.3}$$

For $p=5$ one obtains $N=60$ corresponding to the number of vertices in truncated icosahedron representing thus the symmetry group of 6-point projective finite geometry consisting of the group

A_5 of even permutations of five objects. For $p = 3$ the number of elements is $N = 224$ and corresponds to the group S_4 of permutations of four objects whereas for $p = 2$ the number of elements is $N = 6$ and corresponds to the group S_3 of the permutations of three objects.

The projective transformations of finite projective geometries are counterparts of Lorentz transformations. One can assign to finite geometries also a spinor structure. Spinors have two-components and the action of the projective transformation on the spinor is by matrix multiplication. It was actually this finding which led to the realization that there might be a deep connection between cognitive representations using fermion sub-CDs and finite (projective) geometries.

6.3.2 Representations of finite geometries

An interesting question is what finite geometries can be realized as polygons in plane or as Platonic or Archimedean solids. This requires that the symmetry group of the finite geometry or of its projective counterpart acts as a subgroup of the rotation group $O(3)$. For finite geometries having Z_p as a symmetry group regular polygons of plane with p vertices and edges provide this realization. At molecular level a realization by helical twisting is natural. If the number of units corresponding to a full helical twist of multiple of 2π is p or power of p one has a geometric realization of a finite geometry.

1. Polygons obtainable by ruler and compass construction

Of special interest are the polygons which can be constructed using only ruler and compass: for these structures lengths of various edges are either integers or involve iterated square roots of integers. The well-known theorem of Euler states that the only structures of this kind correspond to regular polygons with n vertices and sides of identical length having vertices at circle. The allowed values of n are given by

$$n = 2^k \prod_k F_k \quad ,$$

where k is any non-negative integer and F_k is Fermat prime

$$F_k = 2^{2^k} + 1 \quad , \quad k = 1, 2, 3, 4 \quad .$$

The list of Fermat primes is $3, 5, 17, 287, 2^{16} + 1$. Interestingly, the lowest three Fermat primes define Mersenne primes M_{F_k} so that they are expected to be of special interest from the point of view of cognition. These structures are not finite geometries but could be regarded as Cartesian products of finite geometries $G(2, k)$ and $G(F_i, 1)$. These structures can be seen as Cartesian products of finite geometries.

A possible geometric representation of these structures is based on many-sheeted space-time concept (see **Fig. ??** in the appendix of this book) so that various factors in the decomposition correspond to different space-time sheets characterized by appropriate p-adic topology (also real space-time sheets are characterized by p-adic prime). The hierarchical helical structures containing helices inside helices correspond to many-sheeted space-time structures and the numbers of basic units corresponding to single period at various levels could correspond to the prime factors appearing in the decomposition.

Bio-systems are full of helical structures. Five finger code and decimal code are included as almost simplest codes. 10 DNA molecules define a structures for which the total helical winding is multiple of 2π. Perhaps here is linear realization of the decimal code: that twist is multiple of 2π indeed says that one can form from DNA a loop where that cyclic group of 10 elements acts. One should look systematically through all helical structures and find the number of units which correspond to a minimal multiple of 2π rotation to see whether ruler and compass codes are realized.

2. Quantized Planck constant, dark matter, and Fermat polygons

One ends up with Fermat polygons from the quantization of Planck constant as $\hbar = \lambda\hbar_0$. Number theoretical arguments suggest a general formula for the allowed values of λ [K6] as $\lambda = n$ where the integer n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K28]. The values of n for which quantum phase is expressible in terms of squared roots are

number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17, F_3 = 257, F_4 = 2^{16} + 1$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales.

The p-adic vision about cognition suggests that algebraic extensions of p-adic numbers define a cognitive hierarchy and the lowest levels of this hierarchy correspond to algebraic extensions of p-adic numbers involving only iterated square root operation. These should emerge first in the evolution and therefore dark matter systems assignable to Fermat polygons should be the most abundant ones.

There is a lot of evidence for the presence of integers characterizing Fermat integers in living systems. For instance, the so called scaling law of [I1] [K10] states that radiation with frequency f_l is accompanied by a radiation with frequency $f_h \simeq 2 \times 10^{11} f_l$. The scaling factor 2×10^{11} corresponds with 1.5 per cent accuracy to the integer $n_F = 2^{36} \times 3 \simeq 2.03 \times 10^{11}$ defining a Fermat polygon. This suggests an interpretation in terms of a decay of dark photon with a given wave-length to a bundle of n_F ordinary photons with the same wavelength. The energy of the dark photon would be by a factor n_F higher. This process could serve as an effective tool of bio-control. Dark photon could also transform to an ordinary photon with wavelength shorter by factor $1/n_F$. Quite generally, integers n_F defining Fermat polygons are a reasonable guess for the generalization of the scaling law of homeopathy and the search for these scaling factors could provide an experimental means of identifying the values of Planck constant relevant for living matter.

Even the time units of everyday life could reflect the properties of the dark matter hierarchy responsible for the control of living matter, in particular those of the sub-hierarchy defined by Fermat polygons. Indeed, one year corresponds to $n_F = 4 \times 3$ months, one month to $n_F = 2 \times 3 \times 5$ days, one day to $n_F = 8 \times 3$ hours, one hour to $n_F = 60 = 4 \times 3 \times 5$ minutes, and one minute to $n_F = 60$ seconds.

3. Chromosomes and exotic quarks?

Helices within helices could give rise to hierarchies of cognitive representations. Magnetic flux tubes can have complex helices inside helices hierarchies and in this case the number of units basically consisting of super-conducting ions or of their Cooper pairs per single period at given level of hierarchy should be prime for a given loop.

Chromosomes are characterized by this kind of hierarchy of coiling and looping which helps to pack chromosome DNA (about 2 meters in humans) in a small volume. This hierarchy could give also make possible a hierarchy of cognitive codes corresponding to the space-time sheets defining the hierarchy. What makes this hierarchy so interesting is that the p-adic length scales in question correspond to the miracle length scales defined by Gaussian Mersennes corresponding to $k = 151, 157, 163$ and 167. The diameter of the largest structure involved with chromosomes is about .7 micrometers whereas the smallest structure has diameter of 11 nanometers. Thus all three primary p-adic scaled up electron Compton lengths ($k = 151, 157, 163$) could be realized and three levelled hierarchy is possible.

1. If the principle of realization is same as for the memetic code based on the pair $k = 127, 120$ (electron CD containing a sequence of quark CDs), the following picture suggests itself. $k = 157$ codon has $n = 2^{157-151} = 64$ bits of duration $T(2, 151)$, $k = 163$ codon has $n = 64$ bits of duration $T(2, 157)$, and $k = 167$ codon has $n = 2^{167-163} = 4$ bits of duration $T(2, 163)$.

   The realization in terms of exotic light quarks quarks would involve only temporal sequences of n sub-CDs. The secondary p-adic time scales determining the time scale of the corresponding CD and thus the time duration of codon are rather long: about 2×10^6 s for $k = 151$ and 10^8 seconds for $k = 157$. A test for this idea is whether the numbers of the basic units per period of helix at various levels are given $n = 32, 32$, and 8 DNA nucleotides (not that these numbers do not correspond to full number of codons).

2. The realization analogous to genetic code would involve $n = 157 - 151 = 6$ bits (genetic code), $n = 163 - 57 = 6$ bits, and $167 - 163 = 4$ bits.

3. One can also consider the possiblity that the number of bits is determined by the p-adic prime characterizing the space-time sheet involved and thus equal to $k = 151, 157, 163$. In

this case the duration of bit would not correspond to a secondary p-adic time scale as it does for the memetic code.

6.3.3 Realization of finite projective geometries using Platonic and Archimedean solids

For projective geometries the realization as Platonic solids in the sense that the projective symmetry group acts as group of symmetries of the Platonic solid are possible only for $p = 2, 3, 5$ cases. The 5 Platonic solids are tetrahedron, cube and octhedron, and icosahedron and dodecahedron. The basic transformation is duality changing faces and vertices. tetrahedron (4 vertices and 4 faces) is self dual whereas cube (8 vertices and 6 faces) and octahedron (6 vertices and 8 faces) are duals of each other, as are also icosadedron (12 vertices and 20 faces) and dodecahedron (20 vertices and 12 faces). The number of edges is fixed by the Euler characteristic of sphere (solids are topologically spheres) given in terms of the numbers of vertices, edges, and faces by $V - E + F = 2$ and one has $E = V + F - 2$ giving for the number of edges $E = 6, 12, 30$ in the three cases respectively. Archimedean solids allow different types of faces and hexagons, octagons and decagons are possible (note that the number of vertices for faces is not prime anymore). Archimedean solids have same symmetry groups as Platonic solids from which they are obtained by "truncations".

It is interesting to look how the symmetry groups of finite geometries can be realized as symmetries of Platonic and some Archimedean solids.

1. For $p = 2$ the group of projective symmetries corresponds to the 6-element group S_3 of permutations of three objects acting on triangle and being generated by 2- and 3-fold symmetries. The 3 vertices represent the 3 points of the projective geometry and the generator of Z_2 acts as a reflection permuting any pair of these points with the third point representing the point at infinity. The three faces of tetrahedron give rise to a representation of $p = 2$ finite geometry too. By assigning to each of these vertices a two-state system one obtains a representation for M_2. Tetrahedron allows M_2^2 representation with information content of 4 bits.

2. $p = 3$ projective geometry has four points and has the permutation group S_4 of four objects as a symmetry group. This group is the symmetry group of tetrahedron and the vertices of any face realize the finite geometry with three points with the fourth vertex taking the role of the point at infinity. Also octahedron and cube having symmetry group generated by 2-, 3- and 4-fold symmetries allow realization of the $p = 3$ finite geometry but not an isometric realization of the projective geometry since the tetrahedron defined by the 3 vertices nearest to a given vertex is not regular. 3-fold symmetries are rotations along diagonals. M_3 cognitive representation results by assigning to the 3 vertices of triangle, tetrahedron or cube two-state systems.

3. The symmetry group of $p = 5$ finite projective geometry and thus also the geometry are represented by dodecahedron and icosahedron which are dual to each other by vertex-face transformation, as well as by a truncated icosahedron, "bucky ball", having 60 vertices and directly representing the projective group associated with the corresponding finite geometry [A2]. This group is isomorphic with the group A_5 of even permutations of 5 objects and contains 2-, 3-, and five-fold elements. The coset space of $A_5/Z_2 \times Z_5$ represents the projective space and consists of 6 pairs of opposite and disjoint pentagons representing the points of the finite projective geometry.

The points of the finite geometry are represented by a single pentagon as is clear from the fact that the cyclic group Z_5 acts on these pentagons) M_5 representation results by assigning to the vertices of any pentagon a two-state system. System allows actually much more: there are 12 disjoint pentagons so that M_5^{12} code can be realized with information content of 60 bits! Thus truncated icosahedron has an exceptional capacity for coding intentions and this might be the reason for why it is the geometry of the clathrin molecules which take care of logistics in cellular systems.

All platonic solids except tetrahedron allow also lattice structures. Therefore cognitive structures allowing symbolic representations in terms of molecular and lattice structures based on Platonic solids are expected to be of fundamental importance. These correspond to correspond to

2, 3, and 5 bit codes and Mersennes M_2, M_3, M_5. M_2 corresponds to geometry of a line interval/triangle, M_3 to triangle/tetrahedron, and M_5 to pentagon/icosahedron, dodecahedron or truncated icosahedron depending on whether one requires projective extension or not. The codes would be represented by assigning to the substructures representing the finite geometry a two-state system. For instance, electric polarization of the protein structure in electric field at larger space-time sheet could define the spinlike variable. By using lattice like structure formed by basic units one obtains products of representations of type M_n^k.

Finite geometries appear naturally in p-adic context and Platonic solids suggests that the primes $p = 2, 3, 5$ and corresponding p-adicities are in special position. Generalized p-adic length scale hypothesis implied by NMP suggests that also the primes new powers of these primes are important. What is intriguing that the times assignable to jumps in biological evolution seems to correspond to powers of 3 for fundamental time scale (`http://tinyurl.com/ycesc5mq`) [I5]. The appearance of Golden mean in biology in turn suggests that 5-adicity is also present. Note however that Golden Mean requires algebraic extension of rationals containing $\sqrt{5}$. What is especially interesting that the model of music harmony and genetic code to be discussed in following involves icosahedron, which corresponds to $p = 5$ finite geometry.

6.3.4 Icosahedral model for music harmony and genetic code

The model for music harmony and genetic code [K17] represents the most recent work, which could be possibly interpreted in terms of discrete 2-D geometries assignable to partonic 2-surfaces. Platonic solids represent the most symmetric discrete geometries assignable to sphere. Icosahedron and tetrahedron represent two Platonic solids and appear in the model.

The work relies on two observations. The number of notes of 12-note scale is same as the number of vertices of icosahedron. Icosahedron has 20 faces, which is the number of amino-acids in standard genetic code. There are however some non-standard features: 2 additional amino-acids appear in Nature and the coding of stop codons is not always the same - as if two codes were present or code is context dependent.

So called quint rule allows to represent 12-note scale as a sequence of 3/2 scalings for the fundamental frequency of the scale. Nearest neighbors at the icosahedron would differ by quint as notes which would mean 3-adic notion of distance for frequencies. There is however a little problem: 12 scalings give 7 slightly more than 7 octaves. Well-tempered scale solves the problem but those with absolute ear like Pythagorean scale. The problem can be also solved by allowing 13:th note very near to one of the 12 notes.

The proposal is that 12-note scale corresponds to a self-non-intersecting closed (by octave equivalence) curve at icosahedron connecting neighboring points. Geometrically non-equivalent curves would correspond to different harmonies defined by the 3-chords assignable to the 20 faces of the icosahedron. These 20 faces would also correspond to amino-acids and also 20 DNAs which indeed consists of 3 nucleotides. The closed curves in question are known as called Hamiltonian cycles and there are 17 cycles altogether. 6 cycles do not have any symmetries. The remaining cycles have symmetry groups $Z_6, Z_4, Z_{2,rot}, Z_{2,refl}$ and their total number is 1+ 2+3+ 5=11.

60 DNAs can be regarded as a fusion of 3-harmonics corresponding to Z_6, Z_4 and Z_2 symmetry groups and one obtains 256 different bio-harmonies having possibly interpretations as correlates for emotional moods (music harmony both represents and generates emotions). It is proposed that the DNA codons are represented as chords defined by dark photon triplets and having frequency spectrum in the same region as ordinary music notes. The transformation between these two representation could take place routinely in living matter.

4 DNAs and also the 2 additional amino-acids are obtained in two manners. By fusing tetrahedron along its face to icosahedron and fusing the codes - this corresponds to adding 13:th note to the 12-note scale - or by keeping icosahedron and tetrahedron as distinct. One would have two separate genetic codes and this would explain the non-uniqueness of genetic code in some situations as well as the 2 additional amino-acids. An interesting possibility is that the two DNA strands talk different languages so that the two codes would correspond to the two DNA strands!

6.3.5 Clathrin molecule and cognition

Icosahedral structure representing $p = 5$ finite geometry populate biology. Water molecular clusters have icosahedral structure or its dual dodecahedral structure defining also $p = 5$ finite geometry. Chlatrin molecule is a further example.

Clathrin molecule [J14] is involved with the transfer of various kinds of cargo through the cell membrane and also through intracellular membranes. Even viruses use clathrin molecule coating. Clathrin molecule induces a pit in the cell membrane and membrane pinches so that clathrin molecule providing coating for a piece of cell membrane and containing the cargo ends up to the cell interior. An area of cell membrane of football plane corresponding to that contained by entire brain is generated during one hour when clathrins coat cell membrane containing receptors and take it inside the cell. The generation of new cell membrane with this gigantic rate should involve huge dissipative losses unless macro-temporal quantum coherence is involved in the process.

Perhaps this argument alone convinces one day anyone about the presence of macro-temporal quantum coherence in brain. Clathrin molecule has the geometry of a truncated icosahedron, also the geometry of the soccer ball and fullerene or buckyball molecule C_{60} containing 60 carbon atoms arranged to the vertices of the truncated icosahedron. In clathrin molecule carbon atoms are replaced by three-legged triskelion molecules consisting of proteins. It is interesting to take a more careful look on the geometry of truncated icosahedron defining the geometry of the clathrin molecule, if not anything else, the for the purpose to get a glimpse about the amazing number theoretical regularities of this structure. Truncated icosahedron has 60=59+1 vertices, 90=89+1 lines, and 12=11+1 pentagonal and 20=19+1 hexagonal faces. Pentagonal faces are disjoint. 6 pentagonal face pairs can be naturally interpreted as points of a finite projective geometry associated with finite field $G(5, 1)$.

What it is interesting is that all these numbers are of form $p + 1$, p prime. With one exception (59) these primes also define Mersennes of Gaussian Mersennes. As a matter fact, the number of faces, edges, and vertices are of this form for all Platonic solids and also for several Archimedean solids. The interpretation in terms of a finite projective geometries suggests itself but the requirement that the symmetries of finite geometry are realizable as rotations excludes this interpretation since these substructures are not representations of the corresponding projective group realized in terms of rotations. Of course, one must keep mind open for the possibility that the imbedding of the symmetry group to rotation group is not necessary.

Clathrin molecule is an excellent candidate for a very effective realization of molecular cognition. If the triskelion proteins at the vertices of disjoint pentagons are electrically polarizable, a dynamical M_5^{12} representation with information content of 60 bits becomes possible by controlling the electric field at the space-time sheet at which the triskelions are condensed at. This information could relate to the basic function of clathrin molecules but also the idea that clathrin molecules transfer also information besides matter must be considered. For instance, this representation could be involved with the transfer of not only the neurotransmitters but also of (micro-tubular?) information from post- to pre-synaptic neurons.

6.4 Application Of Ideas To Micro-Tubuli And Clathrin Molecules

The proposed general principle allow to develop detailed views about what kind of cognitive representations that various molecular structure can accommodate. There is a considerable freedom concerning the choice of the representative system and spin flips or analogous transitions can be amplified to magnetization type quantum phase transitions at higher levels of the self hierarchy.

6.4.1 Micro-tubular representations

Micro-tubuli [J7, J14] are formed as hexagonal lattices of tubulin dimers on cylinder. The two conformations of a tubulin dimer define the two states of the micro-tubular representations. In an external electric field along micro-tubule at the larger space-time sheet the second tubulin conformation is unstable and the codeword is realized as a phase transition leading to the ground state. Spontaneous electric polarization of all tubulins in the same direction forced by an electric field in the direction of the micro-tubule defines the ground state. The ground state itself cannot give rise to conformational flips and thus cannot define a codeword and one obtains M_{13} rather than 2^{13} codewords realizable as a signal resulting in the flip to the ground state.

1. Basic picture Micro-tubuli have helical structure: there are two helical strands with 13-micro-tubule periodicity. A full 2π twist for a tubulin dimer strand corresponds to 13 dimers and corresponds to vertical distance of 8 resp. 5 micro-tubules for the two arrays involved. Thus a full 2π twist defines naturally the codeword and corresponds to 13-bit M_{13} codeword. Each tubulin dimer strand defines a codeword: M_{13}^{13} representations with an information content of $13^2 = 169$ bits associated with single 13-plet of codewords results.

The small value of $p = 13$ means an extreme flexibility concerning the duration of the cognitive code word. All $2^{13k/2} \sim 90.51^k$ multiples of T_{13} are possible. An interesting working hypothesis is that the number N of the tubulin strands contributing to the codeword defined by single connected structure defines the duration of the codeword as $T(N) = 2^{N\times 13/2}T_{13}$.

1. If the $k = 21$ micro-tubules at the wall of micro-tubule doublet contribute give rise to the DNA representation, this rule would predict the duration of the code word to be $T = 2^{(21-13)\times 13/2}T(169) \simeq 67.7$ seconds with the duration of bit about 5.6 seconds, which is somewhat longer than the mysterious time scale of 5 seconds associated with the Comorosan effect [K30]. $k = 20$ would give a codeword with a duration of .8 seconds and with the duration of bit about 62 milliseconds. DNA should control the behavior of micro-tubules in a rather long time scale (translation of single amino-acid takes 1/20 seconds) and these timescales sound rather reasonable.

2. For triplets of micro-tubuli the number of tubuli in the wall is something like 29 and the rule would predict completely unrealistic duration of the codeword about 10^7 years. It seems that the time scale should be same as for doublet: note that only pairs of tubuli have direct contact in the triplet.

3. Micro-tubular representation would correspond to the duration $T(13^2) = T(169)$ the cognitive codeword which is about 1.7×10^{-14} seconds, which is much shorter than the time scale of conformational dynamics and corresponds to the time scale of infrared transitions. This time scale is considerably shorter than the time scale $\sim .1$ nanoseconds associated with the protein conformational dynamics so that some other spin or rpolarization type variable should define the representation if it is realized at all. Neutrino spin is an excellent candidate in this respect. By increasing $k = 13$ to $k = 15$ gives time scale of order.1 nanoseconds. It seems that the working hypothesis could give rough ideas about orders of magnitude but cannot be taken literally.

2. Cilia and centriole

Centriole resp. cilia are arrangements of micro-tubules containing 9 bundles of 3 resp. 2 micro-tubules at the boundary of cylinder like structure and possibly also a doublet of micro-tubuli in the center [J14].

Micro-tubule doublets are associated with cilia crucial for the movement of monocellulars. Cilia consists of nine micro-tubule doublets at the surface of cylinder and one doublet in the center: also two separate micro-tubules are possible in the center. Some tubulin strands (usually three) are lacking from the second fused micro-tubule. According to some sources, the total number of tubulin dimer strands in doublet is 24 and 21 at the outer surface of doublet. 21 is Fibonacci number associated with the micro-tubular sequence of Fibonacci numbers and also the number of DNA triplets in cognitive codes. The complex of 21 tubulin dimer strands would be ideal for coding of M_{13}-bit sequences possibly associated with DNA or amino-acid sequences of 21 units and containing $21 \times 13 = 273$ bits of information. The code words associated with the wall of the cilium define $M_{13}^{9\times 21}$ representation with $13 \times 9 \times 21 = 2457$ bits.

Centriole are crucial for the control of the movement of the cell and are present only in motile cells (not in plants). If nucleus controls the movement of cell, centrioles and cilia should communicate with DNA in both directions in the act of transforming intentions to actions. T shaped centriole form an ideal antenna structure and could communicate both classically and quantally in terms of MEs. Centriole have 9 micro-tubule triplets at the boundary of a cylinder. Various sources give different values for the total number of strands but it seems that the total number of tubulin strands is about 33-34 and outer wall contains about 4 strands. Perhaps it deserves to be noticed that the total number of strands is near to Fibonacci number 34 associated with the

micro-tubular sequence of Fibonacci numbers. In case of centriole the 9 fused triplets of micro-tubules at the boundary each triplet containing about 33 tubulin dimer strands should give rise to a representation $M_{13}^{9\times 33}$ with $13 \times 9 \times 33 = 3861$ bits. Huge amounts of information are involved.

3. Neuronal micro-tubuli

Neurons, which are not motile cells, do not have the usual T shaped centriole structure. Micro-tubuli are however there and start from the region near nucleus and connect this region to the dendrites and to the end of the axon. The micro-tubuli associated with the axons can be very long, up to millimeters and are connected together by MAPs, micro-tubule associated proteins. This strongly suggests that micro-tubuli participate in an essential manner to neuronal communications or to short term information storage. For instance, the propagation of the nerve pulse could alter the electric field of the micro-tubule space-time sheet temporarily and give rise to spin glass state and thus induce representations of cognitive states in terms of tubulin conformations. The return of the membrane potential to the normal value would induce the conscious reading of the resulting representations. The minimal reason for this would be that axonal micro-tubules are responsible for the transfer of neurotransmitters to the axonal end and they must be cognizant about the overall nerve pulse activity.

Against the impressive representational capacity of micro-tubules the idea that nerve pulse involves the transfer of only single bit of information seems weird. Rather, the picture about micro-tubules would suggest that nerve pulse propagation are accompanied by a propagation of conformational spin glass state in the depolarized portion of the axon carrying information, and that one important function of the nerve pulse is to allow the propagation of the conformational wave carrying the information. Of course, also cell membrane could carry informational wave by same mechanism and one could see the events in the axonal membrane also as a realization of p-adic intentions basically. An objection against this view is related to the problem how the micro-tubular signal is transferred between micro-tubuli at MAPs. This is obviously needed if information from micro-tubuli is transferred to postsynaptic neuron. One must seriously consider the possibility is that the information is received only by micro-tubuli and their form an essential part of the conscious sensory pathway. This would explain why the lengths of micro-tubuli associated with sensory pathways are maximized (the information from given side of the body goes to the opposite brain hemisphere).

6.4.2 What about cell membrane?

Cell membrane electric field makes it ideal for the realization of cognitive representations. Lipid molecules and membrane proteins are natural good candidates for representing the bit sequences represented as two different electric polarizations of proteins. The propagation of nerve pulse could generate a representation during de-polarization phase which would be read when membrane potential has returned to its original value. The function of the nerve pulse would be thus to inform entire axon consciously.

7 Cognition And Number Theory

The identification of p-adic physics as physics of cognition and intention suggests strongly connections between cognition, intentionality, and number theory. The new idea is that also real transcendental numbers can appear in the extensions of p-adic numbers which must be assumed to be finite-dimensional at least in the case of human cognition. This idea, when combined with a more precise model for how intentions are transformed to actions, leads to a series of number theoretical conjectures. Also new insights about the number theoretical origin of the universal dynamics of conformally invariant critical systems emerge. The earlier approaches to the proof of Riemann hypothesis can be understood in a unified manner and the assumption that Riemann Zeta exists in all number fields when finite extensions are allowed for p-adic numbers leads to the view that that the zeros of Riemann Zeta correspond to the universal number theoretically quantized spectrum of scaling momenta associated with critical conformally invariant systems.

7.1 Conceptual And Technical Problems Related To P-Adicization

The following two ideas serve as guide lines in the attempt to relate cognition and number theory to each other so that number theory would allow to construct a more detailed view about the realization of intentionality and cognition.

One must face also several technical problems stimulating in turn ideas and in the following some of them are discussed.

1. Real and p-adic number fields form and adelic book like structure with pages represented by number fields glued together along rationals forming the rim of the book. For the extensions of p-adic numbers further common points result and the book becomes fractal if all possible extensions are allowed. This picture generalizes to the level of the imbedding space and allows to see space-time surfaces as consisting of real and p-adic space-time sheets belonging to various extensions of these numbers. Gluing of the sheets to a book-like structure is however carried out at the level of parameter space defined by an algebraic extension of rationals. This generalized view about numbers gives hopes about an un-ambigious definition of what some number, say e, appearing in an extension of p-adic numbers really means.

   It is now clear that adelic view is the only mathematically feasible one and is made possible by the strong form of holography [K37]. The key notion is what I have called intersection of reality and various p-adicities. This intersection can be identified as string world sheets and partonic 2-surfaces parameterized by numbers in some algebraic extension of rationals. These extensions define a cognitive hierarchy since fermions reside at these 2-surfaces already from the condition that electric charge is well-defined.

   Discretization and real-p-adic correspondence via canonical identification as already in p-adic mass calculations for various group invariants - in particular the Lorentz invariants appearing in the scattering amplitudes - takes therefore therefore at more abstract level than originally thought. This allows to circumvent problems with various symmetries encountered if one maps real space-time surfaces to their p-adic counterparts locally. Only for partonic 2-surfaces the concrete discretization by common points in algebraic extension for real and partonic 2-surfaces makes sense.

   The roughest parametrization for the algebraic extension of rationals is by the degree of the polynomial defining it and the so called ramified primes. These parameters have a physical meaning too, and are expected to central for the understanding of cognitive hierarchy. Ramified primes indeed correspond to preferred p-adic primes for which additional degrees of freedom emerge.

   In strong form of holography p-adic continuations of 2-surfaces to preferred extrmals identifiable as imaginations would be easy due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K16]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes. Whether the preferred primes satisfy p-adic length scale hypothesis or its generalization from $p = 2$ to small primes remains an open question.

   The value of effective Planck constant $h_{eff}/h = n$ corresponds to the number of sheets of some kind of covering space defined by the space-time surface. The discretization of the space-time surface identified as a monadic manifold [L5] with imbedding space preferred coordinates in extension of rationals defining the adele has Galois group of extension as a group of symmetries permuting the sheets of the covering group. Therefore $n = h_{eff}/h$ would naturally correspond to the dimension of the extension dividing the order of its Galois group.

2. The first new idea is roughly that the discovery of notion of any algebraic or transcendental number x (such as Φ or e) involves a quantum jump in which there is generated a p-adic space-time sheet for which the existing finite-dimensional extension of p-adic numbers is replaced by a finite-dimensional extension involving also x. Also some higher powers of the number are involved. For instance, for e $p-1$ powers are necessarily needed (e^p exists p-adically).

3. The points of M^4_+ with integer valued Minkowski coordinates using CP_2 length related fundamental length scale as a basic unit is a good guess for the subset of M^4_+ defining the rational points of the M^4_+ involved. CP_2 coordinates as functions of M^4_+ coordinates should be rational or belong to some finite-dimensional extension of p-adics. Of course, also rational points of M^4_+ are possible, and the evolution of cognition should correspond to the increase of the algebraic dimension of the extension.

4. A very powerful hypothesis is that the p-adic and real functions have the same analytic form. This makes possible to construct scattering amplitudes by algebraic continuations from the intersection of reality and p-adicities (the back of the book-like structure defined by 2-surfaces with parameters in algebraic extension of rationals). This assumption favors functions which allow at some point (most naturally origin) a Taylor series with rational valued Taylor coefficients.

7.1.1 Is e an exceptional transcendental?

Neper number is obviously the simplest one and only the powers e^k, $k = 1, ..., p-1$ of e are needed to define p-adic counterpart of e^x for $x = n$. In case of trigonometric functions deriving from e^{ix}, also e^i and its $p-1$ powers must belong to the extension.

An interesting question is whether e is a number theoretically exceptional transcendental or whether it could be easy to find also other transcendentals defining finite-dimensional extensions of p-adic numbers.

1. Consider functions $f(x)$, which are analytic functions with rational Taylor coefficients, when expanded around origin for $x > 0$. The values of $f(n)$, $n = 1, ..., p-1$ should belong to an extension, which should be finite-dimensional.

2. The expansion of these functions to Taylor series generalizes to the p-adic context if also the higher derivatives of f at $x = n$ belong to the extension. This is achieved if the higher derivatives are expressible in terms of the lower derivatives using rational coefficients and rational functions or functions, which are defined at integer points (such as exponential and logarithm) by construction. A differential equation of some finite order involving only rational functions with rational coefficients must therefore be satisfied (e^x satisfying the differential equation $df/dx = f$ is the optimal case in this sense). The higher derivatives could also reduce to rational functions at some step ($log(x)$ satisfying the differential equation $df/dx = 1/x$).

3. The differential equation allows to develop $f(x)$ in power series, say in origin

$$f(x) = \sum f_n \frac{x^n}{n!}$$

such that f_{n+m} is expressible as a rational function of the m lower derivatives and is therefore a rational number.

The series converges when the p-adic norm of x satisfies $|x|_p \leq p^k$ for some k. For definiteness one can assume $k = 1$. For $x = 1, ..., p-1$ the series does not converge in this case, and one can introduce and extension containing the values $f(k)$ and hope that a finite-dimensional extension results.

Finite-dimensionality requires that the values are related to each other algebraically although they need not be algebraic numbers. This means symmetry. In the case of exponent function this relationship is exceptionally simple. The algebraic relationship reflects the fact that exponential map represents translation and exponent function is an eigen function of a translation operator. The necessary presence of symmetry might mean that the situation reduces always to either exponential action. Also the phase factors $exp(iq\pi)$ could be interpreted in terms of exponential symmetry. Hence the reason for the exceptional role of exponent function reduces to group theory.

Also other extensions than those defined by roots of e are possible. Any polynomial has n roots and for transcendental coefficients the roots define a finite-dimensional extension of rationals. It would seem that one could allow the coefficients of the polynomial to be functions in an extension of rationals by powers of a root of e and algebraic numbers so that one would obtain infinite hierarchy of transcendental extensions.

7.1.2 Does the integration of complex rational functions lead to rationals extended by a root of e and powers of π?

These cold showers suggest that the best one might hope is that the numbers like $log(p)$ and $log(\Phi)$ could be proportional to some power π with a coefficient which belongs to a finite extension of p-adic numbers containing e. This might make it possible to continue the theory to p-adic context and also make very strong predictions.

The elementary differential and integral calculus provides important hints for as how to proceed. Derivation takes rational functions to rational functions unlike integration since the integrals of $1/x$ and and $1/(1+x^2)$ give $log(x)$ and $arctan(x)$ leading outside the realm of rational numbers. One can go to complex plane and consider the integrals of complex rational functions with complex rational coefficients and here one encounters integrals over closed curves and between two points. The rational approach is to consider rational complex plane, and first restrict to Gaussian integers which allow primes.

1. The first observation is that residy calculus for rational functions gives always integrals which are of form $2\pi iq$, q a rational number.

2. The integral $I = \int_a^b dz/z$, $a = m_1 + in_1$, $b = m_2 + in_2$ in turn gives

$$I = log(a/b) = \tfrac{1}{2}\left(log(m_2^2 + n_2^2) - log(m_1^2 + n_1^2)\right)$$

$$+i(arctan(n_2/m_2) - arctan(n_1/m_1)) \quad .$$

1. The strongest hypothesis would be that logarithm and arctan are also rationally proportional to π so that all integrals of this kind lead to an infinite-dimensional transcendental extension of p-adic numbers containing π. The strong hypothesis cannot be correct. Consider arcus tangent as an example. $arctan(m/n) = r\pi/s$ would imply $tan(r\pi/s) = m/n$, and this cannot hold true since it would imply that s: th powers of Gaussian integer $n + im$ would give an ordinary integer. This would be also true for Gaussian primes and the decomposition of Gaussian integers as products of Gaussian primes would become non-unique. There is this kind of uniqueness but this is due the units $exp(i\pi/4)$ and its powers. Indeed, $arctan(1) = \pi/4$ and proportional to π.

2. One can overcome this difficulty by replacing the ansatz with

$$arctan(q) = e^{q_1(q)} q_2 \pi$$

such that $q_1(q)$ is non-vanishing for $q \neq \pm 1 \pm i$ corresponding to the units of Gaussian primes. This ansatz is completely analogous to the ansatz for $log(p)$. The beauty of this ansatz would be that the imaginary parts for the integral of $1/(z - z_0)$ between complex rational points would be proportional to π irrespective of whether the integration is over a closed or open curve. The real parts of complex integrals in turn would be proportional to $1/\pi$ of $log(p) \propto 1/\pi$ ansatz holds true.

The requirement that complex integrals are powers of π could also mean quantization of topology in TGD framework. For instance, the conformal equivalence classes of Riemann surfaces of genus g are represented by period integrals of 1-forms defining elements of cohomology group H^1 over the circles representing the elements of homology group H_1. Restricting the cohomology to a rational cohomology, the periods with standard normalization would be quantized to complex rationals multiplied by a power of π. For surfaces characterized by a given power of π one might perhaps perform the p-adicization finite-dimensionally by suitable normalizations by powers of π.

7.2 Should One Allow Also Transcendentals In The Extensions Of P-Adic Numbers?

TGD inspired theory of consciousness leads to the identification of p-adic physics as physics of cognition. This identification leads to a rather fascinating new ideas concerning the characterization of intentional systems.

The basic ingredient is the new view about numbers: real and p-adic number fields are glued together like pages of a book along common rationals representing the rim of the book. This generalizes to the extensions of p-adic number fields and the outcome is a complex fractal book like structure containing books within books. This holds true also for manifolds and one ends up to the view about many-sheeted space-time realized as 4-surface in 8-D generalized imbedding space and containing both real and p-adic space-time sheets. The transformation of intention to action corresponds to a quantum jump in which p-adic space-time sheet is replaced with a real one.

One implication is that the rationals having short distance p-adically are very far away in real sense. This implies that p-adically short temporal and spatial distances correspond to long real distances and that the evolution of cognition proceeds from long to short temporal and spatial scales whereas material evolution proceeds from short to long scales. Together with p-adic non-determinism due the fact that the integration constants of p-adic differential equations are piecewise constant functions this explains the long range temporal correlations and apparent local randomness of intentional behavior. The failure of the real statistics and its replacement by p-adic fractal statistics for time series defined by varying number N of measurements performed during a fixed time interval T allows very general tests for whether the system is intentional and what is the p-adic prime p characterizing the "intelligence quotient" of the system. The replacement of $log(p_n)$ in the formula $S = -\sum_n p_n log(p_n)$ of Shannon entropy with the logarithm of the p-adic norm $|p_n|_p$ of the rational valued probability allows to define a hierarchy of number theoretic information measures which can have both negative and positive values.

Since p-adic numbers represent a highly number theoretical concept one might expect that there are deep connections between number theory and intentionality and cognition. The discussions with Uwe Kämpf in CASYS'2003 conference in Liege indeed stimulated a bundle of ideas allowing to develop a more detailed view about intention-to-action transformation and to disentangle these connections. These discussions made me aware of the fact that my recent views about the role of extensions of p-adic numbers are perhaps too limited. To see this consider the following arguments.

1. Pure p-adic numbers predict only p-adic length scales proportional to $p^{n/2}l$, l CP_2 length scale about 10^4 Planck lengths, $p \simeq 2^k$, k prime or power of prime. As a matter fact, all positive integer values of k are possible. This is however not enough to explain all known scale hierarchies. Fibonacci numbers $F_n : F_n + 1 = F_n + F_{n-1}$ behave asymptotically like $F_n = kF_{n-1}$, k solution of the equation $k^2 = k+1$ given by $k = \Phi = (1+\sqrt{5})/2 \simeq 1.6$. Living systems and self-organizing systems represent a lot of examples about scale hierarchies coming in powers of the Golden Mean $\Phi = (1+\sqrt{5})/2$. According to Selvam [H1] also meteorological phenomena involve spiral waves characterized by Golden Mean.

   By allowing the extensions of p-adics by algebraic numbers one ends up to the idea that also the length scales coming as powers of x, where x is a unit of algebraic extension analogous to imaginary unit, are possible. One would however expect that the generalization of the p-adic length scale hypothesis alone would predict only the powers $\sqrt{x}p^{n/2}$ rather than $x^k p^{n/2}$, $k = 1, 2, ...$ Perhaps the purely kinematical explanation of these scales is not possible and genuine dynamics is needed. For sinusoidal logarithmic plane waves the harmonics correspond to the scalings of the argument by powers of some scaling factor x. Thus the powers of Golden Mean might be associated with logarithmic sinusoidal plane waves.

2. Physicist Hartmuth Mueller has developed what he calls Global Scaling Theory [B1] based on the observation that powers of e (Neper number) define preferred length scales. These powers associate naturally with the nodes of logarithmic sinusoidal plane waves and correspond to various harmonics (matter tends to concentrate on the nodes of waves since force vanishes at the nodes). Mueller talks about physics of number line and there is great temptation to assume that deep number theory is indeed involved. What is troubling from TGD point of view that Neper number e is not algebraic. Perhaps a more general approach allowing also transcendentals must be adopted. Indeed, since e^p is ordinary p-adic number in R_p, a finite-dimension transcendental extension containing e exists.

3. Classical mathematics, such as the theory of elementary functions, involves few crucially important transcendentals such as e and π. This might reflect the evolution of cognition: these numbers should be cognitively and number theoretically very special. The numbers

e and π appear also repeatedly in the basic formulas of physics. They however look p-adically very troublesome since it has been very difficult to imagine a physically acceptable generalization of such simple concepts as exponent function, trigonometric functions, and logarithm resembling its real counterpart by allowing only the extensions of p-adic numbers based on algebraic numbers.

4. Number theoretic entropies measured in bits are proportional to $log(p)/log(2)$. The idea that these entropies are rational fractions of bit is attractive and implies that $log(p)$ for all primes is proportional to the same transcendental number. This would mean that logarithm of the rational number field would be a transcendental multiple of rationals.

These considerations stimulate the question whether, besides the extensions of p-adics by algebraic numbers, also the extensions of p-adic numbers involving e, and perhaps even πandother transcendentals might be needed. The intuitive expectation motivated by the finiteness of human intelligence is that these extensions might have finite algebraic dimensions. On the other hand, if one is only interested in quantities derived from phases $exp(i2\pi/n)$, a finite-dimensional algebraic extension is enough. π is needed only if one wants to deal with say length of circle's circumference in the p-adic context, and one could argue that p-adic Riemann geometry is local and only about angles and infinitesimal distances.

Second question is whether there might be some dynamical mechanism allowing to understand the hierarchy of scalings coming in powers of some preferred transcendentals and algebraic numbers like Golden Mean. Conformal invariance implying that the system is characterized by a universal spectrum of scaling momenta for the logarithmic counterparts of plane waves seems to provide this mechanism. This spectrum is determined by the requirement that it exists for both reals and all p-adic number fields assuming that finite-dimensional extensions are allowed in the latter case. The spectrum corresponds to the zeros of the Riemann Zeta if Zeta is required to exist for all number fields in the proposed sense, and a lot of new understanding related to Riemann hypothesis emerges and allows to develop further the previous TGD inspired ideas about how to prove Riemann hypothesis [L1] , [H2].

7.3 Infinite Primes And Cognition

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.

7.3.1 Infinite primes very briefly

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

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

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime might generalize to quaternionic and even 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.

7.3.2 A connection with infinite primes?

Infinite primes are one of the mathematical outcomes of TGD [K23]. There are two kinds of infinite primes. There are the analogs of free many particle states consisting of fermions and bosons labelled by primes of the previous level in the hierarchy. They correspond to states of a supersymmetric arithmetic quantum field theory or actually a hierarchy of them obtained by a repeated second quantization of this theory. A connection between infinite primes representing bound statesandirreducible polynomials is highly suggestive.

1. The infinite prime representing free many-particle state decomposes to a sum of infinite part and finite part having no common finite prime divisors so that prime is obtained. The infinite part is obtained from "fermionic vacuum" $X = \prod_k p_k$ by dividing away some fermionic primes p_i and adding their product so that one has $X \to X/m + m$, where m is square free integer. Also $m = 1$ is allowed and is analogous to fermionic vacuum interpreted as Dirac sea without holes. X is infinite prime and pure many-fermion state physically. One can add bosons by multiplying X with any integers having no common denominators with m and its prime decomposition defines the bosonic contents of the state. One can also multiply m by any integers whose prime factors are prime factors of m.

2. There are also infinite primes, which are analogs of bound states and at the lowest level of the hierarchy they correspond to irreducible polynomials $P(x)$ with integer coefficients. At the second levels the bound states would naturally correspond to irreducible polynomials $P_n(x)$ with coefficients $Q_k(y)$, which are infinite integers at the previous level of the hierarchy.

3. At the lowest level the polynomials defined by infinite primes correspond to irreducible polynomials characterizing irreducible algebraic extensions. Infinite bound state integers in turn would characterize non-irreducible extensions. Since the algebraic extensions of rationals define a hierarchy identified as giving rise to evolutionary hierarchy based on increasing algebraic complexity and increasing representative capacity, there indeed would be a connection with the infinite primes at the first level of hierarchy at least.

4. What is remarkable that bound state infinite primes at any level of hierarchy would define maximally ramified algebraic extensions at previous level. One indeed has infinite hierarchy of infinite primes since the infinite primes at given level are infinite primes in the sense that they are not divisible by the primes of the previous level. The formal construction works as such. Infinite primes correspond to polynomials of single variable at the first level, polynomials of two variables at second level, and so on. Could the Langlands program could be generalized from the extensions of rationals to polynomials of complex argument and that one would obtain infinite hierarchy?

5. Infinite integers in turn could correspond to products of irreducible polynomials defining more general extensions. This raises the conjecture that infinite primes for an extension K of rationals could code for the algebraic extensions of K quite generally. If infinite primes correspond to real quantum states they would thus correspond the extensions of rationals to which the parameters appearing in the functions defining partonic 2-surfaces and string world sheets.

   This would support the view that partonic 2-surfaces associated with algebraic extensions defined by infinite integers and thus not irreducible are unstable against decay to partonic 2-surfaces which corresponds to extensions assignable to infinite primes. Infinite composite integer defining intermediate unstable state would decay to its composites. Basic particle physics phenomenology would have number theoretic analog and even more.

6. According to Wikipedia, Eisenstein's criterion (`http://tinyurl.com/47kxjz`) allows generalization and what comes in mind is that it applies in exactly the same form also at the higher levels of the hierarchy. Primes would be only replaced with prime polynomials and the there would be at least one prime polynomial $Q(y)$ dividing the coefficients of $P_n(x)$ except the highest one such that its square would not divide P_0. Infinite primes would give rise to an infinite hierarchy of functions of many complex variables. At first level zeros of function would give discrete points at partonic 2-surface. At second level one would obtain

2-D surface: partonic 2-surfaces or string world sheet. At the next level one would obtain 4-D surfaces. What about higher levels? Does one obtain higher dimensional objects or something else. The union of n 2-surfaces can be interpreted also as $2n$-dimensional surface and one could think that the hierarchy describes a hierarchy of unions of correlated partonic 2-surfaces. The correlation would be due to the preferred extremal property of Kähler action.

One can ask whether this hierarchy could allow to generalize number theoretical Langlands to the case of function fields using the notion of prime function assignable to infinite prime. What this hierarchy of polynomials of arbitrary many complex arguments means physically is unclear. Do these polynomials describe many-particle states consisting of partonic 2-surface such that there is a correlation between them as sub-manifolds of the same space-time sheet representing a preferred extremals of Kähler action?

This would suggest strongly the generalization of the notion of p-adicity so that it applies to infinite primes.

1. This looks sensible and maybe even practical! Infinite primes can be mapped to prime polynomials so that the generalized p-adic numbers would be power series in prime polynomial - Taylor expansion in the coordinate variable defined by the infinite prime. Note that infinite primes (irreducible polynomials) would give rise to a hierarchy of preferred coordinate variables. In terms of infinite primes this expansion would require that coefficients are smaller than the infinite prime P used. Are the coefficients lower level primes? Or also infinite integers at the same level smaller than the infinite prime in question? This criterion makes sense since one can calculate the ratios of infinite primes as real numbers.

2. I would guess that the definition of infinite-P p-adicity is not a problem since mathematicians have generalized the number theoretical notions to such a level of abstraction much above of a layman like me. The basic question is how to define p-adic norm for the infinite primes (infinite only in real sense, p-adically they have unit norm for all lower level primes) so that it is finite.

3. There exists an extremely general definition of generalized p-adic number fields (see `http://tinyurl.com/y5zreeg`). One considers Dedekind domain D, which is a generalization of integers for ordinary number field having the property that ideals factorize uniquely to prime ideals. Now D would contain infinite integers. One introduces the field $E$of fractions consisting of infinite rationals.

   Consider element e of E and a general fractional ideal eD as counterpart of ordinary rational and decompose it to a ratio of products of powers of ideals defined by prime ideals, now those defined by infinite primes. The general expression for the p-adic norm of x is $x^{-ord(P)}$, where n defines the total number of ideals P appearing in the factorization of a fractional ideal in E: this number can be also negative for rationals. When the residue field is finite (finite field G(p,1) for p-adic numbers), one can take c to the number of its elements ($c = p$ for p-adic numbers.

   Now it seems that this number is not finite since the number of ordinary primes smaller than P is infinite! But this is not a problem since the topology for completion does not depend on the value of c. The simple infinite primes at the first level (free many-particle states) can be mapped to ordinary rationals and q-adic norm suggests itself: could it be that infinite-P p-adicity corresponds to q-adicity discussed by Khrennikov [A1]. Note however that q-adic numbers are not a field.

7.4 Cognition, Logic, And P-Adicity

There seems to be a nice connection between logic aspects of cognition and p-adicity. In particular, p-valued logic for $p = 2^k - n$ has interpretation in terms of ordinary Boolean logic with n "taboos" so that p-valued logic does not conflict with common sense in this case. Also an interpretation of projections of p-adic space-time sheets to an integer lattice of real Minkowski space M^4 in terms of generalized Boolean functions emerges naturally so that M^4 projections of p-adic space-time would represent Boolean functions for a logic with n taboos.

7.4.1 2-adic valued functions of 2-adic variable and Boolean functions

The binary coefficients f_{nk} in the 2-adic expansions of terms $f_n x^n$ in the 2-adic Taylor expansion $f(x) = \sum_{n=0} f_n x^n$, assign a sequence of truth values to a 2-adic integer valued argument $x \in \{0, 1, ..., 2^N\}$ defining a sequence of N bits. Hence $f(x)$ assigns to each bit of this sequence a sequence of truth values which are ordered in the sense that the truth values corresponding to bits are not so important p-adically: much like higher decimals in decimal expansion. If a binary cutoff in N: th bit of $f(x)$ is introduced, B^M-valued function in B^N results, where B denotes Boolean algebra fo 2 elements. The formal generalization to p-adic case is trivial: 2 possible truth values are only replaced by p truth values representable as $0, ..., p-1$.

7.4.2 p-Adic valued functions of p-adic variable as generalized Boolean functions

One can speak of a generalized Boolean function mapping finite sequences of p-valued Boolean arguments to finite sequences of p-valued Boolean arguments. The restriction to a subset $x = kp^n$, $k = 0, ..., p-1$ and the replacement of the function $f(x)$ with its lowest pinary digit gives a generalized Boolean function of a single p-valued argument. If $f(x)$ is invariant under the scalings by powers of p^k, one obtains a hologram like representation of the generalized Boolean function with same function represented in infinitely many length scales. This guarantees the robustness of the representation.

The special role of 2-adicity explaining p-adic length scale hypothesis $p \simeq 2^k$, k integer, in terms of multi-p-acidic fractality would correlate with the special role of 2-valued logic in the world order. The fact that all generalizations of 2-valued logic ultimately involve 2-adic logic at the highest level, where the generalization is formulated would be analog of p-adic length scale hypothesis.

7.4.3 $p = 2^k - n$-adicity and Boolean functions with taboos

It is difficult to assign any reasonable interpretation to $p > 2$-valued logic. Also the generalization of logical connectivesandOR is far from obvious. In the case $p = 2^k - n$ favored by the p-adic length scale hypothesis situation is however different. In this case one has interpretation in terms B^k with n Boolean statements dropped out so that one obtains what might be called $\hat{B}^k$. Since n is odd this set is not invariant under Boolean conjugation so that there is at least one statement, which is identically true and could be called taboo, axiom, or dogma: depending on taste. The allowed Boolean functions would be constructed in this case using standard Boolean functionsandOR with the constraint that taboos are respected: in other words, both the inputs and values of functions belong to $\hat{B}^k$.

A unique manner to define the logic with taboos is to require that the number of taboos is maximal so that if statement is dropped its negation remains in the logic. This implies $n > B^k/2$.

7.4.4 Some calculational details

In the following the details of p-adic non-determinism are described for a differential equation of single p-adic variable and some comments about the generalization to the realistic case are given.

1. One-dimensional case

To understand the essentials consider for simplicity a solution of a p-adic differential equation giving function $y = f(x)$ of one independent variable $x = \sum_{n \geq n_0} x_n p^n$.

1. p-Adic non-determinism means that the initial values $f(x)$ of the solution can be fixed arbitrarily up to $N+1$: th pinary digit. In other words, $f(x_N)$, where $x_N = \sum_{n_0 \leq n \geq N} x_n p^n$ is a rational obtained by dropping all pinary digits higher than N in $x = \sum_{n \geq n_0} x_n p^n$ can be chosen arbitrarily.

2. Consider the projection of $f(x)$ to the set of rationals assumed to be common to reals and p-adics.

   (a) Genuinely p-adic numbers have infinite number of positive pinary digits in their non-periodic expansion (non-periodicity guarantees non-rationality) and are strictly infinite as real numbers. In this regime p-adic differential equation fixes completely the solution.

This is the case also at rational points $q = m/n$ having infinite number of pinary digits in their pinary expansion.

(b) The projection of p-adic x-axis to real axis consists of rationals. The set in which solution of p-adic differential equations is non-vanishing can be chosen rather freely. For instance, p-adic ball of radius p^{-n} consisting of points $x = p^M y$, $y \neq 0$, $|y|_p \leq 1$, can be considered. Assume $N > M$. p-Adic nondeterminism implies that $f(q)$ for $q = \sum_{M \leq n \leq N} x_n p^n$, can be chosen arbitrarily. For $M \geq 0$ q is always integer valued and the scaling of x by a suitable power of p always allows to get a finite integer lattice at x-axis.

(c) The lowest pinary digit in the expansion of $f(q)$ in powers of p in defines a pinary digit. These pinary digits would define a representation for a sequence of truth values of p-logic. $p = 2$ gives the ordinary Boolean logic. It is also interpret this pinary function as a function of pinary argument giving Boolean function of one variable in 2-adic case.

2. Generalization to the space-time level

This picture generalizes to space-time level in a rather straight forward manner. y is replaced with CP_2 coordinates, x is replaced with M^4 coordinates, and differential equation with field equations deducible from the Kähler action. The essential point is that p-adic space-time sheets have projection to real Minkowski space which consists of a discrete subset of integers when suitable scaling of M^4 coordinates is allowed. The restriction of 4 CP_2 coordinates to a finite integer lattice of M^4 defines 4 Boolean functions of four Boolean arguments or their generalizations for $p > 2$. Also the modes of the induce spinor field define a similar representation.

8 Cognitive representations for partonic 2-surfaces, string world sheets, and string like objects

Cognitive representations are identified as points of space-time surface $X^4 \subset M^4 \times CP_2$ having imbedding space coordinates in the extension of of rationals defined by the polynomial defined by the M^8 pre-image of X^4 under $M^8 - H$ correspondence [L6, L7, L15, L12, L11, L9]. Cognitive representations have become key piece in the formulation of scattering amplitudes [L13] . One might argue that number theoretic evolution as increase of the dimension of the extension of rationals favors space-time surfaces with especially large cognitive representations since the larger the number of points in the representation is, the more faithful the representation is.

One can pose several questions if one accepts the idea that space-time surfaces with large cognitive representations are survivors.

1. Preferred p-adic primes are proposed to correspond to the ramified primes of the extension [L17]. The proposal is that the p-adic counterparts of space-time surfaces are identifiable as imaginations whereas real space-time surfaces correspond to realities. p-Adic space-time surfaces would have the imbedding space points in extension of rationals as common with real surfaces and large number of these points would make the representation realistic. Note that the number of points in extension does not depend on p-adic prime.

   Could some extensions have an especially high number of points in the cognitive representation so that the corresponding ramified primes could be seen as survivors in number theoretical fight for survival, so to say? Galois group of the extension acts on cognitive representation. Galois extension of an extension has the Galois group of the original extension as normal subgroup so that ormal Galois group is analogous to a conserved gene.

2. Also the type of extremal matters. For instance, for instance canonically imbedded M^4 and CP_2 contain all points of extension. These surfaces correspond to the vanishing of real or imaginary part (in quaternionic sense) for a linear octonionic polynomial $P(o) = o$! As a matter of fact, this is true for all known preferred extremals under rather mild additional conditions. Boundary conditions posed at both ends of CD in ZEO exclude these surfaces and the actual space-time surfaces are expected to be their deformations.

3. Could the surfaces for which the number of points in cognitive representation is high, be the ones most easily discovered by mathematical mind? The experience with TGD supports positive answer: in TGD the known extremals [K38] are examples of such mathematical objects! If so, one should try to identify mathematical objects with high symmetries and look whether they allow TGD realization.

4. One must also specify more precisely what cognitive representation means. Strong form of holography (SH) states that the information gives at 2-D surfaces - string world sheets and partonic 2-surfaces - is enough to determine the space-time surfaces. This suggests that it is enough to consider cognitive representation restricted to these 2-surfaces. What kind of 2-surfaces are the cognitively fittest one? It would not be surprising if surfaces with large symmetries acting in extension were favored and elliptic curves with discrete 2-D translation group indeed turn out to be assigable string world sheets as singularities and string like objects. In the case of partonic 2-surfaces geodesic sphere of CP_2 is similar object.

All known extremals, in particular preferred extremals, are good candidates in this respect because of their high symmetries. By strong form of holography (SH) partonic 2-surfaces and string world sheets are expected to give rise to cognitive representations. Also cosmic strings are expected to carry them. Under what conditions these representations are large?

8.1 Partonic 2-surfaces as seats of cognitive representations

One can start from SH and look the situation more concretely. The situation for partonic 2-surfaces has been considered already earlier [L16, L10] but deserves a separate discussion.

1. Octonionic polynomials allow special solutions for which the entire polynomial vanishes. This happens at 6-sphere S^6 at the boundary of 8-D light-cone. S^6 is analogous to brane and has radius $R = r_n$, which is a root of the real polynomial with rational coefficients algebraically continued to the octonionic polynomial.

   S^6 has the ball B^3 of radius r_n of the light-cone M^4_+ with time coordinate $t = r_n$ as analog of base space and sphere S^3 of E^4 with radius $R = \sqrt{r_n^2 - r^2}$, r the radial coordinate of B^3 as an analog of fiber. The analog of the fiber contracts to a point at the boundary of the light-cone. The points with B^3 projection and E^4 coordinates in extension of rationals belong to the cognitive representation. The condition that $R^2 = x_i x^i = r_n^2 - r^2$ is square of a number of extension is rather mild and allows infinite number of solutions.

2. The 4-D space-time surfaces X^4 are obtained as generic solutions of $Im(P(o)) = 0$ or $Re(P(o)) = 0$. Their intersection with S^6 - partonic 2-surface X^2 - is 2-D. The assumption is that the incoming and outgoing 4-D space-time surfaces representing orbits of particles in topological sense are glued together at X^2 and possibly also in their interiors. X^2 serves as an analog of vertex for 3-D particles. This gives rise to topological analogs of Feynman diagrams.

   In the generic case the number of points in cognitive representation restricted to X^2 is finite unless the partonic 2-surface X^2 is special - say correspond to a geodesic spere of S^6.

3. The discrete isometries and conformal symmetries of the cognitive representation restricted to X^2 possibly represented as elements of Galois group might play a role. For $X^2 = S^2$ the finite discrete subgroups of $SO(3)$ giving rise to finite tesselations and appearing in ADE correspondence might be relevant. For genera $g = 01, 2$ conformal symmetry Z_2 is always possible but for higher genera only in the case of hyper-elliptic surfaces- this used to explain why only $g = 0, 1, 2$ correspond to observed particles [K2] whereas higher genera could be regarded as many-particle states of handles having continuous mass spectrum. Torus is an exceptional case and one can ask whether discrete subgroup of its isometries could be realized.

4. In TGD inspired theory of consciousness [L8, L10] the moments $t = r_n$ corresponds to "very special moments in the life of self". They would be also cognitively very special - kind of eureka moments with a very large number of points in cognitive representation. The question is whether these surfaces might be relevant for understanding the nature of mathematical consciousness and how the mathematical notions emerge at space-time level.

8.2 Ellipticity

Surfaces with discrete translational symmetries is a natural candidate for a surface with very large cognitive representation. Are their analogs possible? The notions of elliptic function, curve, and surface suggest themselves as a starting point.

1. Elliptic functions (`http://tinyurl.com/gpugcnh`) have 2-D discrete group of translations as symmetries and are therefore doubly periodic and thus identifiable as functions on torus.

   Weierstrass elliptic functions $\mathcal{P}(z;\omega_1,\omega_2)$ (`http://tinyurl.com/ycu8oa4r`) are defined on torus and labelled by the conformal equivalence class $\lambda = \omega_1/\omega_2$ of torus identified as the ratio $\lambda = \omega_1/\omega_2$ of the complex numbers ω_i defining the periodicities of the lattice involved. Functions $\mathcal{P}(z;\omega_1,\omega_2)$ are of special interest as far as elliptic curves are considered and defines an imbedding of elliptic curve to CP_2 as will be found.

   If the periods are in extension of rationals then values in the extension appear infinitely many times. Elliptic functions are not polynomials. Although the polynomials giving rise to octonionic polynomials could be replaced by analytic functions it seems that elliptic functions are not the case of primary interest. Note however that the roots r_n could be also complex and could correspond to values of elliptic function forming a lattice.

2. Elliptic curves (`http://tinyurl.com/lovksny`) are defined by the polynomial equation

$$y^2 \quad = \quad P(x) = x^3 + ax + b \ . \tag{8.1}$$

   An algebraic curve of genus 1 allowing 2-D discrete translations as symmetries is in question. If a point of elliptic curve has coordinates in extension of rationals then 2-D discrete translation acting in extension give rise to infinite number of points in the cognitive representation. Clearly, the 2-D vectors spanning the lattice defining the group must be in extension of rationals.

One can indeed define commutative sum $P + Q$ for the points of the elliptic curve. The detailed definition of the group law and its geometric illustration can be found in Wikipedia article (`http://tinyurl.com/lovksny`).

1. Consider real case for simplicity so that elliptic curve is planar curve. $y^2 = P(x) = x^3+ax+b$ must be non-negative to guarantee that y is real. $P(x) \geq 0$ defines a curve in upper (x, y) plane extending from some negative value x_{min} corresponding to $y^2 = P(x_{min}) = 0$ to the right. Given value of y can correspond to 3 real roots or 1 real root of $P_y(x) = y^2 - P(x)$. At the two extrema of $P_y(x)$ 2 real roots co-incide. The graph of $y = \pm\sqrt{P(x)}$ is reflection symmetric having two branches beginning from $(x_{min}, y = 0)$.

2. The negative $-P$ is obtained by reflection with respect to x-axis taking y_P to $-y_P$. Neutral element O is identified as point a infinity (assuming compactification of the plane to a sphere) which goes to itself under reflection $y \to -y$.

3. One assigns to the points P and Q of the elliptic curve a line $y = sx + d$ containing them so that one has $s = (y_p - y_Q)/(x_P - x_Q)$. In the generic case the line intersects the elliptic curve also at third point R since $P_{y=sx+d}(x)$ is third order polynomial having three roots (x_P, x_Q, x_R). It can happen that 2 roots are complex and one has 1 real root. At criticalityfor the transiton from 3 to 1 real roots one has $x_Q = x_R$.

   Geometrically one can distinguish between 4 cases.

   - The roots P, Q, R of $P_{y=sx+d}(x)$ are different and finite: one defines the sum as $P+Q = -R$.
   - $P \neq Q$ and $Q = R$ (roots Q and R are degenerate): $P + Q + Q = O$ giving $R = -P/2$.
   - P and Q are at a line parallel to y-axis and one has $R = O$: $P + Q + O = O$ and $P = -Q$.

- P is double root of $P_{y=sx+d}(x)$ with tangent parallel to y-axis at the point $(x_{min}, y = 0)$ at which the elliptic curve begins so that one has $R = O$: $P+P+O = O$ gives $P = -P$. This corresponds to torsion.

4. Elliptic surfaces (see `http://tinyurl.com/yc33a6dg`) define a generalization of elliptic curves and are defined for 4-D complex manifolds. Fiber is required to be smooth and has genus 1.

8.3 String world sheets and elliptic curves

In twistor lift of TGD space-time surfaces identifiable as minimal surfaces with singularities, which are string world sheets and partonic 2-surfaces. Preferred extremal property means that space-time surfaces are extremals of both Kähler action and volume action except at singularities.

Are string world sheets with very large number of points in cognitive representation possible? One has right to expect that string world sheets allow special kind of symmetries allowing large, even infinite number of points at the limit of large sheet and related by symmetries acting in the extension of rationals. If one of the points is in the extension, also other symmetry related points are in the extension. For a non-compact group, say translation one would have infinite number of points in the representation but the finite size of CD would pose a limitation to the number of points.

String world sheets are good candidates for the realization of elliptic curves.

1. The general conjecture is that preferred extremals allow what I call Hamilton-Jacobi structure for M^4 [K36]. The distribution of tangent spaces having decomposition $M^4(x) = M^2(x) \times E^2(x)$ would be integrable giving rise to a family of string world sheets Y^2 and partonic 2-surfaces X^2 more general than those defined above. X^2 and Y^2 are orthogonal to each other at each point of X^4. One can introduce local light-cone coordinates (u, v) for Y^2 and local E^2 complex coordinate w for X^2.

2. Space-time surface itself would be a deformation of M^4 with Hamilton-Jacobi structure in CP_2 direction. w coordinate as function $w(z)$ of CP_2 complex coordinate z or vice versa would define the string world sheet. This would be a transversal deformation of the basic string world sheet Y^2: stringy dynamics is indeed transversal.

3. The idea about maximal cognitive representation suggests that $w \leftrightarrow z$ correspondence defines elliptic curve. One would have $y^2 = P(x) = x^3 + ax + b$ with either $(y = w, x = z)$ or $(y = z, x = w)$. A natural conjecture is that for the space-time surface corresponding to a given extension K of rationals the coefficients a an b belong to K so that the algebraic complexity of string world sheet would increase in number theoretic evolution [L14]. The orbit of a algebraic point at string world sheet would be lattice made finite by the size of CD. Elliptic curves would define very special deformed string world sheets in space-time.

4. It is interesting to consider the pre-image of given point y ($y = w$ or $y = z$) covering point x. One has $y = \pm\sqrt{u}$, $u = P(x)$ corresponding to group element and its negative: there are two points of covering given value of u. $u = P(x)$ covers 3 values of x. The values of x would belong to 6-fold covering of rationals. The number theoretic interpretation for the effective Planck constant $h_{eff} = nh_0$ states that n is the number of sheets for space-time surface as covering.

   There is evidence that $h_{eff} = h$ corresponds to $n = 6$ [L4]. Could 6-fold covering of rationals be fundamental since it gives very large cognitive representation at the level of string world sheets?

   For extensions K of rationals the x coordinates for the points of cognitive representation would belong to 6-D extension of K.

5. Ellipticity condition would apply on the string world sheets themselves. In the number theoretic vision string world sheets would correspond at M^8 level to singularities at which the quaternionic tangent space degenerates to 2-D complex space. Are these conditions consistent with each other? It would seem that the two conditions would select cognitively very special

string world sheets and partonic 2-surfaces defining by strong form of holography (SH) space-time surface as a hologram in SH. Consciousness theorist interested in mathematical cognition might ask whether the notion of elliptic surfaces have been discovered just because it is cognitively very special. In the case of partonic 2-surfaces geodesic sphere of CP_2 is similar object.

8.4 String like objects and elliptic curves

String like objects - cosmic strings - and their deformations, are fundamental entities in TGD based cosmology and astrophysics and also in TGD inspired quantum biology. One can assign elliptic curves also to string like objects.

1. Quite generally, the products $X^2 \times Y^2 \subset M^4$ of string world sheets X^2 and complex surfaces Y^2 of CP_2 define extremals that I have called cosmic strings [K38].

2. Elliptic curves allow a standard imbedding to CP_2 as complex surfaces constructible in terms of Weierstrass elliptic function $\mathcal{P}(z)$ (`http://tinyurl.com/ycu8oa4r`) satisfying the identity

$$[\mathcal{P}'(z)]^2 = [\mathcal{P}(z)]^3 - g_2\mathcal{P}(z) - g_3 \quad . \tag{8.2}$$

   Here g_2 and g_3 are modular invariants. This identity is of the same form as the condition $y^2 = x^3 + ax + b$ with identifications $y = \mathcal{P}'(z), x = \mathcal{P}(z)$ and $(a = -g_2, b = -g_3)$. From the expression

$$y^2 = x(x-1)(x-\lambda) \tag{8.3}$$

   in terms of the modular invariant $\lambda = \omega_1/\omega_2$ of torus one obtains

$$g_2 = \frac{4^{1/3}}{3}(\lambda^2 - \lambda + 1 \quad , \quad g_3 = \frac{1}{27}(\lambda+1)(2\lambda^2 - 5\lambda + 2) \quad . \tag{8.4}$$

   Note that third root of a appears in the formula. The so called modular discriminant

$$\Delta = g_2^3 - 27g_3^2 = \lambda^2(\lambda-1)^2 \quad . \tag{8.5}$$

   vanishes for $\lambda = 0$ and $\lambda = 1$ for which the lattice degenerates.

3. The imbedding of the elliptic curve to CP_2 can be expressed in projective coordinates of CP_2 as

$$(z^1, z^2, z^3) = (\xi^1, \xi^2, 1) = (\frac{\mathcal{P}'(w)}{2}, \mathcal{P}(w), 1) \quad . \tag{8.6}$$

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