Quantum Model of Memory

M. Pitkänen,

December 20, 2024
Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland. ORCID: 0000-0002-8051-4364.

Contents

Abstract

The neural realization of long term memories has remained to a high extent a mystery in the framework of the standard brain science. The TGD based quantum model for memory have developed gradually from the basic realization that in TGD framework the identification of quantum states as quantum histories makes it un-necessary to store information about the geometric past to the geometric now. This has deep implications.

1. It is possible to separate genuine geometric memory recall from apparent memory recalls such as feature recognition, associations, and implicit and procedural memories. There are no memory storages in brain and only memory representations abstracting the essential aspects of experience are needed.

2. The models of long term memory based on the assumption that information about the geometric past is stored in the recent state of the system predict that the new memories should mask the old ones. It is however known that childhood memories are the stablest ones. In TGD framework this ceases to be a problem.

   Mirror mechanism provides a very general mechanism of long term memory. To remember something at a temporal distance T in the geometric past is to look at a mirror at a distance $cT/2$. If the mirror is quantum mirror only a timelike entanglement (allowed by the non-determinism of Kähler action) of the mental image of the geometric past with a mental image in brain now is needed. The un-necessity to communicate memories classically implies extreme generality of the mechanism: all kinds of memories: sensory, cognitive, verbal,.... can be recalled in this manner. Even the mechanism of memory recall by cue can be generalized since the notion of tele association makes in principle sense.

   The basic objections against this over-simplified picture is that there is no guarantee that the reflected ME returns to the brain and that there is no control over the time span of long term memories. The notion of magnetic body allows a more realistic formulation.

3. Zero energy ontology (ZEO) brings in the possibility of temporary change of the arrow of geometric time at some level of the hierarchy of space-time sheets. This provides a justification for the notion of negative energy signals. Brain or the personal magnetic body generates spontaneously negative energy MEs with all fundamental frequencies. These MEs can be also curved and are parallel to the closed flux tubes defining the personal magnetic body and connect geometric now with the brain of the geometric past: multiple reflections are probably required to achieve this. The length of the closed magnetic loop defines the time span of the corresponding long term memory. The sharing of mental images by timelike entanglement allows to communicate the desire to remember to the geometric past, and gives rise to the memory recall in the case of episodal memories. In the case of non-episodal/declarative memories the memory is communicated from the brain of the geometric past by classical communications using positive positive energy MEs which propagate with an effective phase velocity much lower than light velocity along closed magnetic flux tubes and generate in the receiving end symbolic representation of the memory.

Macrotemporal quantum coherence is a further important piece of the model. The understanding of how macrotemporal quantum coherence is made possible by the spin glass degeneracy led to a concrete realization of the mirror model and also provided a connection with the ideas of Hameroff and Penrose. When a bound state is formed the zero modes of the bound state entangled subsystems become quantum fluctuating degrees of freedom. This means that state function reduction and state preparation cease to occur in these degrees of freedom. The bound state is in a kind of long-lasting multiverse state, or state of "oneness" experientially, and the sequence of quantum jumps defined by the duration of the bound state behaves effectively as a single quantum jump. Macrotemporal quantum coherence making possible supercomputer like activities becomes possible.

The hierarchy of Planck constants emerging from the non-determinism of Kähler action implying also spin glass degeneracy provides a more precise view about the emergence of quantum coherence. Also a connection with quantum criticality and hierarchy of breakings of conformal invariance emerges.

The spin glass degeneracy associated with the join along boundaries bonds (the original space-time correlates for the bound state formation replaced later by magnetic flux tubes) lengthens the lifetimes of the bound states dramatically and solves thus the basic objections against quantum consciousness. The spin glass degeneracy is broken only by classical gravitational energy of the system. The quantum jumps between different classical gravitational

configurations involve the emission of gravitational (equivalently Z^0) MEs and the intention to remember is realized as a transformation of p-adic ME to negative energy gravitational ME. The fact that classical gravitational fields couple to classical gauge fields with a coupling which is about 10^8 stronger than the ordinary gravitational coupling, could play an important role too. Water clusters and macromolecules with sizes in the range of cell membrane thickness and cell size are good candidates for generating gravitonic MEs responsible for all geometric memories. Also classical Z^0 interaction might be involved since gravitonic MEs can be regarded also as Z^0 MEs.

A neuro level model of long term memory is discussed. The model conforms with the basic facts known about the relationship of hippocampus and long term memory.

1 Introduction

The ideas related to the quantum model of memory have developed gradually from very general ideas to reasonably concrete models and a connection with biological quantum computer type systems has emerged. It is good to list the basic ideas and notions briefly to get and idea about this process which is still continuing.

1.1 ZEO And Self

Zero energy ontology (ZEO) allows a rigorous formulation of earlier vision about memories as something involving communication with geometric past using negative energy signals.

1. In ZEO unitary M-matrix between positive and negative energy parts of zero energy state defines particular zero energy state. M-matrices characterize zero energy states and are square roots of density matrices reducing to a product of real and diagonal hermitian matrix and unitary S-matrix S common to al of them. M-matrices can be assumed to be orthogonal and form effectively orthogonal basis of matrices.

2. Self corresponds to a sequence of repeated state function reductions in which neither the passive boundary of CD nor states at it is changed. The state function reduction sequence corresponds at the active boundary to a sequence of U-processes each followed by a localization in the moduli of the active boundary but without any state function reduction at it.

   This sequence of state function reductions gives rise to the experienced flow of time and the contributions to consciousness from passive boundary give rise to the experience about static observer, the self and to varying contribution to the experience representing sensory input. Figure-background separation is clearly involved.

   The first state function reduction to the active boundary means death of self and its reincarnation at formerly active boundary. Self experiences time reversal, and for mental images of self (sub-selves) this change is certainly highly non-trivial and must have effect on how self experiences the sub- self.

This chapter was written much before the emergence of ZEO based view about self and I have kept the text almost as such trying to add some comments about how the ZEO based view simplifies the situation. For instance, the considerations related to the life-time of self reduce to few lines if ZEO based view is applied.

1.2 Geometric And Subjective Memories

The identification of moment of consciousness as quantum jump between histories suggest two kinds of time developments, subjective and geometric, and therefore also two causalities and memories. By the 4-dimensional general coordinate invariance (GCI) of quantum TGD, geometric memories contain information about entire quantum and classical histories. This means that there is no absolute need to store memories of the geometric past to the geometric now. This has dramatic implications for the modelling of brain and allows to get rid of the basic problem of the memory models, namely the fact that the storage of new memories unavoidably tends to destroy the old memories whereas it seem that childhood memories are actually the most stable ones.

Strong form of holography allows to make more this picture more precise. Information about memories is coded by data assignable to string world sheets and partonic 2-surfaces and the partonic 2-surfaces and strings connecting them would appear as carriers of the basic data. Even more, at the this level only the strings carry the data about Yangian Noether charges of super-sympelectic generating the zero energy states.

To remember geometrically means sending signal to the geometric past and receiving it. In ZEO this means that some sub-self (mental image) dies (or falls a sleep) and re-incarnates so that signals traverse to the direction of geometric past. After than death and re-incarnation (wake-up) occurs again and this means positive energy signal to the geometric future possibly creating the mental image about memory becoming conscious after wakeup of sub-self.

Subjective memories could result from time-like entanglement between sub-selves defined by M-matrix. In this case the square root of the matrix appearing in M-matrix would reduce to a projection operator multiplied by S-matrix having no elements beween the sub-space defined by projection operator and its orthogonal complement. Therefore one would have negentropic entanglement (NE) with a unit density matrix. This kind of memories would be interpreted as sharing of mental images of future and past selves. It is somewhat questionable whether this mechanism is mathematically feasible.

1.3 Spin Glass Model Of Memories

One of the relatively early ideas was that the 4-dimensional quantum spin glass property of TGD universe must have fundamental role in the realization of memories. Spin glass property predicts fractal energy landscape in which there are valleys inside valleys inside valleys and memories correspond to self-organization patterns associated with sub-self having interpretation as processes leading to bottoms of various valleys. In TGD framework energy minima are replaced by the maxima of Kähler function defining configuration space geometry as a function of zero modes which are effectively classical variables in the sense that in each quantum jump a complete localization occurs in these variables. One can also consider the interpretation of "energy" as binding energy of bound states as function of zero modes. The higher the value of the binding energy, the deeper the valley, and the higher the probability that system ends up to the bound state and the longer the time spent in the bound state.

Four-dimensionality means in ZEO that 3-surfaces are pairs of 3-surfaces at opposite boundaries of CD connected by a preferred extremals for which classical Noether charges in quantum critical sub-algebra of super-symplectic algebra vanish. This means very strong correlations between 3-surfaces at the boundaries of CD implying that they are analogous to Bohr orbits. This also implies that self-organization can be regarded as occurring for the superpositions of space-time surfaces analogous to representations of behaviors or functions in the sense of biology.

One can also regard life as a process of carving a 4-dimensional statue gradually quantum jump by quantum jump. The longer the extension of the valley in the temporal direction and the larger the number of copies of the valley is, the more reliable the memory recall is. The best way to learn to remember is to remember. The depth of emotion determines how deep and long in temporal direction the valleys representing memories are.

1.4 Mirror Mechanism

MEs provide a mechanism of long term memory which differs from ordinary sensory perception only in that the ME giving rise to a geometric memory has much longer duration with respect to the geometric time than the ME giving rise to ordinary sensory perception. To remember something at temporal distance T in the past is to look at a mirror with length $L = cT/2$. The mirrors in question must have astrophysical sizes measured in light years typically and this of course raises obvious objections against the model. Although this mechanism as such is too strong an idealization, it can serve as a starting point. For instance, MEs can be also curvilinear and could propagate along closed magnetic flux loops of the personal magnetic body serving effectively as wave cavities and suffer few reflections: this would make possible high precision targeting.

At quantum level remembering means sharing of mental images: this corresponds to the quantum entanglement between the sub-selves of the geometric now and of the geometric past. The classical non-determinism of Kähler action is essential in making possible entanglement between

systems having time-like separation. This would be the mechanism of episodal memory, For non-episodal memories only the mental image representing the desire to remember would be shared, and the answer from the geometric past could be realized as classical communications using MEs. Commmunication would be based on some code, perhaps memetic code, and would generate a conscious experience in the receiving end, typically verbal memory. Positive energy MEs would propagate with ultra low effective phase velocity inside brain or along magnetic flux tubes of astrophysical size with sub-luminal effective velocity (say alpha wave effective velocity). The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

In this framework synaptic strengths code only cognitive representations and learned associations, not genuine information about the events of the geometric past. Brain can be seen as kind of a collection of standardized features serving as building blocks of sensory and memory representations. Long term memory is coded in the classical em/gravitational fields associated with and in coherent light/gravitons generated by MEs in hologram like way. Any finite space-time region receiving the classical em field of coherent light/gravitons generated by it gets hologram like picture containing info about entire geometric time interval spanned by ME. If vacuum current is localized to some restricted space-time region (it can be!), the hologrammic information is about this region and receiver anywhere along the ME gets more or less the same information since hologram is in question. Note also that the light-likeness of the boundary of ME implies that ME selves have temporal extension defined by the length of ME.

1.5 Third Person Aspects Of Memory

Topological quantization implies the notion of field body: field body accompanies any system be it molecule or human body. Field body serves as kind of a manual providing higher level abstract representations about the quantum aspects of the physical body. The model of sensory representations realized at personal magnetic body and at Earth's magnetic body explains both the first and the third person aspects of our sensory experience. Also memories should have third person and transpersonal aspects realized at the magnetic body of Earth. This prediction is testable: moon traveller consciousness should have different third person aspect or this aspect could be even absent. Third person aspect should be crucial for the generation of social structures and the rapid weakening and reversal of Earth's magnetic field predicted to occur within next 2 millenia might have dramatic effects for the future of the civilization.

The sharing of mental images is crucial for the model of the third person aspect of memories. What happens is that sub-self of brain entangles with with the sub-self of the magnetic sensory canvas in the geometric past. One could perhaps interpret spontaneous episodal memories as a basic example of memories communicated by some sub-self of magnetic Mother Gaia to us.

1.6 Symbolic And Cognitive Representations Of Memories

Most of our memories are not direct re-experiences. In fact, it would be difficult to tell whether memory is really in question if this were the case. Rather, memories are highly conceptual and based on symbolic representations making possible huge filtering and compression of information. Only in some special cases direct re-experiencing occurs. The inherent nondeterminism of the p-adic field equations and the classical non-determinism of Kähler action make possible to represent sequences of quantum jumps determining the contents of consciousness of self at space-time level in terms of p-adic or real space-time sheets, that is cognitively and symbolically. Symbolic representations are crucial for memories whereas cognitive representations are crucial for intentions. Symbolic representations allow to store information about geometric past to geometric now: history writing is just this kind of activity. Also brain is doing history writing: to remember is also to form a new memory representation.

It is highly plausible that memory representations are highly abstracted and that the signals from the geometric past do not recreate directly the experience but serve as names for standardized

self-organization patterns of neuronal activity, "features" giving charicature of the experience. This means that it is not easy to distinguish between TGD based model and standard model of memories.

1.7 Bio-Supercomputers And Memories

The most recent but certainly not the last step in the development of ideas was the realization of a connection between macrotemporal quantum coherence, quantum spin glass property of the TGD universe, classical and quantum gravitation, and the mirror model of geometric memories.

The interpretation of quantum jump as a creation of a totally entangled holistic state $U\Psi_i$ which is then analyzed to pieces allows to interpret self measurement cascade as a conscious analysis. The temporal fractality of consciousness suggest that the lifecycle of any self can be seen as a generation of multiverse of potentialities followed by analysis (and decay) process. One can see the situation also differently. The conscious experience of self is average over moments of consciousness and the eventual thermalization induced by the quantum jump sequence destroys all conscious information. There must be some mechanism hindering this and making macrotemporal quantum coherence possible.

To achieve macrotemporal quantum coherence self must be irreducible self for which self measurements and analysis do not occur. The self must also have large number of zero modes transformed to quantum fluctuating degrees of freedom and this is achieved if self corresponds at space-time level to a join along boundaries condensate. In this process the zero modes of the condensing space-time sheets become quantum fluctuating degrees of freedom. In this "state of oneness" self is able to carry out quantum computer like information processing which is the diametrical opposite of analysis. The decay of this bound state to its components corresponds to the analysis period at the level of self.

Macrotemporal quantum coherence is possible by the quantum spin glass property of TGD universe making the lifetimes of bound states much longer than in the universe obeying standard physics. Different almost degenerate vacuum space-times differ only because they have different classical gravitational energies. The quantum transitions between these almost degenerate states involve emission of MEs representing gravitons. These topological graviton rays are reflected from the curved almost vacuum space-time sheet acting as a gravitational mirror and self energy diagrams involving emission and absorption of the gravitonic ME have interpretation as correlates for the geometric memory recall. The time scale of human memories is between millisecond and 100 years and this time scale characterizes the gravitational energies for systems having sizes between cell size and cell membrane thickness (the number theoretical miracle is that all p-adic length scales in this range correspond to Gaussian Mersennes). Microtubules are excellent candidates for realizing long term declarative memories at bit level so that a connection with Penrose-Hameroff views emerges.

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` [**?**].

2 Different Types Of Memories

TGD predicts two kinds of memories corresponding to two different time developments. There is deterministic (in generalized sense) time development with respect to the geometric time and the nondeterministic time development by quantum jumps with respect to the subjective time. The memories with respect to subjective time are about previous conscious experiences and "real" whereas geometric "memories" are prophecies giving simulations of the geometric past and future assuming that quantum jumps do not alter the macroscopic properties of the space-time surface. A good visualization is following: each quantum jump represents particular geometric memory whereas the heap of these memories gives rise to subjective memory. The comparison between expectations and reality is obviously a central part of mentality and the heap structure implies that this comparison is a basic function of conscious mind not reducible to anything simpler. It is well-known that our memories involve a lot of construction and are more like stories consistent with what we actually have experienced than actual documents of what happened. Perhaps geometric memories constrainted by subjective memories give rise to the "story".

One can distuinguish between several memory types such as short term memory and long term memory, episodal memory, procedural memory, implicit memory and associative memory, and it is interesting to try to find whether these memories could be understood in the proposed conceptual framework. In the discussion below concrete mechanisms for the realization of geometric memory are not discussed: the reader interested on this aspect of geometric memory can consult [K13].

2.1 Geometric And Subjective Memories

There are two times in TGD: subjective and geometric. In accordance with this there are also two kinds of memories: subjective and geometric[1].

1. The temporal binding of the experiences associated with quantum jumps occurred after the last "wake-up" of the self gives rise to subjective memory defined as memory about earlier conscious experiences and is identifiable as an immediate conscious memory, "psychological now", presumably of duration of fraction of second in case of sensory experiences. There is infinite hierarchy of subjective memories and if long term memories are genuine subjective memories (this need not be the case!), they could correspond to conscious short term memories of higher level selves somehow communicated to the lower level. An essential element is the possibility of sub-selves inside self having much shorter lifetime and organized in a subjecto-temporal sequence: without them the average over the quantum jumps would destroy the information and it would not be possible to remember the digits of a phone number. Various rhythmic actions (such as micro tremor of eyes at 80 Hz frequency and muscle tremor) could generate a sequence of sub-selves with constant duration and thus a clock measuring subjective time.

2. Geometric memories are like a classical physics based model for the universe. They are memories with respect to geometric rather than subjective time and predict what must have happened in the geometric past and what will happen in the geometric future assuming that world is classical (no quantum jumps). The temporal extension of the mind-like space-time sheets and the notion of the association sequence (3-surfaces consisting of a sequence of space-like 3-surfaces with time-like separations providing a simulation of classical history) make possible geometric memories. A natural hypothesis is that the macroscopic space-time associated with the final state of the quantum jump represents the geometric memory. Of course, only part of it becomes conscious and temporal binding implies that self experiences kind of temporal average of the geometric memories associated with the quantum jumps. An attractive possibility is that our long term memories, which have narrative character and are unreliable, correspond to geometric memories. This would mean that there is no need for memory storage mechanisms, four-dimensional brain would take automatically care of memory storage.

Intentionality manifests itself in many ways: as expectations of the future, planning, goals, desires, fears, imagination, intuition etc.. It seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to identify all aspects of intentionality with the predictions of the expected geometric future provided by the mind-like space-time sheet. Geometry as such contains nothing intentional. Rather, the intentional aspects of the conscious experience reflect the attitudes towards the expectations provided by the geometric memory.

2.1.1 "Memories" with respect to geometric time as simulations

Geometric memories are predictions/simulations for what would happen if no further quantum jumps would occur and what would have happened if no quantum jumps had occurred in the past. Simulations and expectations rather than real memories are in question. Geometric memories become reliable in the classical limit, when the effect of quantum jumps becomes negligible. In the deterministic world of classical physics geometric memories would be absolutely reliable. It

[1]The attribute "subjective", as it is used in TGD context, does not have quite the same meaning as it usually has as something non-objective and unreliable: "subjective" derives its meaning from "subjective time" as consciously experienced time as opposed to the geometric time of physics.

is indeed possible to predict rather reliably what will happen in the solar system during the next decade. Geometric memories are a prerequisite of the intentionality often regarded as a basic characteristic of conscious mind: beliefs, expectations, plans, etc. involve geometric memory in an essential manner. The computational approach to mind assumes only geometric memories.

The memory with respect to geometric time is possible even assuming that single quantum jump determines the contents of conscious experience completely. However, if the contents of conscious experience are determined completely by the initial and final quantum histories of single quantum jump, it is in principle impossible to have genuine memories about previous conscious experiences. This does not make it impossible to have a model for the most probable subjective life history through simulation. Quantum statistical determinism could make these simulations possible. One must however admit that the hypothesis about subjective memory, naturally identifiable as a short term immediate memory defining the duration of psychological moment, makes things extremely simple and natural. One could also argue that in a universe without subjective memory it would not be possible to discover the notion of quantum jump so that internal consistency of the theory of consciousness requires genuine memory about earlier conscious experiences.

2.1.2 Mindlike space-time sheets and simulations

It is a fact that we can plan future in the time scale of life time. We can also quite reliably extrapolate to the past without direct memory of what happened. The simplest explanation is that the time extension associated with those mind-like space-time sheets, which we have access to, is of the order of lifetime or perhaps even longer. The simplest model for the simulation would be based on an ensemble of thoughts scattered around entire material space-time history defined by, say, my body. Quark sub$-CD$s could realize thoughts as Boolean algebra of statements and could be present everywhere in condensed matter, in particular in water, which is expected to have very rich hierarchy of space-time sheets. Self would experience the sum of the abstracted experiences of ensemble members and experience a simulation about what happens in future and what happened in past assuming that quantum jumps will not occur in future and did not occur in past.

Of course, selves could also do what computers do, namely mimic other selves by building cognitive representations about them at their own space-time sheets. This would make it unnecessary to jump between the levels of the self hierarchy. These representation could have quite different temporal and spatial scales and the presence of the time scaled versions about time development of other selves would realize the fractality aspect related to the idea about Universe as a hologram. DNA could be an example of this kind of simulation of the entire lifespan of individual in molecular length and time scales. Monte Carlo simulation of elementary physics experiment could be also regarded as a simulation of this kind.

2.1.3 The difference between intentions and geometric memories

Intentionality, understood here as time-directedness, manifests itself in many ways: as expectations of future, planning, goals, desires, fears, imagination, etc.. The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. The temporal extension of the mind-like space-time sheet makes possible expectations of what happens in the future assuming that no quantum jumps occur or at least that quantum jumps do not change the macroscopic space-time. Single quantum jump contains information about this kind of expectations. Subjective memory in turn tells what happened actually. Therefore it seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to identify the predictions of the expected geometric future provided by the mind-like space-time sheet as a basic prerequisite of intentionality.

Subjective memory makes it possible to compare the expectations with what really occurred since subjective memory is kind of a heap of predictions of future arranged with respect to the value of the psychological time. The origin of at least some emotions, which often involve a comparison of what happened and what was expected to happen, is perhaps here. It is quite well possible that all comparisons must be realized as comparisons of the subjective and geometric time developments. It seems that self can also compare its sub-selves, which correspond to simultaneous mental images.

The possibility of this comparison provide a solution to the paradox raised by the innocent question "How do I know that the me of today is the same as the me of the yesterday? How do I even know that I existed yesterday?". The solution might be simple: mind-like space-time sheets have extension which can be much longer than the duration of the subjective memory. Therefore subjective memories contain information about the geometric me of the yesterday and geometric me of today and since these me's resemble each other quite a lot, the conclusion is that also the yesterday's me was a conscious self living in this same body. It is however quite possible that temporal entanglement with higher selves still remembering my past wake-up states is also involved and realized as a formation of join along boundaries bonds between the mind-like space-time sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

2.1.4 What is the temporal extension of mind-like space-time sheets?

With respect to subjective time self and its sub-selves can be characterized by the typical durations of the wake-up state. With respect to the geometric time self (or rather, mind-like space-time sheet) can be characterized by its own duration and the durations of the mind-like space-time sheets which it contains. The time span for the predictions and memories provides an estimate for the duration of mind-like space-time sheets. mind-like space-time sheets can have time-like separations. Mind-like space-time sheets of geometric past could represent memories so that conscious memories could be regarded as multitime experiences and the distances between mind-like space-time sheets could be quite large, of order lifetime.

Zero energy ontology allows to answer this question quantitatively. Space-time surfaces correspond to surfaces inside causal diamonds (CDs) having space-like ends at the boundaries of CDs and the size scale of CD characterized the size scale of self as a geometric entity. The order of magnitude for the size scale is expected to be of the same order of magnitude as duration of life cycle of self.

In ZEO based view about self, the size of CD is not equal to the life-time of self. Rather, the increase of the size scale of self during state function reduction sequences taking place at same boundary of CD and not changing state at it defines the life-time of self.

2.1.5 Life-spans of sub-selves

Sensory experiences seem to correspond to a well defined geometric now having perhaps duration of order .1 seconds. Thus it seems that mind-like space-time sheets representing my sensory sub-selves have rather short time extension, of order .1 seconds. "Ontogeny recapitulates phylogeny principle" (ORP) suggests that the extension is of same order as the duration of the immediate subjective memory, something like .1 seconds. This prediction is certainly consistent with the typical resolution of the sensory experience, say the ability of the visual system to discriminate subsequent pictures as separate pictures. Quite generally, the p-adic time scale $T_p = L_p/c$ characterizing the mind-like space-time sheets gives the first guess for the duration of the mind-like space-time sheet and duration of geometric memory provided by it. Note that .1 seconds gives for the p-adic length scale L_p and estimate which is about circumference of Earth!

The fact is that we have childhood memories, plan future and make reliable predictions. This is not in contradiction with the duration of the mind-like space-time sheets associated with sensory sub-selves. The mind-like space-time sheets representing sub-selves (mental images) can be located in geometric past or future so that multitime experiences with mind-like sheets of past and future contributing to the experience are possible.

The duration of .1 seconds is the duration of typical sub-selves representing our mental images. The geometric duration of the mind-like space-time sheet representing our "main self" should be much longger since it contains mind-like space-time sheets distributed along entire life span.

The sub-selves which have fallen asleep, wake-up again generating new wave of sensory experience. For instance, mental images (after images) typically re-appear periodically. We are also mental images of larger self in the hierarchy and the periodical appearenc e of of our mental images suggests that also we appear periodically as mental images of this larger self. This would mean reincarnation in the geometric past so that our life would be lived again and again. Entire trains of mind-like space-time sheets could wander through time again and and experience what it is to

live in a particular body. Therefore my body could live again and again: by p-adic evolution each life would tend to be slightly better than the previous one. The civilizations of past could be still well and alive and even more civilized! This picture could perhaps explain why persons in their old age sometimes begin to live their childhood again.

As already noticed, the ZEO based view about self allows a precise identification for the life-time of self.

2.1.6 What is the subjective duration of "our" self?

Our conscious experience is some kind of an averaged sum over all conscious experiences associated with the quantum jumps occurred after the last "wake-up". If the averaging is completely democratic, the only possibility is that our sensory sub-selves have duration not much longer than the the time resolution of the sensory experience of order .1 seconds. Contrary to the original beliefs, this does not in principle pose any limitation to the duration of "our" self.

There are thus several options concerning the duration of our self.

1. Our self could have duration not much longer than the duration of immediate short term memories of order .1 seconds. The ability to remember digits of a phone number requires that the duration is indeed longer. For this option it is not at all obvious how the subjective experience of personal continuity is possible.

2. The duration could also correspond to the wake-up period. Also now the problem is how we know that this self existed already yesterday. Note that the gradual thermalization of sub-selves means that subjective memories represented by sub-selves get gradually fuzzy so that the digits of a phone number are forgotten even if our self has duration of order wake-up time.

3. Our self has a duration of order lifetime, or even longer and only the mental image representing our physical body has duration of order lifetime. A possible objection is that the mental image representing our self becomes gradually more and more entropic unless it manages to fight against second law. This might of course correspond to ageing.

Third option deserves a more detailed consideration.

1. The geometric duration of our "main" mind-like space-time sheet should be of the order of life span if geometric memory explains long term memories. "Ontogeny recapitulates phylogeny" principle would suggest that also the subjective duration of our "main" self is of order life time. This option would explain elegantly the fact that we possess subjective identity: this kind of subjective identity would be a logical deduction in case that our main self has duration shorter than life time.

2. This option would mean that we are not actually unconscious during sleep but are only unable to remember anything about what happened during sleep. This would be rather natural since various sensory and cognitive sub-selves are not conscious during sleep periods so that also multitime experiences in which sensory sub-selves wake-up in night time are rare! It might be also possible to remember events occurred during sleep state only during sleep.

3. Note that the claims about near death experiences in which entire life is experienced as a kind of film, could be interpreted as very intensive experiences in which mind-like space-time sheets along the entire life span "wake-up" and give rise to multitime geometric memories. Alternatively, if bodily self with a duration of order lifetime is a sub-self of our self (perhaps identifiable as the self associated with our magnetic body), the bodily self representing entire life cycle could be experienced as a mental image. Also shorter bodily sub-selves forming a subjectotemporal sequence, "film", could be experienced in the absence of the ordinary sensory input.

ZEO based answer is that our life-time corresponds to the increase of the size scale of CD serving as correlates for us. The simplest expectation is that this size scale is of same order of magnitude as our CD.

2.2 Habits, Skills, Associations

The universe of TGD is quantum spin glass [K27]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/ associations are formed.

1. Mental images (in particular memories) correspond to sub-selves undergoing self-organizing time development by quantum jumps leading to self-organization patterns selected by dissipation. Thus both memes and genes, in particular long term memories, can be regarded as winners in the fight for survival in which dissipation is the ultimate Darwinian selector. Inhibitory and excitatory nerve pulses might physically realize "frustrations" which make possible large number of almost degenerate energy valleys.

2. The universe of TGD is quantum spin glass characterized by a fractal "energy" landscape having valleys inside... inside valleys (directories inside...inside directories). This structure is ideal for a hierarchical representation of memories. Memories must correspond to valleys of the spin glass "energy" landscape into which dissipation takes the system. Memory formation is active process and memories are charicatures rather than photos and deep valleys of the energy landscape represent these charicatures. Hippocampus, known to be involved with the formation of the long term memories, could control the rate of motion in these control variables. The plastic regions of the brain are the most spin-glassy ones and are the most probable seats of the long term memories.

3. System has some territory in the energy landscape. The motion in the zero modes serving as control variables causes a slow shift of the entire territory. Synaptic strengths corresponds naturally to the slow control variables characterizing the position of the territory. In the presence of a metabolic energy feed and sensory input system moves around this territory.

ZEO and NMP provide powerful additional tools, which were not available when the first version of this chapter was written. In ZEO self-organization can be seen as self-organization of 4-dimensional patterns having as space-time correlates space-time surfaces (preferred extremals of Kähler action) connecting space-time 3-surfaces at opposite boundaries of causal diamond. One can say, that basic objects are not 3-D time=constant snapshots but entire time evolutions. Behavioral patterns, functions, habits are the natural basic notions. This has especially interesting implications to morphogenesis, where the notion of magnetic body as kind of morphogenetic field and template for the self-organization of matter around it, becomes the key notion [K17]. Equally interesting are the applications to genetics and neuroscience [**?**]

2.3 Is Genuine Subjective Memory Really Necessary?

For a long time the basic hypothesis of TGD inspired theory of consciousness was that the contents of conscious experience are determined totally by the initial and final states of *single* quantum jump. A heavy objection against this assumption is that the hypothesis makes it impossible to have genuine memories about previous conscious experiences. The concept of self however allows the possibility that the connected series of sequential quantum jumps performed by self after its last "wake-up" integrates to single conscious experience. This hypothesis realizes self as an extended object in subjective time allowing it to have memories about previous conscious experiences rather than only memories with respect to geometric time. An attractive additional assumption is that the conscious experiences of self are kind of subjecto-temporal statistical averages. This would make experiences reliable. In particular, sensory experiences can give objective reliable knowledge despite the fact that the outcomes of individual quantum jumps are not predictable. The undesired implication is that for long sequences of quantum jumps averaging leads to a total loss of information.

The original vision was that geometric memory is made possible by the finite temporal duration of the what I called mind-like sheets. The emergence of zero energy ontology led to the conclusion that all space-time sheets are mind-like since one can assign them to the interior of CDs. Depending on one's tastes one could of course refer to p-adic space-time sheets as mind-like (or cognitive). p-Adic space-time sheets are identified correlates of intentions, plans, desires, ... whereas real space-time sheets would correspond to sensory experience and sensory memories. Geometric memories are about geometric past and serve as prophecies telling what would have happened if quantum

jumps were not constantly replacing macroscopic space-time with a new one. Precognitions which can be only geometric tell what would happen if no further quantum jumps take place. Subjective memory makes it possible to compare what actually happened with what was expected to happen. It might be that this comparison is one of the fundamental irreducible mental acts. There is a sharp difference between ordinary memories on one hand and precognition and memories about time before birth (the region in the geometric past of the CD assignable to the 4-dimensional biological body) since the interior of "personal" CD is in a preferred position. Interestingly, the CD corresponding to a life time of order 100 years corresponds to a primary p-adic length scale of order 10^{-7} meters and the age of the universe to 10^{-4} meters, the size scale of a large neuron.

A natural identification of the subjective memory is as immediate short term conscious memory, or actually a hierarchy of short term memories corresponding to the hierarchy of selves. This identification requires that the subjective durations of our sensory selves are typically of a fraction of second, .1 seconds is suggested by various arguments relating to the ability to experience subsequent stimuli as separate ones and corresponds to the duration of psychological moment. This time scale corresponds to the temporal size scale of the CD of electron. The narrative character of the long term memories suggests their identification as geometric memories: long term memories could correspond to multitime experiences with contributions coming also from the geometric past (say childhood). It turns out that this identification explains basic facts about long term memories. Declarative memories are assumed to involve negative energy signals suffering a time reflection from the brain of the geometric past. The condition that the energies of the corresponding photons are above thermal threshold can be satisfied if the value of Planck constant is large enough. The emergence of long term memory and planned action would involves in an essential manner the emergence of large values of Planck constant [K12].

2.4 Spin Glass Model Of Learning And Long Term Memories

The universe of TGD is quantum spin glass [K27]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/associations are formed.

1. Mental images (in particular memories) correspond to sub-selves undergoing self-organizing time development by quantum jumps leading to self-organization patterns selected by dissipation. Thus both memes and genes, in particular long term memories, can be regarded as winners in the fight for survival in which dissipation is the ultimate Darwinian selector. Inhibitory and excitatory nerve pulses might physically realize "frustrations" which make possible large number of almost degenerate energy valleys.

2. The universe of TGD is quantum spin glass characterized by a fractal "energy" landscape having valleys inside... inside valleys (directories inside...inside directories). This structure is ideal for a hierarhical representation of memories. Memories must correspond to valleys of the spin glass "energy" landscape into which dissipation takes the system. Memory formation is active process and memories are charicatures rather than photos and deep valleys of the energy landscape represent these charicatures. Hippocampus, known to be involved with the formation of the long term memories, could control the rate of motion in these control variables. The plastic regions of the brain are the most spin-glassy ones and are the most probable seats of the long term memories.

3. System has some territory in the energy landscape. The motion in the zero modes serving as control variables causes a slow shift of the entire territory. Synaptic strengths corresponds naturally to the slow control variables characterizing the position of the territory. In the presence of a metabolic energy feed and sensory input system moves around this territory.

One can consider two general models of learning and memory recall in this framework, the TGD version of the neural network model and the genuinely TGD based mechanism on the notion of the geometric memory. Consider first the TGD based version of the neural network model of memory.

1. The possible memories of the system correspond its territory in the "energy" landscape. Learning means slow change of the shape of the territory so that memory valleys get gradually deeper and system ends up to them with larger probability in future.

2. Repeated simulated annealing provides a promising memory recall mechanism. The feed of energy from metabolism kicks the system into a motion and dissipation leads it into some valley. If the valley is quite not correct (correct subdirectory but wrong subsubdirectory), a smaller kick leads the system to the bottom of some nearby valley which might be correct. By applying a sequence of increasingly smaller kicks system finally finds the correct memory valley. The conscious attempt to remember corresponds naturally to an external force forcing the system to move in a correct direction.

There are several objections to this scenario. The first mystery is how system knows that the experience is a memory: there seems to be nothing which would distinguish memory from the experience occurring for the first time. Second problem is that the formation of the new memories tends to destroy the old ones: the new territory is simply not the old one. Even if one could circumvent this paradox, it is difficult to understand why the lively episodal memories of childhood are the most stable ones.

If long term memories are geometric memories then memory recall mechanism corresponds to multitime experiences involving generation of mind-like space-time sheets in both geometric now and past.

1. Learning by repetition means keeping some subsystem in some deep valley for a long period of geometric time (system is still in that valley in the geometric past!). This corresponds to reverberating patterns in neuronal circuits generated automatically or by learning by repetition. In this picture the modification of synaptic strengths is not learning of memories but just what it seems to be: a modification of responses to sensory inputs necessary for survival.

2. The attempt to remember creates mind-like space-time sheets located in the geometric past. The probability that a newly created mind-like space-time sheet is located in the memory valley of long time duration is high and thus conscious memory recall becomes probable. Also very emotional and "catchy" experiences generating long lasting memory valleys are easily remembered. Childhood memories are often very emotional ones and therefore also the most stable ones.

No final vision about what memories are in TGD framework exists yet. What is certain is that one can distinguish between geometric and subjective memories. The idea that episodal memories are ordinary sensory experiences with the object of the perceptive field in the geometric past is very attractive and speculative hypothesis which might work in TGD Universe, but more conventional explanation sounds more realistic in the context provided by the standard neuroscience. What is lacking still is a clear vision about the precise physical realization of long term memories.

2.5 Long Term Memories

An important question is whether our long term memories correspond to either geometric or subjective memories or whether they involve both aspects somehow.

2.5.1 Long term memories as geometric memories?

The unreliability and narrativeness of the long term memories would support strongly the interpretation of at least episodal long term memories as geometric memories, that is multitime experiences involving active mind-like space-time sheets scattered along entire life span. This option is consistent with the short duration of subjective memories, which can be even of order .1 seconds characterizing the duration of immediate sensory memories.

Geometric memories could be realized as multitime experiences involving mind-like space-time sheets located around several moments of the geometric time, provide the simplest realization for the long term memories.

1. The model solves the basic difficulties of the neural net models of long term memory. In the neural net models long term memories are represented by synaptic strengths. The problem is that the learning of new memories destroys old memories. In particular, the stability of

the childhood memories is difficult to understand. It is also hard to understand how brain knows that the experience represents memory. One cannot avoid the difficulty by saying that novelty detection tells that experience occurs for the first time since the notion of novelty does not make sense if conscious experience contains only information from single moment of geometric time.

2. TGD model is consistent with neural net models and actually generalizes them. Neural net in the spirit of TGD corresponds to brain as system moving in spin glass energy landscape. Self-organization by quantum jumps leads the system to a bottom of an energy valley representing memory. This model is consistent with the fact that there is no upper bound for autobiographical memory. One can also understand how learning occurs. The repetition of an experience means that energy valley becomes a canyon in time direction so that mind-like space-time sheets in the geometric past have a large probability to end up to the region representing memory. In particular, reverberating nerve pulse patterns are ideal for representing long term memories.

3. Highly emotional experiences generate deep valleys and increase the probability of the system of the geometric past to stay at the bottom of valley. This explains why cildhood experiences are so stable. In fact, one could identify primitive emotions of pleasure and pain as related to the motion in the spin glass energy landscape. Pleasure and pain could even directly correlate with the sign of the increment of the Kähler function in the hopping motion in the spin glass energy landscape. Note that primitive pleasure and pain are are very much like sensory experiences and one could regard them as sensory experiences of brain about its own motion in spin glass energy landscape. This leads to the generalization of the notions of sensory experience and motor action to include the motion in spin glass energy landscape and to a considerably new insight about the meaning of the brain architecture.

There are also perinatal experiences, memories about previous lives and transpersonal experiences having natural explanation in terms of geometric memory realized as multitime experiences associated with mind-like space-time sheets located at different values of the geometric time. Transpersonal experiences suggests that self is dynamical: if prenatal experiences, memories about previous lives and transpersonal experiences are really what they seem to be, the geometric time extension of self should dramatically increase during these experiences.

If "our" self has duration of order lifetime, also subjective memories can contribute to our long term memories. As already found, this option does not exclude the possibility that our long term memories correspond to subjective memories.

2.5.2 Geometric memories as sensory experiences with the object of the perceptive field in the geometric past?

The general theory of qualia to be developed in [K13] leads to the conclusion that geometric memories could be regarded as special kind of sensory experiences for which some objects of the perceptive field located in the geometric past. One also ends up with a concrete models for the mechanism making long term memories possible by "waking up" sub-selves of the geometric past in selective manner by EEG frequencies. The unavoidable conclusion is that massless extremals (MEs) with durations of order lifetime, and hence with sizes which are measured in light years, are necessarily involved. Needless to say, one must give up the idea that we are nothing but our brains.

The fact that the light-like boundaries of MEs serve as quantum holograms and have gigantic information storage capacities by the almost degeneracy of the states fits nicely with view. Lightlikeness means that 3-dimensional time=constant slice of Minkowski space is replaced with a slice which can have arbitrary long temporal duration so that memories become indeed possible. The fact that at least vision represents directly information about outer surfaces of 3-dimensional objects rather than objects themselves but contains information about time development over an interval of order .1 seconds fits nicely with this view.

The realization of long term memories in terms of magnetic quantum phase transitions induced by ME frequencies requires incredibly high frequency resolution. The resolution is of order $\Delta f/f \sim \Delta T/T$ giving $\Delta f/f \sim 10^{-9}$ for time resolution of about $\Delta T = 1$ seconds. An unrealistically high

frequency resolution is required if temporal coding by EEG frequencies is assumed. There is also another problem: if the signal to the geometric past and back is between parts of brain, one cannot avoid zigzag type MEs effectively representing a repeated reflection between two mirrors. In the p-adic context these zigzag MEs are allowed by conservation laws (this might relate with the fact that long term memories are mostly cognitive) but not in the real context.

These observations suggests that one should allow MEs and magnetic flux tube structures with length scales of order light lifetime and try to invent a more elegant mechanism of long term memory. One might start from the mirror idea and consider the possibility that memory recall involves a question sent to the geometric past as a classical signal reflected back to brain in a mirror formed by a magnetic flux tube: perhaps passive MEs are involved at this stage. Thus MEs with lengths of order of light lifetime ($L = cT$) would be required. The answer could involves a transformation of passive MEs to active em MEs and the generation of quantum entanglement unless it is present already: the recalled experience is shared by the experiencer now and experiencer in the geometric past. The mechanism involves several purely TGD based features: the light-like character of the boundaries of MEs making possible light-like selves; space-time sheets with a negative time orientation allowing classical signals to propagate backwards in time; the magnetic flux tube structures associated with brain having sizes of order light years making possible MEs to form mirrors. Precognition is the temporal mirror image of this mechanism.

If long term memories are in some sense sensory experiences with the object of the perceptive field in the geometric past, the notion of the magnetic canvas should work also in these astrophysical length and time scales. Consider first the constraints on this mechanism.

1. The sensory experiences at different levels of the magnetic hierarchy cannot be identical. This means that standard sensory representation using magnetic canvas must be applied to realize the episodal memory. This leaves only two possibilities. Either the experience is coded to a light-like vacuum current and this information, when sent into future, regenerates the sensory experience there. Alternatively, future self could entangle with the self of the geometric past and share its experience.

2. Since MEs correspond to 3-surfaces moving with light-velocity, the only possible realization of the communications between geometric past and geometric now is in terms of "laser mirrors" connected by MEs representing geometrically the light reflected in the mirror. The length of ME is given by $L = cT$: $2T$ is the moment of the geometric past which gives rise to the memory. Interestingly, Peter Gariaev has suggested that laser mirrors are involved also with DNA [I1]. This means that a ME extending from the brain of the geometric now to the geometric past and the ME from the brain of the geometric past fuse with the same magnetic flux tube to form a representation for light reflected in a cosmic mirror. The MEs and magnetic flux tube structures associated with the relevant parts of brain must form pre-existing, tightly correlated structures since the probability for the formation of this kind of mirrors accidentally is extremely small and there is no guarantee that they connect parts of the same brain. Second mirror would be obviously defined by the join along boundaries contact/flux tubes of ME with the magnetic flux tube. Hippocampus is a natural candidate for the brain structure, at which the first mirror is located. The fact that MEs represent channelled energy means that distance is not a problem as far as energetics is considered.

3. Active memory recall must involve a question sent to the geometric past followed by an answer communicated to future in some manner. There must be some difference between precognition and memory recall so that the question and answer cannot be realized in the same manner. This serves as an important guideline. Various arguments lead to the view that the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

   Sharing of mental images if time-like quantum entanglement is generated between the selves of the geometric past and geometric now. This is possible in TGD framework, thanks to the non-determinism of Kähler action making also MEs quantum holograms in quantum gravitational sense. The fact that MEs represent light-like selves, would be essential for this

realization. The beauty of this realization is that the information need not be transferred classically. This realization is actually a special case of the realization in terms of zigzag ME in much shorter length scale: in this case a huge number of reflections in the mirror pair would be required and it is difficult to understand how one could control the temporal position of the self of the geometric past in this kind of situation.

This picture deserves some further comments.

1. If the higher levels of the magnetic self hierarchy are intelligent as one might expect (and even more intelligent than us), one can also consider the possibility that the step in which the interaction of ME representing a question sent to the geometric past with the magnetic flux tube at the higher level of the hierarchy is far from a mechanical interaction. Rather, the magnetic flux tube structure could act as an intelligent conscious system rather than a mechanical relay station.

2. The process could also have interpretation as an exchange of two virtual MEs between brain and magnetic flux tube structure: kind of a very low frequency counterpart of self energy Feynman diagram realized as a generalized Bohr orbit. The Feynman diagrams for the emission of parallel photons are infrared divergent. This encourages the expectation that the probability for the presence of MEs parallel to the magnetic flux tubes is very high and increases with the increasing length of ME. The spontaneity of the episodal memories is in accordance with this view. An interesting question is how these MEs relate to $1/f$ noise.

3. The assumption that the lengths scales of MEs and magnetic structures are identical implies that the frequency of EEG ME equal to the magnetic transition frequency f_m fixes the length of the two MEs involved and thus the temporal location of the long term memory in the geometric past:

$$T = \frac{2}{f_m} \quad .$$

This represents a frequency coding for the temporal location but in a way different from the one proposed originally. In particular, this coding does not require ME frequencies to be in EEG range and defined with a relative accuracy of order $E-9$. In standard physics the idea about brain generating MEs with a frequency scale of the order of the inverse of lifetime does not make sense: in TGD context situation is different since this process occurs in subjective time.

If this picture has captured something essential from the nature of the long term memories, the conclusion is that we are not at the top of the magnetic sensory hierarchy. Human body and brain generates extremely weak magnetic fields and the corresponding magnetic flux tube structures could serve as a sensory canvas making possible long term memories. Near death experiences [K4] could be understood in this framework if the weak magnetic fields associated with the higher levels of the fractal hierarchy of magnetic structures utilize brain and body as kind of sensory and motor organs. Note that there is flux tubes inside flux tubes structure so that ordinary sensory experiences can be associated also with these flux tubes.

2.5.3 Long term memories as memories of higher level self?

The natural identification of the immediate short term memory as subjective memory predicts that the life time of a human sensory self cannot be much longer than .1 seconds, the duration of psychological moment of time. Our long term memories correspond to much longer time interval and cannot thus correspond to our subjective memories. Entire hierarchy of subjective memories is however predicted and a possible model for *genuine* long term memories is as resulting from temporary entanglement with selves belonging to the higher level of the hierarchy. Also this identification is consistent with the fact that there seems to be no upper bound on autobiographical memory. Summation hypothesis implies that our genuine long term memories would be sums over a large number of wake-up periods of self in the subjective past of the self. Therefore one could

perhaps understand how aging self gains gradually wisdom from experience: also the identification of the long term memories as geometric memories explains this.

Higher level selves could communicate their subjective and geometric memories as well as the emotions generated by their comparison to us. The first idea to come into mind is that communications occur during totally entangled state, sleep or trance. For this option it is not at all clear how the experiences of the higher level selves during entangled state could be ours! In fact, we should lose our selves during entanglement with self characterized by larger p-adic prime. For instance, during sleep without dreams entanglement with some higher level self should occur and we do not remember anything about this. Trance is a second example of this: subject person does not remember anything about the trance state. Thus it seems that this mechanism cannot give rise to conscious long term memories. This does not however exclude the possibility that cognitive representations are formed during the communication and lower level self experiences them later as memories. One function of sleep might be the generation of the entanglement with higher selves making in turn possible the communication of genuine memories of subjective past to our mind. This communication could realize these memories as thoughts about the experiences of past realized as nerve pulse patterns regenerating these thoughts.

The so called semitrance mechanism [K29] avoids the objections against communications occurring in totally entangled state. During semitrance parts of brain are entangled with some higher level self. These selves can communicate their memories to that part of brain which is awake (communication means generation of mental images). Ancient men received these communications as sensory hallucinations ("God's voice"), very much like schizophrenics, whereas modern man experiences them as thoughts and emotions which are often "hallicinatory" in the sense that they are not automatic reactions to the sensory input. The TGD based vision for the development of language and civilization modifies Jaynes's vision about bicameral man as a schizophrenic of modern society and relies on the notion of semitrance. Semitrance mechanism is extremely general and could be present in all length scales. For instance, semitrance could provide the inhabitants of cell societies (organisms) and protein societies (cells) with a personal self narrative (genetic determination of cell as self narrative!).

Semitrance mechanism survives the most obvious counter arguments.

1. The general objection is that the memories of the higher level selves are rather abstract. The assumption communication mechanism is restricted to thoughts and emotions is however consistent with the abstract nature of the non-episodal long term memories. The most natural identification of episodal memories is indeed as personal geometric memories or possibly as artificially generated sensory hallucinations stimulated by higher level self during semitrance.

2. Since semitrance mechanism is only a communication method, geometric and subjective memories remain the fundamental memory mechanisms. Therefore the nice features of the geometric memory are not lost. For instance, one can understand learning and the role of emotions and repetition in learning.

2.5.4 More complicated scenarios

One can consider also more complicated scenarios for realizing long term memories.

1. Ensemble of mind-like space-time sheets could generate continuously cognitive representations remaining in ideal case unchanged and memories as ability to re-experience would be carried by mind-like space-time sheet when it wanders to the direction of future. This would require that mind-like space-time sheets replicate just as material space-time sheets (DNA, cells, members of species) do. If mind-like space-time sheets responsible for memories of this kind have finite lifetime, say of order one second, short term memories could be realized in this manner without cognitive population explosion. In fact, cell division might realize long term memories in cell populations. Perhaps also DNA replication might be regarded as this kind of memory.

2. The realization of long term memory and communication relying on replication is rather primitive and the fact is that neurons do not replicate. A natural explanation is that neurons have discovered procedural memory, which means that long term memories could be

realized dynamically: standardized nerve pulse patterns generate standardized temporal patterns of quark magnetization. This implies ability to regenerate the thought stimulated by the primary experience and associative learning would associate memories to experiences as thoughts. This picture would correspond to that of ordinary associative nets and is subject to the standard counter arguments such as the loss of old memories caused by the learning of the new ones.

3. Sustainment of the mental images is indeed one of the basic mechanisms behind human intelligence and can be also seen as a way to enhance the probability that a geometric memory in the past is recalled. Sustained mental images are analogous to the icons of the computer screen, which in fact supports the idea that the evolution of computers mimics in many respects the evolution of the brain. At program level icons correspond to program loops. At neural level to periodic neural process generating again and again the same mental image (not necessarily directly conscious to us).

4. Written language and symbols are the next step to the internal sustainment and make possible to achieve a given sensory and cognitive experience in a controlled manner. Program files are obviously analogous to the written language (the electronic control systems preceding the computer era were effectively computer programs but were not written as computer code, externalized). DNA could be seen also as ROM type memory of living systems.

2.6 Implicit Memories

A possible definition of implicit memories is as memories which exist but are not created in conscious experience of the subject person. Also implicit learning could be defined in this manner. A good example of implicit memory is provided by a situation in which unaesthetized patient can quite accurately remember what has been said during the operation [J18]. An example of implicit learning is the learning of grammatical rules without any explicit (conscious) representation for them. The status of the implicit memories and learning is not established. A possible reason for this is that it is not easy to understand them in computational paradigm of consciousness. Connectionism explains implicit learning and memories as unconscious formation of associations and mathematically modelled by the dynamics of the neural networks.

In TGD framework implicit learning and memories could correspond to learning and memories at the lower levels of the self hierarchy not usually conscious to us. In case that the mind-like space-time sheet corresponding to our sub-self forms flux tube with a lower level self so that lower level self fuses with the sub-self in question, its memories can become our conscious memories. ORP suggests that this process involves also the formation of quantum entanglement and this indeed must occur. Biofeedback could be understand as a special case of this process. In the TGD based model for the quantum correlates of the sensory qualia this process is key role. The memories communicated by semitrance mechanism can indeed be and probably often are implicit.

One can consider also formation of flux tubes between our sub-selves and sub-selves of other persons. This is quite possible if our sub-selves indeed correspond to topological field quanta representing ELF photons associated with the EEG frequencies having size of even size of Earth. Formation of flux tubes between topological field quanta of this size would make for us to experience the memories of other persons. This kind of mechanism could explain the memories of anesthetized patient about what happened during the operation as memories of sub-selves of the persons participating the operation. An open question is whether the mechanism could also explain also out-of body experiences, in which patient looks himself from outside, sometimes involved with this kind of situations.

Implicit learning could also correspond to the development of various cognitive skills realized as self-organized self cascades so that no explicit representation of the skill is needed: when initial value self wakes up, the cascade proceeds with highly predictable manner due to quantum statistical determinism. Even the ontogeny could be regarded as this kind of skill implicitely coded in DNA!

2.7 Procedural Memories

Procedural memories seem to be mostly stabilized sequences of thoughts and mental images and the proposed model for cascade like generations of selves provides therefore a model for procedural

memory. Procedural memories could be simple cognitive acts occurring again and again as a reaction to some specific stimulus. mind-like space-time sheet would carry them while drifting into the future. For an ensemble of selves with each self initiating cognitive acts is in question, reliability of memories would result.

Quantum spin glass model of brain explanains for formation of the procedural as resulting from quantum self-organization. Dissipation caused by quantum jumps would automatically select skills, habits and eigen behaviours as surviving self-organizing patterns. These patterns would correspond to deep valleys in the fractal energy landscape of the spin glass landscape, which is effectively four-dimensional. Repetition would automatically lead to the learning of procedural memories since it would extend the valleys in time direction so that mind-like space-time sheets would have larger probability to enter to the valley and give rise to memory. For instance, reverbrating nerve pulse patterns in the memory circuits of brain would realize this repetition.

3 Model For Long Term Memories

In the following an attempt is made to understand how long term memories could be realized at neuronal level. I hope that my fragmentary knowledge about the details of brain science would not mask from the reader the beauty and simplicity of the general mechanism. The model is constructed first at general level and then basic facts about long term memory are discussed in the framework of the model.

3.1 General Ideas

In TGD framework one can make a precise distinction between genuine memories and apparent memories such as procedural and implicit memories, associations, feature recognition, and standardized neuronal "features" serving as building blocks of memories. The basic question is whether the representations of the long term memories are realized in the brain geometrically now or in the brain of the geometric past. In TGD the latter option is allowed by time-like quantum entanglement made possible by the non-determinism of Kähler action. The very fact that the memory storage of past memories to the geometric now is not needed, means that there is no need to carve long term memories to associative structures so that geometric now would contain representations about moments of the geometric past. Only the representation of the event at time when it occurred is needed. For example, this implies that long term potentiation (LTP) is just learning and adaptation to a new situation and can only be related to the modification of memory representations and possibly the construction of new standardized features.

3.1.1 Mirror mechanism

Mirror mechanism is the simplest quantum mechanism of episodal memories and involves only a sharing of mental images by time-like entanglement. p-Adic physics suggests that the entanglement should be negentropic. Negentropic time-like entanglement is indeed possible and would correspond to density matrix which is projector. The corresponding entanglement matrix would be unitary.

Another mechanism is based on communications in time direction giving rise to the analog of reflection in time direction. The brain hemisphere sends a negative energy ME to the geometric past reflected at a large distance and returning back to the hemisphere and induces a sharing of mental images. The desire to remember something and the memory of the past fuse to a single mental image shared by the brains of the geometric past and now. The desire to remember would be communicated to the geometric past also in case of non-episodal memories whereas memory itself would be communicated classically by positive energy MEs.

In a more realistic situation multiple reflections for a curvilinear negative energy ME along a closed magnetic flux loop would occur and guarantee precisely targeted communications to the geometric past. The sizes of these loops would be measured in light years. MEs and magnetic flux loops associated with the personal magnetic body are the most realistic candidates since in this case the interaction with matter is minimized.

The notion of memory field supports this idea. Retrograde amnesia leads to a selective loss of memories in some time interval, and the notion of memory field provides a possible explanation. This means that brain structures with a given memory field entangle with those events of the

geometric past which are located in some time interval ΔT at temporal distance T in the past. A closed magnetic flux tube with a given length $L(T)$ would obviously be a correlate for a memory field with a given time span T.

The sharing of mental images mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/sharing.jpg` or **Fig. ??** in the appendix of this book) requires only that gravitational MEs take care of only quantum entanglement and because it allows arbitrary kinds of episodal long term memories. The electric stimulation of neurons can induce complex episodal memories. This can be understood if the episodal memory recall involves only the entanglement by the negative energy ME and the field pattern associated with ME does not matter at all. The unique experimental signature of the quantum entanglement mechanism is that no direct correlates for the memories themselves are necessary in the brain geometrically now. One can wonder what distinguishes the resulting experience from precognition by the self of the geometric past: could it be that to precognize now is to remember in the geometric future?

The direct sharing of sensory experience is non-economical in the sense that the amount of the irrelevant information is very high. The conceptualization involved with the symbolic representation allows to represent only the absolutely essential aspects. In case of classical communications symbolic representations is of course the only practical possibility. Since the brain of the geometric past serves as a passive entangler and does not have the possibility to process the communicated information, the sharing of the mental images is not flexible enough and does not allow an active precisely targeted memory recall. It is also very difficult to tell whether sensory experience represents memory or a genuine experience.

3.1.2 Classical communications and non-episodal memories

For non-episodal memories classical communication mechanism suggests itself as a more appropriate mechanism. Classical signalling requires the coding of the data to the shape of the field pattern propagating along positive energy ME, which could be curvilinear and analogous to a radiation propagating in a wave cavity defined by a magnetic loop of the magnetic body.

MEs are indeed optimal for the coding of the classical signal since the vacuum current for given moment of geometric time is non-deterministic. Classical communications would allow and also require the minimization of the data communicated. These memories would not be sensory unless back-projection to the sensory organs is involved at the receiving end. The formation of the symbolic representation is subject to errors: for instance, temporal order of events can change. It is known that declarative memories can often involve changes of the temporal order. It must be emphasized that declarative need not be synonymous with non-episodal. Declarative memories could be also episodal and correspond to sharing of a symbolic mental images of the geometric past. The "features" of Freeman [E1] having during of about.1 seconds are good candidates for the representation of the classical signals and the time scale suggests that electron's causal diamond is involved as also quark CDs with time scale of 1 ms. If EEG MEs are involved, the modulation of hippocampal theta frequency is a candidate for the representations of classical signal.

In ZEO this mechanism corresponds to a process in which sub-self representing mental image dies and re-incarnates at the opposite boundary of CD. This corresponds to a negative energy signal travelling to the geometric past. Also this self dies and re-incarnates at original boundary of CD: this corresponds to the positive return signal from the geometric past. Mental image simply falls asleep and wakes up and after that represents the memory as a conscious information.

There are are two basic options for how the classical communication could occur.

1. Positive energy ME would not leave brain at all and would therefore have ultra slow effective phase velocity along the brain structure in question, say axon, so that it would not leave brain during its travel to the geometric future.

2. Positive energy ME would be curvilinear and parallel with magnetic flux loop of the personal magnetic body serving effectively as a wave guide. In this case the reduction of the phase velocity to EEG wave phase velocity would be enough. For instance, for the phase velocity of alpha waves propagating along loops with the size of the order of the Earth's circumference, the time span of the memory would be of the order of one year. In this picture one of the functions of the part of EEG representing evoked responses could be classical communications making possible non-episodal memories. Only part of these memories would be conscious to

us. The length of the magnetic loops is expected to directly correlate with the period of EEG frequency involved with the classical communication via the relationship $L = vT$ would provide a second correlate for the notion of the memory field. There are indeed reasons to expect that the structures communicating signals to the geometric future are specialized to communicate signals to a certain distance.

The most plausible neurophysiological excitations associated with the received signal are Ca^{++} waves known to have extremely wide velocity spectrum. For the option a) the required velocity would be of order neuronal sizes per year, and this is perhaps unrealistically low velocity. It is also difficult to see how the neuronal noise would not spoil the signal. For the option b) the positive energy ME entering brain at the moment of memory receival would induce Ca^{++} waves in turn inducing neural activity.

For classical signalling the transformation of the classical signal to a conscious experience is needed. MEs could directly generate membrane oscillations and nerve pulse patterns via the general mechanism of nerve pulse and EEG discussed in [K26]. EEG MEs could in turn induce cyclotron transitions at the magnetic flux tubes of the Earth's magnetic field in turn affecting nerve pulse generation. Also a transformation of the signal to Ca^{++} waves could be possible. The conscious experience does not involve sensory component unless there is back-projection to the level of sensory organs involved.

Interesting questions relate to the interpretation of the ultraslow effective phase velocity of MEs acting as bridges connecting two space-time sheets.

1. The classical fields from a larger space-time sheet A can be transferred to a smaller space-time sheet B topologically condensed on A by inducing the motion of the wormhole contacts, which in turn generate classical fields at the smaller space-time sheet. The fields can also penetrate along flux tubes connecting the boundaries of two space-time sheets.

2. Quite generally, the "topological" half of Maxwell's field equations implies that tangential component of E and normal component of B are continuous at the junctions connecting the boundaries of two space-time sheets. One could assume that quantum effects can be modelled phenomenologically by introducing the phenomenological D and H fields introduced also in the Maxwell's theory. In the Maxwell's theory the discontinuity of the normal component of the D field equals to the density of the free surface charges and the discontinuity of the tangential component of the H field equals to the free surface current. These conditions can be assumed also now, at least as the first approximation.

3. One could model the propagation of MEs topologically condensed at a space-time sheet labelled by a p-adic prime $p \simeq 2^k$, k prime or power of prime, by introducing the di-electric constant $\epsilon(k)$ and the relative permeability $\mu(k)$ satisfying the condition $\epsilon(k)\mu(k) = 1/v^2 > 1/c^2 = 1$, where v is the effective phase velocity of ME depending in general on its fundamental frequency. The fields D and H would be defined as $D = \epsilon(k)E$, $H = B/\mu(k)$: this condition generalizes to that for the Fourier components of the fields. The reduction of the effective velocity for the propagation of the topologically condensed MEs to say alpha wave phase velocity does not seem plausible.

4. The propagation of MEs which serve as bridges between boundaries of two space-time sheets (say cell membrane space-time sheet and cell exterior space-time sheet) must be modelled differently. One could introduce a generalized di-electric constant $\epsilon(k_1, k_2)$ and permeability $\mu(k_1, k_2)$ characterizing the pair of space-time sheets such that the effective phase velocity $v(k_1, k_2)$ of MEs acting as bridges satisfies $\epsilon(k_1, k_2)\mu(k_1, k_2) = 1/v^2(k_1, k_2)$, and also now depend on the fundamental frequency of ME. A very large value of $\epsilon(k_1, k_2)$ implying the needed very small value of the effective phase velocity would mean that the orthogonal component of the electric field does not appreciably penetrate inside ME from either space-time sheet. Since MEs are the fundamental topological field quanta, this looks a natural assumption. The extremely low effective phase velocity should be due to the replacement of the wormhole contact coupling with the join along boundaries coupling causing the "sticking" of MEs. Note that the join along boundaries coupling is topological sum coupling for boundaries whereas wormhole contacts represent topological sum coupling for interior. Furthermore, join along

boundaries contacts can have a macroscopic size whereas wormhole contacts are CP_2-sized: this could explain the huge reduction of the effective phase velocity for the boundary MEs.

3.1.3 Negative energy MEs as ideal entanglers with the geometric past?

MEs with negative energies are especially favoured for quantum communications. The reasons are many-fold. The interaction with the matter is very weak in long length scales but strong in cellular length scales, negative energy implies that ME is identifiable as a virtual particle and analogous to a part of a Feynman diagram so that no dissipation is involved and quantum communication is possible. The reversal of the arrow of geometric time means also that there is not macroscopic dissipative dynamics which would spoil the quantum coherence.

The requirement that the entanglement process is highly selective suggests a resonance mechanism. This requires that receiving and sending structures are similar and generate ULF MEs with fundamental frequencies measured typically in cycles per year. If negative energy energy ME is in question, as suggested by the idea that a classical communication to the geometric past is involved, it cannot be emitted unless there exists a receiver absorbing the negative energy and in this manner providing energy for the sender by buy now-let others pay mechanism. For negative energy MEs resonance mechanism plus a simple classical signal serving as a a password could also guarantee that correct part of the brain receives the signal.

Negative energy MEs represent time reversed level of the p-adic length scale hierarchy so that the dissipative effects associated with the space-time sheets with the normal arrow of time should not interfere with the quantum communication. This at least, when the energy of the negative energy ME has a magnitude larger than the thermal energy associated with the space-time sheets with which it interacts: there is simply no system which could make a transition to a lower energy state by the absorption of a negative energy ME. Furthermore, since the systems with reversed arrow of geometric time are expected to have extremely low density, the dissipative effects in the reversed direction of time are expected to be small.

Since the generation of negative energy MEs does not require energy feed, the memory recall to the geometric past occurs more or less spontaneously, and the scanning of the geometric past becomes possible. The intentionality of the memory recall would be realized as generation of a p-adic ME transforming to a negative energy ME, when the real system jumps to a higher energy state. This process makes possible precisely targeted intention also in the case of memory recall since the transitions in question cannot occur spontaneously. In the case of precognition precognizer must intentionally receive negative energy MEs from the geometric future so that energy feed is needed. This perhaps explains why precognition is so rare. Note that p-adic variant of precognition having interpretation as intentionality occurs easily since p-adic energy is conserved only in a piecewise manner.

The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

3.2 Could Gravitation Have Something To Do With Long TermMemories?

Penrose has proposed that quantum gravitation might be crucial for understanding consciousness. In TGD framework the hierarchy of Planck constants labelling a hierarchy of quantum criticalities and the prediction that quantum gravitation gives rise to quantum coherence in astrophysical scales replaces this vision [K30, K22].

The quantitative formulation is in terms of the gravitational Planck constant characterizing the flux tubes of two-body system and having the expression $\hbar_{gr} = GMm/v_0$, where v_0 corresponds to a characteristic velocity associated with the system. The hypothesis $h_{eff} = n \times h = h_{gr}$ relates h_{gr} to the large Planck constant h_{eff} characterizing the cyclotron condensates of charged particles in living matter.

Gravitational Compton length does not depend on the mass of the particle and cyclotron energy spectrum proportional to h_{eff} is universal (no dependence on the mass of charge particle) and in

visible and UV range. The dark photons in question can transform to ordinary photons identifiable as bio-photons and defined fundamental communication and control tools in living matter. This implies that they are crucial also for the memory. This vision is discussed in [K25, K5, K6, K7, K8, K3].

The text below was written much before this vision but I have left it essentially as such.

3.2.1 Could classical gravitation stabilize irreducible bound state entanglement?

Bound state entanglement gives rise to a "state of oneness", in which quantum computing system is totally bound-state entangled and does not decay into sub-selves in self measurement process and can thus behave effectively as a non-dissipating system and quantum compute. The estimates for the duration of this kind of bound states tend to be much shorter than required [J17]. The question is whether classical gravitational interaction could somehow stabilize these bound states.

The extremely low value of the gravitational binding energy is an objection against the view that gravitational interaction could help to stabilize the bound states. The huge degeneracy of the bound states could however change the situation.

1. Suppose that spin glass degeneracy gives rise to a huge number of almost degenerate bound states for which only the classical gravitational energy is different and that for non-bound states this degeneracy is much smaller. The dominant part of the binding energy is of course something else than gravitational. If this is the case, the number of the bound states is so large as compared to the number of unbound states that the branching ratio for the decay to unbound state is very small and bound state entanglement can last for much longer time as usually. Although the lifetime of an individual bound state need not increase, the time spent in bound states and defining de-coherence time become much longer than predicted by standard physics.

2. If the flux tubes are sufficiently near to vacuum extremals, they indeed allow immense spin glass degeneracy with slightly different gravitational interaction energies and the desired situation can be achieved.

3. This argument can be refined by using unitarity. If the net rate for the transitions to bound states is enhanced by the degeneracy of the bound states, probability conservation implies that the probability for the occurrence of de-cohering decays is reduced correspondingly.

A rough order of magnitude estimate for the gravitational binding energy for a cubic blob of water (that is living matter) having size given by p-adic length scale $L(k)$ is

$$E_{gr}(cubic,k) \sim \frac{GM^2}{L(k)} = G\rho^2 L^5(k) \sim \frac{Gm_p^2}{L(137)}\frac{L^5(k)}{L^5(137)} \simeq 2^{-127}2^{5/2(k-137)}\frac{1}{L(137)} \quad .$$

Gravitational binding energy is larger than the p-adic energy $2\pi/L(k)$ for $L(k = 179) \simeq .169$ mm. In the range $L(163) = 640$ nm and $L(167) = 2.56$ μm gravitational binding frequency varies between 1 Hz and 1 kHz, that is over EEG range up to the maximal frequency of nerve pulses. If the binding energy gives estimate for the lifetime of the gravitationally bound states, this might fit nicely with EEG energies in typical cell length scales!

For $k = 157$ and $k = 151$ (the range from cell 10 nm-80 nm, microtubules are at the lower end of this range) the gravitational binding frequency corresponds to a time scale of 8.5 hours and 32 years respectively so that the time scales relevant for life are spanned by the Gaussian Mersennes. What sounds paradoxal is that short length scales would correspond to long time scales but this indeed follows from the inverse square law for the gravitational force.

One can perform a similar estimate for linear structures. Parametrizing the microtubular transversal area to be $d = x^2L^2(151)$, $L(151) = 10$ nm, one has

$$E_{gr}(lin,k) = x^5 \times E_{gr}(cubic,151)\frac{L(k)}{L(151)} \quad .$$

This gives for $L(k) \sim 1$ meter, the frequency of $.1 \times x^5$ Hz. The time scale varies between $10/x^5$ seconds and $32/x^5$ years and certainly covers the time scale for human long term memories. Of course, this rough estimate involves numerical factor which can increase the upper bound.

Note that the increments of the gravitational energy between transitions between almost degenerate bound states are some fraction of the gravitational binding energy. Also the gravitational interaction energy associated with the classical em fields could contribute significantly to the density of the gravitational energy in TGD framework and tend to increase the overall energy scale. The reason is that the gravitational constant associated with classical fields is roughly 10^8 times larger than the ordinary gravitational constant [K2]. Thus, if the energy of classical fields is more than $10^{-8}m_p \sim 10$ eV per proton the classical field energy of, say, flux tubes becomes significant factor. Since hydrogen ground state binding energy is about 13 eV, this kind of energy density per atomic volume looks quite reasonable in case of water.

TGD universe is quantum critical system in the sense that space-time sheets representing magnetic and electric fields with arbitrary large sizes are present and correspond to two phases in equilibrium (compare with ice and water at melting point). Electric-magnetic duality is second fundamental symmetry of quantum TGD. Magnetic flux tubes carrying constant magnetic field (in lowest order approximation) have as their duals space-time regions carrying electric fields (constant in lowest order approximation). In biosystems various electrets and magnetic flux tube structures are the concrete realization of these two phases. Classical gravitational effects generate vacuum 4-currents near the boundaries of these structures serving as sources of magnetic resp. electric fields. The boundaries of these structures are singularities of the classical gravitational fields and these gravitational fields are good candidates for generating gravitional MEs responsible for long term memories.

Spin glass degeneracy corresponds in the formulation of hierarchy of Planck constants in terms of hierarchy of quantum criticalities [K12, K5, K6, K7, K8] to the existence of space-time surfaces, which can be regarded as many-sheeted singular coverings of space-time surface such that the sheets coincide at the ends of the space-time surface at boundaries of CD. The number of sheets corresponds to the value of $h_{eff}/h = n$. There are deep connections with p-adic length scale hypothesis and its generalization, with the notion of negentropic entanglement, with strong form of holography, and the vision about hierarchy of algebraic extensions of rationals as correlate for evolution [K31].

3.2.2 Long term memory and gravitational MEs

Interestingly, MEs (topological light rays) with fundamental frequencies with time scale measured using year as a unit are needed in the mirror model of long term memories (to remember event at a distance of T in past is to look in mirror at a distance $L = cT/2$). The gravitational transitions between huge number of almost degenerate spin glass states could be coded to the fundamental frequencies of MEs. In particular, structures with sizes slightly above cell membrane thickness, such as microtubules, could generate these MEs as the topological correlates of graviton emission with frequency equal to the increment of the gravitational binding energy in quantum jump involved. Thus there would be a direct correlation with long term memories and microtubules: microtubule conformations could code for long term memories.

The mirror mechanism of long term memory has beautiful interpretation in terms of topological correlates for virtual graviton exchange with vacuum.

1. The light reflected in mirror corresponds to topological light rays assignable to gravitons and is reflected from the curved vacuum. Topological counterpart of virtual graviton is emitted by (say) tubulin, absorbed by vacuumandemitted again by vacuum, and finally absorbed by tubulin. Curved vacuum acts as a mirror for gravitons and you see yourself in this mirror.

2. Why gravitons are the only possibility in time scale of years is simply that they interact so weakly that they can propagate light years before absorbed by curved vacuum. Time scales come out correctly and microtubules are known to be crucial for long term memories (Altzheimer's disease involves changes at microtubular level).

3. There are also genuine vacuum extremals interpretable as topological graviton rays. These graviton rays could reduce to vacuum MEs except in the turning point. This would mean "self-reflection" without scattering from background and interpretable as an absorption and emission of a virtual graviton. In case of non-vacuum extremals, classical momentum conservation however requires that the topological graviton exchanges momentum with the background space-time surface and thus is mirrored from it.

4. One could interpret the low energy topological graviton rays responsible for long term memory as a particular kind of $1/f$ noise accompanying all critical systems, in particular TGD Universe, which can be regarded as a quantum critical quantum spin glass. Gravitonic $1/f$ noise would be emitted in the transitions between almost degenerate spin glass states and would be kind of analog for gravitational brehmstrahlung.

If this view is correct, the time scales of long term memory at DNA level would correspond to very long time scales characterizing consciousness at the level of species. As a matter fact, the gravitational binding energy associated with $L(139) \sim .1$ nm (atomic physics) corresponds to the age of the universe: perhaps this explains why Schröedinger equation applies to the description of atom. $1/R$ dependence of the gravitational interaction energy would explain why very short length scales code biological information about very long time scales rather than vice versa.

While writing the above piece of text I did not known about the hierarchy of Planck constants. A photon with given energy can have arbitrary long wave length so that the minimum scale for macroscopic quantum coherence given by the wavelength is scaled up dramatically. For instance, the scaling by a factor 10^{12} can quite well be considered, and in the case of visible photon means scale of thousand kilometers- the scale of Earth.

3.3 Is The Right Brain Hemisphere The Quantum Entangler?

There are some reasons to suspect that the quantum communications with the geometric past occur more dominantly in the right brain hemisphere whereas classical communications would occur in the left hemisphere. This would explain among other things the holistic aspects of right brain consciousness. Left brain hemisphere is specialized more to symbolic processing of information and would indeed be more suitable to classical communication of this information.

Clearly, right brain would be passive receiver whereas left brain would be active expresser. DNA strands would be an example of this dichotomy at molecular level. This dichotomy would be realized also at the level of gene expression using MEs as the model of bio-photons involving in essential manner negative and positive energy MEs suggests. Of course, this statement must be take only in the spirit of fractality and would hold true only in certain range of p-adic time scales.

The following arguments lend some support for the proposed division of labour between right and left brain hemispheres.

3.3.1 Synesthesia as a key to the mechanism of episodal memory

What forces brain region to send negative energy MEs and thus to remember? "Hunger!" is the possible answer! During synesthesia the metabolism in the left cortex is reduced by by 18 per cent due to the abnormally high metabolism in memory circuit (for the model of synesthesia see [K28]). Perhaps the generation of the negative energy MEs is forced by the starvation of the neurons of the left cortex induced by the over-activity of the neurons of the memory coordination circuit. The starving cortical neurons of the left hemisphere would send massive amounts of negative energy MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. Thus the miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction.

There are good reasons to expect that same mechanism might be at work also in the normal situation but involve a less dramatic artificial starvation of the neurons of the right brain hemisphere. Clearly, the role of hippocampus is dramatically different from what is usually believed and also forces to question the naïve belief that neuronal activity is a measure of the contribution of brain area to the conscious experience. While building long term memory representations as classical signals hippocampus and memory circuit would steal energy from certain areas of cortex, and the resulting metabolic starvation would force them to send negative energy MEs to gain energy in this manner. This in turn would lead to the generation of long term episodal or non-episodal memories as a side product. Quite generally it is known that limbic brain and cortex tend to work in complementary modes: when the cortex is in a high state of arousal, limbic brain is in a state of low arousal and vice versa. Perhaps the passive brain region is involved with memory recall and the active one with the construction of sensory or memory representations.

3.3.2 Left-handedness and episodal memory

It is known that persons with many left-handed family members have better ability for episodal memory recall and that this probably relates closely to the communication between left and right hemispheres. We begin to have verbal memories only after the age of four: at this time also the connection between right and left hemispheres has matured. The proposed mechanism of non-episodal memories requires that the right brain hemisphere shares the mental image representing the desire to remember and the left brain hemisphere communicates the memory classically. Als the communication between right and left hemisphere is necessary for this process to occur. Children before the age of four could live in a kind of a dream time experiencing mostly sensory episodal memories and presumably not being able distinguish memories from genuine experiences. This would also explain why we do not have declarative memories dating to the time before the age of four.

How could one understand the tendency of persons with many left-handed family members to have better episodal memory recall? The ability to have sensory memories can appear also when a damage occurs to the regions of the left hemisphere. It could be that classical communications between the hemispheres are worser than usually when episodal memory recall is favoured, and are replaced by quantum communications. The mental images in the left brain hemisphere would entangle with those in the right hemisphere entangling in turn with the geometric future and give rise to episodal memories. Thus the quantum communications between hemispheres might be better than usually. This kind of persons would be more "holistic" than ordinary persons.

3.3.3 NDEs and long term memories

That negative energy MEs could be responsible for episodal long term memories is supported by near death experiences. Persons having near death experiences are clinically dead: in particular, EEG is absent. If these persons indeed have conscious experiences and if they are able to remember them as it seems, and since EEG signals are out of question, only MEs generated during NDE remains as a viable alternative in TGD framework. Brain or possibly body should be involved with the receival of geometric memories if spin glass degeneracy is essential for the time-like entanglement by MEs.

Life review is one important aspect of the NDE experiences: entire 4-dimensonal body is experienced simultaneously. The starvation of neurons forcing them to generate negative energy MEs could explain the episodal memory feats of synesthetes and the eidetic memory, and would naturally be at work also during NDE experience. This is not the only possibility. This experience might also be partially due to the absence of the volitional actions. This life review memory could be interpreted as geometric memories not masked by the normal contributions to the contents of consciousness. An interesting possibility is that this contribution is generated by theta and delta bands of EEG during lifetime and is present also normally but, being strongly masked, is not recognized.

3.3.4 Dejavu experiences and memory feats

Dejavu experiences provide a challenge for any realistic model of memory. In Dejavu the sensory experience is accompanied by the feeling "I have experienced this already earlier".

A natural working hypothesis is that purely sensory memories, sensory re-experiences, do not contain information about the value of the geometric time associated with the sensation. This means that sensory memories cannot be distinguished from real experiences. On the other hand, cognitive and symbolic memories differ so radically from the sensory experiences that there is no difficulty of distinguishing them from genuine experiences. Therefore one knows that the experience represented by this kind of memory occurred in geometric past or represents an expectation of future. Symbolic (real) and cognitive (p-adic) representations are very probably continually transformed to each other. If this view is correct, then the simultaneous occurrence of the sensory and cognitive memories implies dejavu experience. The event giving rise to the sensory and cognitive memories might have occurred only few seconds earlier.

This view has some nontrivial implications concerning the character of conscious experience of children. Cognitive abilities are thought to appear only after the age of four or five years. If also symbolic memories are absent, small children might live in a kind of dream time, as also members

of primitive cultures, such as aboriginals, are believed to live in. Also dream consciousness could involve in an essential manner sensory memories as suggested by temporal acontinuity of dream consciousness. One could also see dreams as transformations of cognitive representations to sensory ones and such reverse to what occurs in wake-up consciousness so that surreal dream logic could basically result from p-adic non-determinism. The back projection to the sensory organs would be an essential element of the mechanism.

The absence of a temporally organized consciousness would explain why we do not possess memories from the age before four. Perhaps also the bicameral consciousness, which according to Jaynes preceded modern consciousness, was kind of dream time consciousness in which memories were direct sensory experiences, like voices experienced as voices of gods and visual hallucinations. According to Jaynes, also schizophrenics are modern bicamerals.

Some time ago I saw a TV document about some autistic persons, who have very serious cognitive defects like inability count the number of objects if it exceeds two, are capable of miraculous memory feats. One of these fascinating individuals was an artist who could draw in full detail a picture about an area of London containing thousands of buildings after having seen the area once from a helicopter. Another autistic artist, virtuoso pianist, could reproduce every piece he had heard with highly personal style. Perhaps also great musical wunderkinds like Mozart have had similar direct sensory memory for music. Also a brain damage spoiling cognitive abilities can lead to the blossoming of exceptional artistic gifts. If the neuronal metabolic starvation forces the generation of negative energy MEs in turn giving rise to long term episodal memories then one could indeed understand how brain damage could have this kind of positive consequences.

The explanation suggesting itself is that the loss of cognitive memory is compensated by sensory memory in this kind of situations. A plausible reason for why average human being has dominantly cognitive memories is simple. Sensory memory contains huge amounts of un-necessary data: symbolic and cognitive memories have much higher survival value since only the relevant data are stored. Sensory genii have very hard time in the modern society unless they work as artists!

In light of foregoing, the poor cognitive abilities of animals suggest that also animals remember predominantly sensorily and live in dream time (note however that rats have hippocampal theta). For instance, dogs might have sensory memory dominated by odours. The challenge is to invent tests for this hypothesis. One could also try to device a non-destructive method leading to a temporary loss of cognitive consciousness and making possible to spend a day as a dog.

3.4 Going To The Neuronal Level

The following attempt to develop the model of long term memory at the neuronal level is made involves many uncertainties and must be taken as an exercise in order to get accustomed with the ideas involved.

3.4.1 Which parts of the brain are the quantum entanglers?

It is known that the electrical stimulation of amygdala, hippocampus, and temporal lobes can generate lively sensory memories. The simplest explanation is that quantum entanglement with the sensory representations of the geometric past is in question. The role of the electric stimulation would be only the generation of time like entanglement, not providing any information characterizing the memory. This would mean that large portions of brain can participate to the generation of episodal memories.

The fact that the part of body must be able to generate negative energy MEs with a proper ULF time scale, poses constraints on the system involved. Cellular sub-systems and microtubules are good candidates in this respect since the transition frequencies for the transitions involving change of classical gravitational are in the required range. Since resonance mechanism is probably involved, there are good reasons to believe that similar system is is involved with both the receival and sending of the message. Microtubular structures are good candidates adn accompany both neurons and glial cells.

Energetics poses also constraints. The receivers of negative energy MEs should have an easy access to the metabolic energy resources compensating the negative energy. In fact, the receiver must be in an excited state, which decays when negative energy ME is received (dropping ions to

a larger space-time sheet could be also involved). Glial cells serve as metabolic resources of the brain and interact with neurons via Ca^{++} waves and are the first guess for the system entangling with negative energy MEs. Other parts of brain and body, even sensory organs, can get metabolic energy by entangling with astrocytes via negative energy MEs so that the desired sharing of mental images would indeed result.

The notion of memory field [J19] was derived from the study of short term memory and applies to the neurons of the frontal lobes at least. The span T of the memory field is essentially the time span of the long term memory. T correlates strongly with the fundamental frequency associated with the negative energy ME if quantum entanglement is involved, and the length of magnetic loop and curvilinear negative energy ME satisfies $L \sim cT = c/f$, where f is a frequency related to a transition in which gravitational energy of the system is question changes.

When f is expressed in terms of the size of the water blob generating gravitational negative energy ME in spin glass transition this gives $T \propto L^{-5}$, where L is the size of the water blob serving as a gravitational quantum antenna. MEs with T varying in the range 8.5 hours- 32 years in the length scale range 80 nm-10 nm are generated. One day (24 hours) would correspond to a length scale 33 nanometers: 3.3 times the thickness of the cell membrane. In case of neurons only the intracellular structures having much larger sizes and much higher gravitational binding energies might serve as entanglers (larger space-time sheets would be in question) and give rise to short term memory. The time scale of 1 minute corresponds to about .3 micrometers, millisecond corresponds to $L(167) \simeq 2.3$ micrometers, whereas $L(163)$ corresponds to a time scale of 1 second. This would suggests that sub-neuronal water blocks larger than the size of cell nucleus could generate short term memories which need not be conscious-to-us. Perhaps the flux loops of the magnetic body of the cell nucleus are involved.

For linear structures like microtubules one has $T \propto 1/L$. Even in this case a rather strong dependence on the time span of the long term memory on the system generating negative energy MEs results. The fact that microtubules are ideal for representing conscious information symbolically, suggests that neuronal/astrocytic microtubules serve as the entanglers at sending/receiving end of the quantum communication line responsible for long term memories. This picture also suggests that the magnetic flux loop of a given astrophysical length scale is associated with a microtubule of a given length.

3.4.2 Where the classical signals are generated and received?

There are several bits of information helping to guess how long term memories might be realized.

1. The damage of the hippocampus leads only to a loss of the ability to generate new declarative memories but does not lead to a loss of long term memories from the period when hippocampus was intact. Thus it seems that hippocampus plays essential role in the communication of our non-episodal declarative memories to the geometric past and that at least a dominant part of the receivers are somewhere else than in hippocampus. Since the stimulation of both amygdala, hippocampus and temporal lobes induces long term episodal memories, it would seem that all these structures can serve as quantum entanglers.

2. New neurons and glial cells are regenerated in hippocampus and the regeneration is especially intense during ischemia which can destroy a lot of neurons [J16]. This would suggest that both glial cells and neurons are essential for the realization of long term memories.

These pieces of data give some guide lines in the attempt to build a more detailed model of long term memories.

1. The generation of classical signals requires metabolic energy and this suggests that the generation occurs as near as possible to energy resources. Glial cells are known to be the providers of the metabolic energy. Synchronously firing neuron groups are accompanied by astrocytes forming gap junction connected structures. For a long time it was believed that astrocytes play only the role of passive energy storages but it has become clear that there is signalling between astrocytes and neuronal groups based on Ca_{++} waves. Astrocytes couple also strongly to sounds: for instance, it is known that very mild blow in head inducing sound waves can lead to a loss of consciousness. Perhaps the astrocyte structures associated with hippocampal

neurons generate positive energy MEs responsible for the classical communications making our non-episodal memories possible.

2. The receival of the classical signal does not require metabolic energy. If astrocytes are involved with the sending of the classical signal, then neurons would be naturally the receivers of the signal and the energy received with the signal would partially explain why synchronous firing of neuronal groups seems to require less metabolic energy than expected. Of course, quantum entanglement by negative energy MEs wither energy sources could also explain this.

3.4.3 Is memetic code used to code declarative long term memories?

Memetic code is a good candidate for the coding of declarative long term memories. The duration of single memetic codeword would be about .1 seconds and the duration of a single bit would be about 1 millisecond. This hypothesis fits nicely with the facts that many cyclotron frequencies are around 10 Hz and the frequency of neuronal synchronal firing is about kHz.

Quite recently it became clear that TGD predicts counterpart of Tesla's scalar waves as two sheeted structure defined by pairs of massless extremals having different directions of light-like four-momenta [K11, K24, K23]. These waves represent a pulse of electric field propagating with a velocity of light and an electric field in the direction of propagation. These waves corresponds in TGD to space-time sheet of finite length and duration ($L = cT$) carrying constant electric field and propagating with velocity of light to the direction of the field. This solution type is extremely general and dual to the magnetic flux tubes. Electrets are one manifestation of these structures in living matter (membrane potential is one example of this kind of structure).

One could consider the hierarchy of MEs representing geometrically a hierarchical structure of commands and that memetic code corresponds to the lowest level with bit represented by a electric pulses whose polarity determines whether "1" or "0" is in question: very much like in case of computers. Electret sequences would ultimately give atomic nuclei kicks in a direction depending on the value of the bit.

3.4.4 What about other synchronous EEG frequencies?

Genuine theta (hippocampal theta which spans both theta and alpha bands) and delta bands could correspond to more abstract levels of consciousness not directly experienced by us usually. During slow wave sleep theta and delta bands dominate and the interpretation in terms of the binding of the mental images to memory representations is highly suggestive. Hence these bands would contribute to our consciousness in the geometric future rather than in the geometric now.

1. Theta band might relate to long term memory consolidation by a construction of temporal replicas of ordinary long term memory representations generated already during the wake-up period. Sleep state is certainly ideal in this respect.

2. naïve extrapolation suggests that delta band memories correspond to a rather long temporal distance T (that is very low frequency $f = 1/T$ for gravitonic MEs). Delta band memories would be therefore generated by structures with sizes below the thickness of cell membrane. One could understand why delta band is strongest in childhood and weakens towards old age. If delta band memories correspond to very long temporal distances T, it is useless to generate these memories at the old age since there would be no brain receiving these memories. The long time span of the delta band memories would explain why childhood memories are stable and why some persons "return" to their childhood at the old age. The return to the sensory world of childhood at old age suggests that delta band memories must be sensory memories. Delta band representations might even give rise to transpersonal memories experienced during the later lives. The absence of ordinary sensory input masking delta band memories would explain why earlier life cycles can be recalled in meditative states.

3. The contribution of theta and delta band memories to our consciousness could also relate to the third person aspect of consciousness. Theta and delta waves could be associated with the magnetospheric sensory representations giving rise to multi-brained selves. The entanglement between sleeping brains inducing a loss of personal consciousness would induce a kind of collective stereo consciousness in which a large number of individual views about

world fuse together would be in question. The search for correlations between the EEGs of sleepers having a close personal relationship might be rewarding. For instance, DNA could quantum entangle and give rise to conscious memories in very long time scale at the level of species.

Note that the presence of synchronous or asynchronous EEG correlate of memory generation is present also during memory recall does not seem to be necessary since the memory is indeed in the geometric past.

3.4.5 Questions

One important question is whether positive energy EEG MEs are involved with long term memories or only with sensory representations (assuming that sensory representations are realized at the magnetic body). The idea that MEs take care of memories and EEG MEs of sensory representations is attractive idea at least.

Fascinating questions relate to cognitive representations since these involve p-adic physics. Frontal lobes are known to be the seat of planning, volition and cognition. Therefore p-adic cognitive representations, p-adic entanglement and the p-adic selves characterized by positive entanglement negentropy should be realized in the neural circuits involving frontal lobes. These circuits have been even proposed to be "conscious circuits" but this probably reflects the erratics identification of consciousness as cognitive consciousness only. Cognitive representations could be realized at magnetic cognitive canvas using beta frequencies as resonant frequencies and beta MEs would entangle with the points of the cognitive magnetic canvas p-adic mental images representing intentions and plans. The transformation of these p-adic mental images to real ones would somehow generate generalized motor actions, in particular ordinary motor actions. That frontal lobes contain motor areas conforms with this view.

3.5 Hippocampus And Long Term Memories

The findings about hippocampal system provide a good test for the general ideas about long term memory. For a review about the role of hippocampus in long term memory see [J15].

3.5.1 Anatomy of hippocampal system

The anatomy of hippocampus is discussed in [J3]: here only very rough summary is given: possible inaccuracies are due to my amateurish knowledge of brain science.

Hippocampus is located with the inferior medial wall of the temporal lobe posterior to the amygdala. Hippocampus decomposes into anterior and posterior regions. Hippocampus consists of a number of subcomponents, and adjoining structures, such as the parahippocampal gyrys, perirhinal and peritorhinal cortex and uncus. The main body of the hippocampus consists of the dentate gyrus (here brain cells are regenerated), the subiculum and the sectors referred to as CA1, CA2, CA3 and CA4. The uncus is a bulbar allocortical protrusion located in the anterior-inferior medial part of the temporal lobe.

There are three major neural pathways leading to and from the hippocampus. These include the fornix-fimbrial fiber system, and a supracallosal pathway which passes through the cingulate, and via the entorhinal area: this is the mesocortical gateway to the hippocampus. Through the fornix-fimbrial pathways hippocampus makes major interconnections with the thalamus, septal nuclei, medial hypothalamus, and exerts either inhibitory or excitatory influences on these nuclei.

The entorhinal cortex acts to relay information to and from the hippocampus. The hippocampus maintains via the entorhinal cortex interconnections with the neocortical multi-modal associations areas of the temporal, frontal, and parietal lobes, including surrounding structures, e.g., the parahippocampal gyrus, and allocortical tissues, the perirhinal cortex, septal nuclei and amygdala. The parahippocampal gyrus, entorhinal and perirhinal cortex, being directly interconnected with the hippocampus and the neocortex, act to relay input from the neocortical association areas to this structure.

The entorhinal cortex consists of 7 to 8 layers rather than only 6 layers. The entorhinal cortex maintains massive interconnections with all multi-modal neocortical association areas (as well as with the amygdala, hippocampus, septal nuclei, olfactory bulb, etc.) but none of the primary

sensory areas which presumably relates to the fact that hippocampus is responsible for declarative rather than sensory memories.

3.5.2 Memory deficits and hippocampus

Memory deficits provide important information about the role of hippocampus with respect to the memory. In anterograde amnesia the ability to generate new long term declarative memories is lost and it is known that a damage to the hippocampus can cause this defect. Thus it seems that hippocampus is crucially involved with the construction of long term memories. Also the damage to the medial temporal lobes and subcortical structures such as medial thalamus and mammillary bodies can destroy the ability to generate long term memories. This supports the view that hippocampus is kind of a central entangler binding together mental images from various parts of brain: most naturally entanglement occurs along the three neuronal pathways going through hippocampus and presumably associated with torus-like magnetic flux tubes.

In retrograde amnesia memories about some period of time in past are lost. It seems that this deficit does not correlate with the damage of hippocampus. Thus the cautious conclusion is that long term memory recall occurs also elsewhere in brain. The selectivity of the retrograde amnesia suggests that the notion of the memory field applying in the case of short term memory [J19] generalizes. The brain structures responsible for the receival of long term memories are specialized in the sense that they entangle with the mental images of the geometric past located only in an interval around certain temporal distance T. If the memories involve only few reflections along a closed magnetic flux loop, the corresponding MEs have fundamental frequency $f = 1/T$ and correspond to spin glass transition for microtubules or for 3-dimensional sub-neuronal structures at a length scale between cell size and cell membrane thickness if the simplest estimate makes sense. This kind of resonant selectivity might be possible to achieve if the receiving system is driven to the bottom of the spin glass landscape with a depth which corresponds to the gravitonic energy $E = 2\pi f$ If memories involves large number of reflections, it is difficult to imagine, how this kind of selectivity could be achieved.

3.5.3 Hippocampus and declarative memory

It is known that there are several memory types and hippocampus is responsible for the construction of only declarative memories, which are verbal and highly symbolic representations of the geometrical aspects external world. Hippocampus is not essential for the recognition of familiar objects nor for procedural/motor memories which are implicit memories. The natural identification of declarative memories is as memories communicated classically using some coding but one cannot exclude sharing of mental images. Memetic code or its scaled up/scaled down is a good candidate in this respect. The modulation of hippocampal theta might provide the coding.

Sensory memories can be induced by the electric stimulation of both hippocampus, amygdala and temporal lobes. This suggests that lower levels of self hierarchy which we do not experience directly can have sensory memories. The entanglement by negative energy ME with the geometric past giving rise to an episodal memory is the most natural interpretation for the effect. Neural loops are the geometric correlates for entanglement at the level of CNS, and time-like quantum entanglement of parts of the electrically stimulated structures with primary sensory areas with the mediation of these loops should be involved. If the stimulation is too strong, hallucinations result. In this case the sensory representations in the brain geometrically now are presumably activated and back projection to the sensory organs would occur. An interesting possibility is that the strength of stimulation correlates with the temporal distance of the sensory representation in the geometric past activated in the stimulation.

3.5.4 Hippocampus provides spatial and temporal context

The right hippocampus of the taxi drivers in London is enlargened. This supports the view that hippocampus provides kind of a symbolic map of the spatial layout of the environment. Studies in animals suggest that hippocampus adds a spatial context to the mental images from cortex entangled with mental images in subhippocampal structures entangled with the mental images in hippocampus. The spatial map is based on various spatial cues serving as landmarks. Left hippocampus is in turn involved with the verbal memories and this suggests that it is responsible

for providing a temporal context and time ordering of events. This suggests that hippocampus is responsible for the temporal and spatial organization of conscious experience besides generating memory representations. Perhaps a high level sensory representations at the magnetic body is in question.

Hippocampus is known to contain place cells providing cognitive representations for the objects of perceptive field. These place cells are pyramidal cells containing magnetic crystals which suggests that they act as projectors to the magnetic memory canvas. All kinds of features could be associated with these landmarks, and more generally, with the symbolic objects of the memory field.

Long term potentiation (LTP) does not occur in hippocampus but hippocampus is highly dynamical with synaptic contacts being generated all the time and even the size of hippocampus continually changing. It would seem that hippocampus provides by its own dynamical structure a context for various data coming from cortex, kind of a geometro-symbolic model for the external world. The mental image associated with this model of external world quantum entangles with the mental images in cortex, amygdala, hypothalamus, etc...

Not only spatial but also temporal context is important and hippocampus should provide also this. Purely sensory memories do not carry any information about whether memory is in question or not. For symbolic representations the situation is different. Symbolic representations would be realized as association sequences, perhaps in the time scale of hippocampal theta such that each 3-surface of association sequence contains lower level association sequences contains.... Memetic code words of duration .1 seconds would be at the lowest level and perhaps correspond to mesoscopic features of Freeman [E1].

The intronic portion of DNA could provide the fundamental hardwave representation of memes in terms of sequences of 21 DNA triplets: spoken language would be only a tip of an iceberg if this picture is correct [K14]. Positive energy em and MEs could realize these memes in the shape of vacuum current, which at given moment of time is non-deterministic and therefore optimal in this respect. Memetic code realized in terms of magnetization direction for quark sub-CDs is a further candidate for realizing the symbolic representations. This highest level representation adding context to the other data located in the geometric past would entangle via MEs with the brain of the geometric now in case of episodal memories. The fact that hippocampus is thought to be involved with the transfer of items in short term memory to long term memory in cortex conforms with the mirror mechanism.

Entorhinal cortex serves as some kind of a relay station between hippocampus and neocortex. Entorhinal cortex has very special structure being 7-to-8 layered rather than 6-layered. Entorhinal cortex maintains rich connections to various multimodal regions in temporal, parietal and frontal cortices but not to the primary sensory areas. This is consistent with the idea about three-leveled hierarchy *multimodal areas*$\rightarrow$ *entorhinal* $\rightarrow$ *cortex-hippocampus*, with the fact that the mental images associated with hippocampal memory representations are symbolic rather than sensory, and with the assumption that multimodal areas, entorhinal cortex, and hippocampus entangle.

Hippocampal theta corresponds to EEG frequency range varying from about 4 Hz to 12-14 Hz and thus spans both theta and alpha bands. Hippocampal theta can be seen as a correlate for the binding of various cortical and subcortical mental images to a single mental image representing both that aspect of consciousness which makes possible organized view about space and time and declarative memory. MEs at hippocampal theta frequencies could project to the magnetic memory canvas providing an abstract representation about world analogous to sensory representation but without sensory qualia. It must be emphasized that the memory representation should provide an essential part of our everyday consciousness making possible space and time categories of everyday conscious experience. Novel and painful stimuli indeed induce hippocampal theta as well as orienting reactions, learning, selection and discrimination.

3.5.5 Remote emotions and associations?

Amygdala seems to be responsible for the formation of emotional aspects of the memories in accordance with entanglement paradigm. Amygdala is known to be sensitive to emotional contextual cues which can trigger perceptive experiences similar to previous ones. Associative memories seem to be in question.

Whether the associative memory is in the geometric now or past is not obvious and time-like quantum entanglement might perhaps allow to induce remote associations in the geometric past.

If the cue is entangled with the cue in the geometric past, the activation of this cue by quantum entanglement could activate neural process generating the memory in the geometric past. This kind of mechanism would provide a general mechanism of active memory retrieval. The active scanning of memory neurons with memory fields characterized by different values of T would be a second mechanism of this kind. In fact, there need not be any sharp difference between ordinary associations and associations in past.

3.5.6 Memory consolidation and long term potentiation

The notions of memory consolidation and long term potentiation relate to the more standard views about long term memory and it is interesting to try to interpret them in TGD framework. Memory consolidation means the strengthening of memories by "replaying" them. Certainly a repettiion of mental image provides a manner to learn and establishing a long term memory also in TGD. The mere generation of gravitational MEs associated with a given mental image means consolidation: no modification of the existing neural connectivity is needed. Of course, standardized mental images are probably generated but this is not construction of memories in the strict sense of the word.

Memory consolidation involves hippocampal theta. In TGD framework hippocampal theta is a correlate for that part of consciousness which gives rise to an organized view about space and time: not necessarily in the geometric now however. Mirror mechanism implies that this process defines automatically memory representations about the state of brain so that memory consolidation is an automatic side effect.

It has been proposed that during REM sleep hippocampus is "replaying" the memories unconsciously [J21]. The fact that there is no sensory input at night time would suggest that sleeping brain is like an empty magnetic tape freely usable for the memory construction. Theta and delta bands could relate to the memory representations replayed during sleep period but could be also responsible for the construction of higher level sensory representations important for non-episodal memories.

There are however objection against the idea that REM sleep is specialized with the replaying. First, hippocampal theta, believed to be crucial for the formation of long term declarative memories, is not synchronous during REM sleep. Secondly, during dreams only the posterior portion of the hippocampus is active whereas during learning the active part is the anterior portion of the hippocampus.

TGD based vision suggests a first principle explanation for the activity of hippocampus during sleep and dreams. Both classical communications to the geometric future and the receival of negative energy MEs from the geometric future require metabolic energy feed. Since the metabolism related to the motor activity and sensory preception is absent during sleep, the optimal realization of the long term memories is based on the entanglement with the sleeping brain of the geometric past. This would also explain why we do not have conscious experiences about memory recalls from the geometric future. Sleeping brain can also help the situation by performing memory recalls itself. REM sleep would not be in any special role except that it could make possible episodal sensory memories.

The memories about dream experience fade out rapidly after wake-up. This suggests that the lengths of the magnetic flux tubes along which classical communications occur during dreams, are short and therefore also the time span of the resulting declarative memories is brief. This as it should be since otherwise dreams would make possible pseudo memories. We could be conscious during dreams but would not remember it since long term memories would not be generated during this period. Alternatively, dream memory representations could be generated by the larger self to which we are fused during sleep. The above mentioned findings about the hippocampal activity during dreams could mean that magnetic flux loops of declarative memory get longer in posterior-anterior direction: this would mean a concrete identification for the neurophysiological correlates of the declarative memory fields. Also the dominating frequency of EEG/ZEG would become lower in this direction.

The basic question relates to the interpretation of the hippocampal theta. There are two options.

1. Hippocampal theta is associated with the MEs responsible for the classical communications to the geometric future making possible long term memories.

2. MEs take care of the classical communications to the geometric future (memetic code) whereas hippocampal theta contributes to the conscious experience of the geometric now by generating high level sensory representations at the personal magnetic body.

For the latter option hippocampal theta could be also involved with the generation of entanglement between various parts of brain crucial for the construction of long term memories making possible an organized view about space and time. This assumption conforms with the idea that EEG rhythms are responsible for the synchrony and entanglement. This would not happen during REM sleep since hippocampal theta is asynchronous during dreaming and during cortical synchrony (not much sensory input). Visual dream consciousness is indeed sensory consciousness without an organized view about space and time categories. This applies also to the non-REM verbal dreams. Furthermore, the de-synchronization of both hippocampal and cortical EEGs implies a confused state of mind. This would suggest that hippocampus indeed contributes also to our consciousness in the geometric now, and makes possible the organized view about space and time by constructing higher level sensory representations.

Long term potentiation (LTP) has been suggested as a mechanism by which hippocampus generates long term memories by strengthening the synaptic communications between neurons. In TGD framework this interpretation does not make sense: rather LTP can be seen as a special case of associative learning which is just gradual modification of the brain structure as a response to the conscious experience. Of course, LTP modifies gradually memory representations but these memory representations do not contain information about past.

As noticed, LTP does not occur in hippocampus itself. Instead, hippocampus grows rapidly in neuron number and synaptic connections during long term memory generation. This conforms with the view that hippocampus is more or less a real time dynamical representation for what might be called changing context. In particular, new neurons generated in hippocampus could be essential in representing the context and could generate gravitonic MEs crucial for the entanglement.

3.5.7 Relationship between cortical and hippocampal EEGs

Cortical de-synchronization accompanies hippocampal synchronization and vice versa. The simultaneous de-synchronization of cortical and hippocampal EEGs involves distractability and hyperresponsiveness so that person becomes owerwhelmed, confused, and may orient to and approach several stimuli.

These findings can be understood in TGD framework.

1. During cortical asynchrony there are good reasons to build long term memories so that hippocampus should be in synchronized state and bind various mental images to long term memories.

2. During cortical synchrony there is nothing to represent as long term memories and hippocampus can do something else. Perhaps participate in imagination and day dreaming as suggested by the fact that also during REM sleep hippocampal theta is asynchronous.

3. When both cortical and hippocampal theta are de-synchorized, not only the long term memory representations fail to be generated but also the construction of spatial and temporal context and this leads to confusion and difficulties with orientation to various stimuli.

3.6 Microtubuli And Long Term Memory

When I began consciousness theorizing whole-daily around about 1994, I became deeply fascinated about microtubuli (as probably most others in the field of quantum consciousness). I launched off by developing a rudimentary model about how microtubuli could act as quantum antennae in the TGD universe: massless extremals were the key element of the model. Needless to say, too much of the general theory of consciousness and of biosystems as macroscopic quantum systems needed for a deeper understanding was unconscious-to-me at that time.

After the rapid self-organization of the theory during this year and still continuing (I am living last days of August 2002 while writing this), it occurred to me that it might be a good idea to take a fresh look on the role of the microtubuli. While re-reading the wonderfully inspiring article

of Nanopoulos dating back to 1995 [J8], I realized that the TGD based view about macrotemporal quantum coherence, the mirror mechanism of long term memory, and the quite recent discovery of cognitive codes and their physical realization, provide the tools for developing a view about the role of microtubuli in long term memory.

What made me somewhat skeptic about the importance of the microtubuli for *our* consciousness was the naïve view that the size L of the system system generating the memory increases when the geometrotemporal distance T of the long term memory increases. Microtubuli would be conscious but from our point of view this would represent something analogous to bit level in computers.

The understanding of how the macrotemporal quantum coherence is generated however challenged this view. TGD Universe is quantum spin glass and spin glass degeneracy is broken only by the classical gravitational binding energy. Quantum transitions between almost degenerate quantum spin glass states correspond to frequencies defined by the differences of the classical gravitational binding energy and generate gravitational MEs responsible for the quantum mirror mechanism. Gravitational binding energy increases with the system's size and this means an effective inversion of the length scale hierarchy, so that systems like microtubuli can contribute to our conscious experience much more significantly than some subsub....sub-self level at the bottom of the self hierarchy might be expected to do.

3.6.1 Basic findings about the correlation between long term memory and microtubuli

A basic difference between ordinary cell and neuron is that the microtubuli associated with the T shaped centriole in case of the ordinary cell, are in neuron replaced by long microtubule bundles starting in a region near nucleus and connecting it to dendrites and axonal ends. The natural guess is that at least these microtubuli are closely involved with the brain consciousness.

What happens in microtubuli is indeed very intimately related to what happens in synapses. The minimal modification of the standard neuroscience belief system is that microtubuli control how synapses, still assumed to be responsible for the memory representations, are modified during learning identified as generation of long term memories. In [J8] a lot of basic facts about microtubuli plus the evidence for the correlation between microtubuli and long term memory is discussed and references can be found in this article. Here I just summarize the basic points of the discussion of [J8].

1. The production of tubulin and MT activities correlate with peak learning, memory and experience in baby chick brains. Experiments with baby rats show that when they first open they eyes, neurons in their visual cortex begin producing vast quantities of tubulin.

2. The experiments with trained goldfishes show that the drug colchicine produces retrograde amnesia. The interference with MTs responsible for the structural modification of certain synapses is believed to affect memory fixation. In TGD framework one must carefully distinguish between learning and memory: microtubuli could provide both the long term memory representations and also control learning by controlling synaptic strengths.

3. The selective dysfunction of animal brain MTs by the drug colchicine causes defects in learning and memory which mimic the symptons of Alzheimer's disease (AD). It has been reported that in rats a continuous MT disruption induced by a chronic colchicine administration results in a dose-dependent learning deficit, and memory retention is also impaired. It has also been stressed that these colchicine-induced cognitive defects resemble those of AD, e.g., amnesia of the recent learning and loss of formerly established memories. These findings encourage to think that microtubuli are involved both with the generation of the memory representations and long term memory recall by mirror mechanism in accordance with the idea that microtubuli act as both receiving and sending quantum antennae in the sense that they generate MEs making possible time-like quantum entanglement. MEs generate coherent photons or gravitons according to the original definition of quantum antenna [K21]. Certainly, the antenna which sends is also optimal for receiving.

4. It has been suggested and also supported by detailed experimental studies that the impairment of MTs, leading to tangled and dysfunctional neural cytoskeleton, may be one explanation for the pathogenesis of AD.

5. In specific hippocampal regions of the brain of schizophrenic patients, distorted neuronal architecture has been found due to a lack of 2 MAPs. This suggests that the splitting of consciousness characterizing schizophrenia has a geometric correlate already at the microtubular level: macroscopic bound state entanglement responsible for the binding to long-lived holistic microtubular mental images and the generation of memory representations would not occur as they should.

3.6.2 How microtubuli could relate to declarative long term memories?

For several reasons microtubuli are tailor-made for the realization of long term declarative memories in TGD Universe (the structure of microtubuli is discussed in some detail in [K20], where the realization of cognitive codes is discussed). Microtubuli are however not the only candidates: also 2-D membrane like structures and genuinely 3-D structures could be involved and correspond to different types of long term memories.

1. Microtubuli can entangle with each other and with the surrounding world in conformational degrees of freedom to yield macrotemporal quantum coherence. Microtubule associated proteins (MAPs) can mediate naturally bound state entanglement between conformational patterns of different microtubuli. This makes possible macrotemporal quantum coherence and processes resembling quantum computation when bound states are formed. MAPs can act as switches initiating quantum computation and halting it. The simplest possibility is that MAP protein becomes just disconnected at some levels of the hierarchy of space-time sheets.

2. Tubulin dimers allow two different conformations and the patterns of tubulin conformations are ideal for binary representations of data natural for the representation of long term declarative memories. In [K20] a cognitive code explaining the numbers associated with microtubular geometry is discussed and a model for how the conformational patterns are coded into conscious experience in the phase transition in which spontaneous electric polarization occurs and forces all tubulin dimers to the ground state conformation. That microtubuli allow the realization of the symbolic counterparts of cognitive representations realized using cognitive neutrinos and possibly also by p-adic MEs, conforms with the fact that colchicine which affects MTs, induces cognitive defects characteristic of Alzheimer's disease. The linearity of microtubuli would be obviously essential and at least parts of the sensory pathways could be responsible for the representations of these memories.

3. In the standard view about long term memories one cannot identify microtubuli as seats of long term memory representations. The reason is simply that microtubule conformations are quite too short-lived for this purpose. This leaves only the identification of the synaptic strengths as a representation of long term memories. In TGD the situation is just the reverse and flexibility requires fast enough dynamics. The time scale defining sensory resolution is obviously a bottle neck time scale. The time scale for the phase transition leading to ground state of tubulin dimer in an external electric field and the time scale related to the control of the external electric field at the microtubular space-time sheet are the most obvious guesses. The first time scale should be of order of the time scale of conformational dynamics, about nanosecond. The latter time scale would be basically the duration of nerve pulse if nerve pulses are responsible for the phase transition in question. In TGD framework the modification of synaptic strengths can be more naturally seen as representing generation of new "habit routines" rather than memory representations which are much more involved and information rich.

4. Microtubuli are ideal for quantum mirror mechanism of long term memories. As already found, in case of spherical structures the dependence of gravitational binding energy on size of the structure is $E_{gr} \propto L^5$, whereas the gravitational binding energy depends on the length L of a linear structure as $E_{gr} \propto L$. For membrane like structures $E_{gr} \propto L^3$. Since microtubule lengths vary in the range 10 nm- 1 mm, this means that the temporal distance $T \propto 1/L$ of long term memory varies between 32 years 2.8 hours (very roughly; increase of the overall time scale due to the fact that increment of the gravitational binding energy in the transition is smaller than the gravitational binding energy itself). Inside axons microtubuli can bind to

longer structures by MAPs and even meter sized structures associated with sensory pathways are possible. This lowers the lower bound for the time span to 10 seconds. The longest microtubuli are responsible for the representation of the shortest term memories realizable in this manner. Of course, memory circuits should regenerate again and again microtubular memory representation and in this sense synaptic strengths become an essential part of the memory representation.

5. Colchicine affects both memory recall and memory generation. This inspires the working hypothesis that microtubuli of a given length $L \propto 1/T$ in the geometric past entangle with a microtubule of same length in the geometric now during memory recall. For instance, the receiver in the geometric now could correspond to a postsynaptic microtubule whereas the sender in the geometric past corresponds to a presynaptic tubule. This is not the only alternative, receiving cells could be even glial cells.

6. That the memories of childhood are the most stable ones could be interpreted as reflecting the fact the microtubuli act both as receiving and sending quantum antennae, and that the long microtubuli responsible for generating the short term memory representations and for receiving them deteriorate towards the old age with much higher probability than the shorter ones. It could be possible to induce selective amnesia restricted to memories with a temporal distance $\sim T$ by a treatment which affects microtubuli of given length $\sim L \propto 1/T$.

7. Microtubuli could be also ideal for the communication of non-episodal memories involving classical communication by ultra slow MEs perhaps accompanied by Ca^{++} waves known to have an extremely wide velocity spectrum. Ca^{++} ions are associated with the outer surface of the microtubuli and dynamically comparable to a crop field in a wind. Ultra-slow orientational waves for these Ca^{++} ions representing sensory inputs and propagating along axons could make possible a classical communication of data from the geometric past as declarative memories. For sensory pathways the sequences of microtubuli could have a total length of order one meter. For the average length $L_0 = 10\ \mu m$ of the microtubule in brain, the time span $T_0 = 10$ seconds would give $v_0 \sim 1\mu m/s$, a typical velocity of in cellular level. In this case 10 nm length of microtubule would correspond to 10^{-2} seconds of time. This would mean that roughly 13 parallel sequences of 13 bits of information about 10 millisecond period. The bit rate of one bit per millisecond corresponds to the information storage capacity of the memetic code. For longer time intervals T and microtubule lengths L the bit rate would scale like $(L/L_0) \times (T_0/T) = v/v_0$. For $T = 1$ year and $L = L_0$ one would have roughly one bit per hour. It seems that this mechanism can be at work only for short term memories whereas long term memories would involve closed magnetic loops.

3.6.3 Relation to the general model of long term memories

It is interesting to relate the proposed model with the general model of long term memories.

1. Long term memory is lost when tubulins return to ground state unless there is some mechanism regenerating the conformational state. In brain the function of neuronal loops generating the nerve pulse patterns repeatedly would take care of regenerating the memory representation. If this view is correct, then also memories of childhood involve this kind of continual regeneration. Sensory pathways do give rise to long term memories unless the feedback from brain to primary sensory organs (oto-acoustic sounds and the movement of eyes during REM sleep) regenerates these memory representations. During dream long term memories correspond to small value of T: does this allow to conclude that the feedback to the primary sensory organs during dreams results in long term memories with T about few minutes? The maximization of the lengths of the sensory pathways (left side of the body is connected to right brain hemisphere and vice versa) would relate to the maximization of the representational capacity if this mechanism is at work. The most natural assumption is that sensory representations are regenerated for time interval of order T so that the maximal values of T and stablest memories correspond to relatively short microtubuli in the interior of neuron.

2. Hippocampus is believed to be crucial for the generation of long term declarative memories and responsible for spatio-temporal organization of perceptive field. Hippocampus could act as a kind of entanglement center entangling with "features" at various brain areas and project them to the sensory magnetic canvas (the episodal component representing spatial relationships might accompany also non-episodal memories!). Feature sub-selves would have microtubular selves as sub-selves: this would mean entanglement between hippocampal and other microtubular memory representations. The microtubuli acting as central entanglers in hippocampus should be relatively short, with lengths not much longer than the length determined by the lower bound for temporal distance T for long term memories. The maximal length L of hippocampal axons should correspond to this T and $L \sim 10^{-2}$ meters from the size of the hippocampus might be a reasonable guess giving a time scale of about 15 minutes (these estimates are just orders of magnitude).

3. The recall of long term memories could basically correspond to a transition of a neuronal microtubule to a higher energy state by an emission of negative energy ME. The process would be preceded by the emission of a p-adic ME representing the intention to remember and transformed to a real negative energy MEs in the jump to a higher energy state. The neuronal/astrocytic microtubules of the right brain hemisphere could be specialized to send/receive negative energy MEs, whereas the astrocytic/neuronal microtubules of the left hemisphere would be specialized to send/receive positive energy MEs. Of course, this is just a naïve guess inspired by the right/left–holistic/reductionistic dichotomy. What is however clear that microtubuli with abnormally small metabolic energy feed would be responsible for generating long term memory recalls and those with abnormally large energy feed responsible for generating long term memories.

4. Tubulin dimers correspond to the Mersenne prime $p = M_k = 2^k - 1$, $k = 13$, and the n-ary 13-adic time scale nearest to p-adic prime nearest to .1 second time scale of the memetic code word is $T(20, 13) \simeq .8$ seconds whereas single bit lasts for $T(20, 13)/13 \simeq 61$ milliseconds. .8 seconds is rather natural time scale from the point of view of human consciousness. Corresponding frequencies are 1.25 Hz in delta band, and 16.25 Hz in the lower end of the beta band which conforms with the fact that cognition correlates with the beta band activity of EEG. That delta frequency alone does not give rise to conscious experience would be due to the fact that no phase transition giving rise to a conscious experience occurs if all tubulins possess same ground state conformation. The facts that delta band weakens during aging and also memory generation mechanisms deteriorate towards the old age, conform with the idea that this band is responsible for the generation of memory codewords. If this view is correct, hippocampal theta should be responsible for the binding of mental images rather than coding of our long term memories. Of course, also a lower level representations in time scale of hippocampal theta could be in question.

5. At this stage it is not possible to answer the question whether microtubuli correspond to sub-selves or subsub....selves. If the entangled microtubuli correspond to our sub-selves, the microtubuli belonging to different neurons should be able to entangle with each other. This requires the presence of flux tube contacts between pre- and postsynaptic microtubuli. MEs with lengths of neuron length scale could serve as this kind of contacts and generate time like entanglement between the microtubuli of neurons along the neural pathway.

3.6.4 What about effectively 2-D and 3-D memory representations?

Microtubuli need not be solely responsible for our long term memory representations. The fact that microtubuli seem to correlate with cognition and declarative memories which involve typically representations linear with respect to time suggests that the effective dimension D of the structure involved determines the character of the long term memory and also that of sensory experience. Moreover, it is quite possible that a large number of entangled neurons results in a kind of "stereo consciousness" fusing a large number of slightly different views about the same sensory input. This would mean large number of entangling Grandmother neurons.

1. Cell membranes consist of a large number of parallel rather than serially ordered units. Hence cell membranes could be responsible for the storage of sensory memories, which are 2-

dimensional at the basic level, say visual images. The neuron size of 10^{-4} meters corresponds to the lower bound of about millisecond for $T \propto L^3$.

2. Three-dimensional blobs of biomatter in length scale range 1 micron-10 nanometers span the range 1 millisecond-32 years for temporal distance T. This allows to consider the possibility that 3-D structures could be also responsible for long term memory representations. If one takes seriously the dimensional rule, 3-D structures should give to genuinely three-dimensional sensory memories and make 3-D spatial imagination and sensory experience possible. It is not obvious whether neurons contain any 3-D lattice like structures besides liquid crystal blobs of ordered water. Effectively 3-D structures could also result as composites of 2-D structures.

4 Hyper-Finite Factors Of Type Ii_1, Dark Matter Hierarchy, And Long Term Memories

This section is devoted to the progress that has occurred during since 2004 and represents new material which has not yet been fully integrated with the older material. The realization that the von Neumann algebra known as a hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition. One of the most important outcomes is a prediction of a hierarchy of quantum phases with arbitrarily large values of quantized Planck constant identified as dark matter and assumed to be the quintessence of living matter.

4.1 Hierarchies Of Algebraic Extensions Of Rationals, Quantum Criticalities, Planck Constants, Dark Matter, And Of Hyperfinite Factors

Quite recently (2004-2005) the hierarchy of Planck constants labelling hierarchy of dark matters was understood as labelling a hierarchy of quantum criticalities giving a precise content for the vision that TGD Universe is quantum critical and direct connection with super-symplectic symmetries of TGD emerges.

This hierarchy accompanies an even deeper hierarchy of algebraic extensions of rational numbers allowing to realized number theoretical universality by fusing reals and various p-adic number fields to anadelic structure inducing adelic counterparts at the level of space-time, embedding space, and WCW. This approach allows to identify preferred p-adic primes as ramified primes of algebraic extension.

In strong form of holography p-adic continuations of 2-surfaces to preferred extremals 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 [K20]. 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 these primes correspond to p-adic lengths scale hypothesis or its generalization to small primes, is an open question.

The hierarchy of algebraic extensions realized abstractly at the level of WCW in terms of parameters characterizing space-time surfaces so that one avoids problems with symmetries. In the adelic approach cognition having p-adic space-time surfaces as its correlates is a basic aspect of existence in all length scales in this vision. Strong holography allows to reduced the intersection of realities and p-adicities to string world sheets and partonic 2-surfaces.

The fractal hierarchy of sub-algebras of super-symplectic algebra isomorphic to algebra itself realizes the quantum critical hierarchy. These algebras have conformal structure and for sub-algebra the conformal weights are n-ples of those for the entire algebra.

The Clifford algebra spanned by gamma matrices of WCW defines standard example about a von Neumann algebra known as hyper-finite factor of type II_1. Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of the WCW ("world of classical

worlds"). The hierarchies of inclusion sequences for sub-algebras of super-symplectic algebra labelled by $n_i = m_i \times n_{i-1}$ define excellent candidates for hierarchies of inclusions of hyper-finite factors. The measurement resolution increases along this sequence since at each phase transition $n_i \to n_{i+1}$ gauge degrees of freedom are transformed to physical ones. This hierarchy also relates naturally to evolutionary hierarchy. According to the arguments of [K31] the value of n relates closely to the dimension of algebraic extension of rationals and ramified primes are factors of n: this however only by physical argument. Number theoretically the dimension of extension and ramified primes are independent.

4.2 Dark Matter Hierarchy

The identification of dark matter as phases having large value of Planck constant [K30, K32, K9] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [K32]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

4.2.1 Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of [J9] [K10]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K16, K10]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K10].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations.

1. The argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of h_{eff} at all.

2. The failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy.

3. The phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

4. The recent view about quantum criticality allows to identify the space-time counterpart for $h_{eff} = n \times h$ as space-time surface, which is singular n-sheeted covering with the branches of the covering fusing to single 3-surface at the boundaries of CD. The very essence of quantum criticality is that n distinct space-time sheets collapse to single space-time sheet at the ends of CD. This identification replaces the earlier proposal that singular n-sheeted coverings of embedding space are in question. This view serves however still as a convenient auxiliary tool. The non-determinism associated with n-sheeted covering corresponds to the four-dimensional spin glass degeneracy.

4.2.2 Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1. The characteristic

property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [K12].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [K32]. In particular, the notions space-time as a hyper-quaternionic four-surface of embedding space emerges.

2. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. In particular, experimentally favored values of h_{eff} in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2, C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. I have proposed that the most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2, C) \times SU(2)$.

3. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimic these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

4.2.3 Dark matter hierarchy and the notion of self

The introduction of dark matter matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed. The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [K9, K10].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. The hierarchy comes as $h_{eff} = n \times h$, n integer. There are indications for important sub-hierarchies such as hierarchies, for which n is power of prime. In particular, for the hierarch for which one has $n = m^r$, $m = 2^k$. The first guess about Planck constants was $m = 2^{11}$, which corresponds roughly to the ratio of proton and electron masses. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto 2^{kn}$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels.

The averaging of mental images over quantum jumps would occur only for the mental images sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

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

4.3 The Time Span Of Long Term Memories As Signature For The Level Of Dark Matter Hierarchy

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

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution [K10]. EEG frequencies correspond at this level dark Josephson photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question. The level in the would determine also the time span of long term memories as discussed in [K10].

The emergence of these levels must have meant evolutionary leaps since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K16, K10]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

4.4 Remote Metabolism, Long Term Memory, And Zero Energy Ontology

The notion of negative energy signals and time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) emerged before zero energy ontology. Since the mechanisms of remote metabolism, of memory, and of intentional action rely on time mirror mechanism, one should check that this mechanism is indeed consistent with

zero energy ontology. Zero energy ontology could also yield new insights to these mechanisms.

4.4.1 Zero energy ontology

Zero energy ontology states that physical states have vanishing net conserved quantum numbers and states decompose to positive and negative energy state and that the latter one can be said to be located in the geometric future with of the positive energy state at the time-like boundary of the space-time sheet representing the system. It is possible to speak about energy of the system if one identifies it as the average positive energy for the positive energy part of the system.

The matrix ("M-matrix") representing time-like entanglement coefficients between positive and negative energy states unifies the notions of S-matrix and density matrix since it can be regarded as a complex square root of density matrix expressible as a product of real squared of density matrix and unitary S-matrix. The system can be also in thermal equilibrium so that thermodynamics becomes a genuine part of quantum theory and thermodynamical ensembles cease to be practical fictions of the theorist. In this case M-matrix represents a superposition of zero energy states for which positive energy state has thermal density matrix. As a matter fact, M-matrices for an orthonormal basis and it is now possible to construct unitary U-matrix relating various M-matrices in terms of S-matrix and the basis of hermitian square roots of density matrices [K19].

1. If the positive energy parts of zero energy states appearing in the superposition have only single value of energy, the notion of remote metabolism is certainly well-defined. Even in the case that the system is thermalized, remote metabolism makes sense since average energy can be increased by remote metabolism. One can even imagine a statistical variant of the process in which the temperature increases.

2. The critical question is whether crossing symmetry prevails in the sense that the positive energy signal propagating to the geometric future is equivalent to a negative energy signal propagating to geometric past.

The recent view about quantum measurement theory in ZEO allows to formulate the notion of negative energy signal propagating to geometric past in rigorous manner. State function reductions at both boundaries of CD are possible and the sequence of repeated reductions at fixed boundary gives rise to self as a conscious entity (Zeno effect). The first reduction to the opposite boundary means the death of self and re-incarnation at opposite boundary as time reversal of the original for which geometric time is opposite to that in original situation.

4.4.2 Time mirror mechanism and metabolism

Energy conservation and geometric arrow of time poses strong conditions on the mechanism. If positive energy part of state sends negative energy signal, then negative energy part of state must send a compensating positive energy signal. Furthermore, positive (negative) energy signals propagate towards geometric future (past).

1. If only single space-time sheet is involved, either negative energy signal S_-: $X^4_- \to Y^4_-$ or positive energy signal S_+: $X^4_+ \to Y^4_-$ is possible. The energy of both states is reduced in magnitude. For instance, this process tends to reduce destroy long term memories represented as bit sequences with bit represented by population inverted laser system.

2. Second possibility is that X^4 are Y^4 are disjoint and X^4 is in the geometric future of Y^4.

   The first possibility is S_+: $X^4_+ \to Y^4_-$ and negative energy signal S_-: $X^4_- \to Y^4_-$: the energy of both X^4 and Y^4 is reduced in this case.

   Second possibility is S_-: $X^4_+ \to Y^4_+$ and S_+: $Y^4_- \to X^4_-$. X^4 would suck energy from Y^4 in the geometric past. This option could correspond to both remote metabolism, memory recall, and intentional action. The presence of topological light ray connecting two systems would be also a correlate for time-like quantum entanglement making possible sharing and fusion of mental images and creating a sensation about flow of time just like it creates sensation of depth in stereo vision by fusion of right and left visual fields. Depending on the sign of the energy of the signal one would have memory or precognition. Precognition would require use of metabolic energy and this might be one reason for why it is rather rare.

3. Suppose next that the zero energy space-time sheet, call it X^4, is inside larger space-time sheet, call it Y^4: $X^4 \subset Y^4$. In this case one can have S_-: $X^4_+ \to Y^4_+$ accompanied by S_+: $X^4_- \to Y^4_-$. $X^4 \subset Y^4$ would suck energy from a larger system Y^4. It is of course possible to replace signals with signals of opposite energy in opposite time direction.

   A possible interpretation is as a metabolic charging of smaller space-time sheets by sucking energy from longer scales or by active pumping of energy to shorter scales. The transformation of long wavelength photons with large Planck constant to short wavelength photons with smaller Planck constant is an analogous process and might realize metabolic charging in biology. For instance, Sun-Earth system could correspond to Y^4 and biosphere to X^4.

To sum up, zero energy ontology completes the picture in the sense that it also provides a process making possible metabolic charging.

4.4.3 Thermodynamical considerations

It is not at all obvious whether the proposed picture is consistent with the standard thermodynamics. The transfer of energy from long to shorter length scales making possible to gain metabolic energy and realize the mechanism of long term memory indeed seems a genuinely new element. This process resembles dissipation in the sense that energy is transferred from long to short length scales. In an approach to thermal equilibrium temperature gradients are however reduced whereas remote metabolism favors the active generation of "hot spots".

These considerations relate closely to the notions of entropy and syntropy by Italian mathematician Luigi Fantappie [J14] assigned with the two arrows of time. I learned from the work of Fantappie in SSE conference held in Röros from Antonella Vannini [J7] and Ulisse Di [J20] [J20].The discovery of Fantappie was that in living systems entropic processes seem to be accompanied by syntropic processes which seem to be finalistic. He assigned these processes to the advanced solutions of wave equations.

It would seem that entropy and syntropy do not relate directly to the notion of remote metabolism.

1. Syntropy growth would indeed be the mirror image of entropy growth associated with negative energy mirror image of positive energy dynamics. This dynamics could be seen as sequences of downwards scalings leading from long time scale to short time scale. This sequence would define time sequences proceeding in opposite directions of time for positive and negative energy parts of states. Thus entropy growth would be accompanied by syntropy growth.

2. Syntropy growth could be also seen as a consequence of generalized second law applying with respect to subjective time and growth of syntropy would be growth of entropy but manifesting itself at space-time level in reversed direction of geometric time. For instance, the spontaneous assembly of bio-molecules from their parts could be seen as a decay process in the reverse direction of geometric time controlled by phase conjugate control signals.

3. Remote metabolism as generation of "hot spots" does not seem to reduce to these notions and might represent a genuine breaking of standard thermodynamical view about the world.

One must also distinguish the notions of entropy and syntropy from the notion of number theoretic entanglement negentropy N assignable with quantum entanglement with algebraic entanglement probabilities.

1. N is defined as the maximum of the p-adic entanglement negentropy $N(p)$ as a function of the p-adic prime p and thus assigns to an entangled system a unique prime p_{max}. $N(p)$ is obtained by replacing in the definition of the Shannon entropy the argument of logarithm with its p-adic norm. N is in general positive and thus defines a genuine measure of information.

2. The non-negative negentropy defined in this manner characterizes entanglement as a carrier of information rather than the state of either of systems and has nothing to do with the ordinary (non-positive) entropy characterizing the lack of knowledge about the state of either subsystem. Negentropy Maximization Principle [K18] favors the increase of the number theoretic negentropy and thus formation of entanglement quantum systems and generation of

quantum coherence. Depending on the character of entanglement negentropic entanglement might be interpreted as a correlate for some conscious experience with positive content: say experience of understanding (time-like entanglement implying causal structure), of love (space-like entanglement), etc...

It is not obvious to me whether the remote metabolism as a way to build hot spots and diversity could be reduced to NMP or whether it should be regarded as something completely independent.

4.5 Applying Computer Analogy To The Model For Long Term Memories

The general model for long term memories does not say anything detailed about how memory recall can take place effectively. Taking seriously the idea that we made computers as our images, one can try to see whether the basic facts about memory storage and recall in the case of computers could help to guess how the memory recall is realized in TGD Universe.

The basic metaphor is 4-D brain as a kind of magnetic tape in time direction carrying memories as a text consisting of letters with fixed width (temporal duration) and decomposing into paragraphs, sections, etc... just like written text. Rhythms of generalized EEG would realize the decomposition to letters, and larger sub-units.

Computer analogy suggests also the analog of directory system allowing an easy and rapid access to a particular record in a particular file. Fractality would automatically make possible fractally scaled down variants of the system with life span scaled down to a second but details absent or not visible in the cognitive resolution available.

Web suggests a link system in temporal direction realizing temporal associations automatically and topological light rays which would be vacuum extremals in passive state could realize the link system.

4.5.1 The two kinds of memories seem to be closely related

There are two kinds of memories. The proposal is that the sharing of mental images of the geometric past gives rise to episodal memories, re-experiences. These memories would correspond to mental images identified as quantum jumps containing quantum jumps containing... for zero energy states. This hierarchy would correspond to dark matter hierarchy and hierarchy of Planck constant.

One can criticize this idea.

1. Does the quantum entangled zero energy state of the magnetic body and brain of the geometric past really give rise to the episodal memory as sharing of mental images? The sharing aspect would certainly give rise to experience of time as analog for the depth experience in stereo vision assumed to result from the sharing of left and right visual mental images. But why not interpret this kind of state as a representation for a "law of nature" telling that state pairs in the superposition of states are causally related? Isn't state function reduction reducing entanglement necessary to experience sharp sensory qualia? The answer to these questions is that it is entangled system whose qualia are in question, not either of the individual systems. In quantum context this would mean that the sum of observables giving rise to the qualia of separate systems are measured in quantum jump.

2. What it really means to have an episodal memory? For sharing of mental images by space-like entanglement of sub-selves the space-time correlate is the flux tubes connecting the space-time sheets condensed at larger disjoint space-time sheets. In the case of episodal memories it would seem that the experiencer-now and and experiencer-then must correspond to disjoint space-time sheets and containing smaller space-time sheets connected by a topological light ray. Hence also classical communications would be an essential part of the mechanism of memory and the distinction between episodal and declarative memories does not seem so sharp as thought originally.

3. The mere re-experiencing of events of the geometric past by quantum entangling with a subsystem representing sensory mental image is not very effective mechanism. A more effective

manner to remember is to represent memories symbolically as bit sequences with bits represented as population inverted state and ground state of laser (say many-sheeted laser). In this case metabolism is required to keep the representations intact.

4.5.2 Memory recall as communications between magnetic body and brain of geometric past

Memory recall would be communications between magnetic body and brain of the geometric past. Magnetic body can be visualized as a kind of onion with several layers: the larger the radius of layer the longer temporal distance T to the geometric past it corresponds. In memory recall the size of the active layer would correspond naturally to the temporal distance to the brain of the geometric past where the memory is stored. The frequencies of large Planck constant photons involved with communications would correspond to this distance ($f \sim 1/T$) and a de-coherence to photons with much shorter wavelength would take place in the process.

Neuroscience suggests that theta waves, which still have wavelength of order Earth size scale, are involved. They could result in de-coherence of waves with wavelength of order $\lambda = cT$ reducing the value of Planck constant.

The most primitive memory recall would rely on the scanning of brain of geometric past by using negative energy signal with a slowly varying carrier frequency. One can however consider MEs which are present permanently as vacuum extremals and activated to non-vacuum extremals during memory recall: this would mean a realization of a link system.

4.5.3 How could one realize links in time-like direction?

Links are certainly one of the most powerful functions of the web. Links are always present and activated when used. The obvious counterpart for the web link would be a topological light ray connecting two subsystems with a time-like separation. Topological light rays can also reduce to vacuum extremals and the activation of the link could correspond to a feeding of energy to a topological light ray deforming it to a non-vacuum extremal. This kind of links would be naturally associated with long term memories and would make it un-necessary to scan the entire geometric past in the search of a particular episodal or declarative memory.

4.5.4 Dreams and building up of copies of memories

Important memories should be stored in several copies since would increase the probability that the scanning of the geometric past allows to build ME bridge to the subsystem representing the memory mental image. Memories represented as bit sequences can be also lost in a repetitive recall since they might fail to receive metabolic energy feed.

Dreams might be a way to build this kind of copies. The copies built up in this manner can involve a considerable processing and it could even happen that for painful memories large number of less painful variants are constructed. Also the original memory could be transformed to less painful during the period of time-like entanglement. When it is important that memory remains unchanged, PS might in fact be not favorable and it is known that PS deprivation can help of keeping memory intact [J10].

There is a lot of evidence that memory processing indeed occurs during sleep (memory consolidation): in particular during paradoxical sleep (PS, REM periods with dreams) and during periods of deep slow wave sleep (SWS) preceding them. The sequential model for memories [J10] assumes that both periods are necessary. The first guess is that dreams and preceding SWS periods could build copies of both episodal and declarative memories.

The sensory experience associated with a dream possibly resulting partially by sharing of sensory mental image of geometric past (say previous day) could give rise to a symbolic representation realized as a kind of record. If also a copy of sensory mental image is created, the dream would involve virtual visual input generated by sending signals from brain to retina and other sensory organs involved (in TGD sensory organs carry fundamental sensory qualia). This back projection is present also during wake-up state and essential part of building sensory representation from the raw sensory data. The fact that dreams are by no means direct copies of the sensory inputs of the geometric past suggests that an active buildup of sensory mental images indeed takes place. One could however stretch the limits of imagination and argue that the dreams could be composed of

sequences of shared mental images from different times: this would conform with the short time range of "dream logic".

If the brain can be regarded as a kind of magnetic tape in the temporal direction, SWS period might be interpreted as a kind of empty interval in the tape telling that a memory record comes next (kind of silence before concert). Second function of SWS pattern would be to divide the time axis to frames analogous to letters appearing as units in computer memory. The SWS interval might also contain a temporal pattern defining among other things what might be regarded as a name of the record in question. The temporal pattern of the negative energy signal used in memory recall should have such a pattern that it would "resonate" with this pattern. Note that vacuum extremal MEs could define "static" links to memory mental images activated during memory recall to non-vacuum extremals and one can imagine also sequences of these extremals building a sequence of links.

4.5.5 Directory system, holograms, and p-adic fractality

Directory system is necessary in order to handle computer memory effectively. Basically the directory would be a scaled down fractal variant of the geometric past with a reduction of details leaving only titles of sections and subsections, so to say. These directories would make possible an effective scanning of the brain of the geometric past by going directly to the correct directory coded roughly by the temporal distance. The fact that we can construct mentally fractally scaled down memory representations about what happened during day and even during lifetime without effort suggests that this kind of fractal representation indeed is there.

The obvious idea is that the items of directories serve as links to subdirectories so that it is possible to active link in each directory item leading to a subdirectory associated with that item.

The fact that p-adically small is large in the real sense would automatically realize small time scale representations of long temporal intervals. This would suggest that the memory storage mechanism is hologram like so that copies of memories in various time scales are present. Effective p-adic topology would indeed suggest the presence of this kind of representation with various copies appearing as p-adically scaled variants of basic pattern for given p. For this option declarative memory recall would not require a precisely targeted signal to a particular moment of geometric past whereas sensory memories would require it (note however the possibility that dreams build more or less faithful copies of sensory memories).

One could imagine a fractal coding of names of directories and subdirectories by temporal distances in various p-adic length scales. Here effective p-adic topology giving rise to a hierarchy of p-adic length scales might play key role in the coding. Also dark matter hierarchy and hierarchy of Planck constants would be involved in an essential manner and code for various scales of long term memory. The fact that favored value of Planck constants and p-adic length scales come in octaves suggests a close interaction between the two hierarchies.

The p-adic view about cognition suggests that p-adic numbers give a representation for the addresses of records and that effective p-adic topology for real space-time sheets is essential. Their space-time counterparts would be discrete intersections field bodies and p-adic space-time sheets having literally infinite size. The density of points of intersection would reduce as one moves away from biological body both in temporal and spatial direction and the fact that p-adic numbers correspond always to non-negative real numbers would conform with the fact that memories are about geometric past and the memories of nearest past are the most precise and for time scales which are fractions of second become sensory experiences which are actually very short term memories as findings of Libet demonstrate.

4.5.6 What is the role of generalized EEG rhythms from the point of view of memory?

TGD predicts entire hierarchy of EEG rhythms which are predicted to correlate with various biorhythms. One challenge is to understand the precise role of EEG rhythms, in particular theta band known to be involved with memory consolidation. Functional magnetic resonance imaging led to the discovery of so called so called spontaneous fluctuations in BOLD (blood oxygen level dependent) signal having 1/f spectrum in average sense [J12] (I am grateful for Vesa Kiviniemi

(who is also working in this field [J11]) for sending me this review article). The frequency spectrum of these fluctuations is in the range range $.1 - .001$ Hz.

This activity is regarded as spontaneous in the sense that it is not induced by stimulus, motor output, or task but is something independent and thus conflicts with the paradigm that EEG corresponds directly to the brain state dictated by the input to brain and motor output and by cognitive tasks. For this reason spontaneous BOLD fluctuations were originally interpreted as noise but it has become clear that the fluctuation patterns possess both spatial and temporal coherence and that it is possible to assign regions of spatial coherence with brain functions in various brain areas.

The variation of spontaneous BOLD fluctuations explains also the variation of responses in experimental situations involving fixed stimulus or tasks. Spontaneous BOLD fluctuations seem to superpose linearly with the effect due to stimulus or task. BOLD fluctuations seem correlate with the slow fluctuations in EEG known to modulate the power spectrum in various EEG bands. Interestingly, there are also ~ 1 Hz slow fluctuations of membrane potential, which could be related to the cyclotron frequencies of DNA nucleotides (carrying constant negative charge density).

These findings conform with the fact that TGD predicts a fractal hierarchy of EEGs corresponding to the hierarchy of values of Planck constant. A further prediction would be that scaled variants of alpha band and its harmonic should appear in BOLD fluctuations as also the counterparts of beta and theta bands whose positions cannot however predicted without further assumptions.

EEG and its generalization would allow to interpret EEG rhythms as dividing the magnetic tape in time direction to a linear lattice of separate frames which each could represent a record in turn containing further records. This would be much like a fractal variant for the decomposition of a written text to letters with an approximately constant width. SWS would define kind of empty lines between paragraphs in this text and during wake-up state similar empty lines might be present.

Of course, the strict linear lattice is an idealization. It could be perturbed by insertions just like written text by pictures. These insertions could represent sensory mental images due to sensory input. Another analogy for sensory input would be as external force inducing kicks to the harmonic oscillator changing the amplitude of oscillation and inducing phase increments.

5 A Proposal For Memory Code

In an article in the March 8 issue of the journal PLoS Computational Biology, physicists Travis Craddock and Jack Tuszynski of the University of Alberta, and anesthesiologist Stuart Hameroff of the University of Arizona propose a mechanism for encoding synaptic memory in microtubules, major components of the structural cytoskeleton within neurons. The self-explanatory title of the article is "*Cytoskeletal Signaling: Is Memory Encoded in Microtubule Lattices by CaMKII Phosphorylation?*" [J13] (see `http://tinyurl.com/7dcgjwf`).

5.1 Basic Ideas Of The Model Of Memory Code

The hexagonal cylindrical lattice of microtubule suggests the possibility of lattice consisting of bits and probably very many proposals have been made. One such idea is that bit is represented in terms of the two basic conformations of tubulin molecules called α and β. The recent proposal is that bit corresponds to the phosphorylation state of tubulin. Also a proposal that the bits form 6-bit bytes is considered: 64 different bytes are possible which would suggest a connection with the genetic code.

The motivation for the identification of byte is that CaMKII enzyme has in the active state insect like structure: $6 + 6$ legs and the legs are either phosphorylated or not. This geometry is indeed very suggestive of connexion with 6 inputs and 6 outputs representing genetic codons representable as sequences of 6 bits. The geometry and electrostatics of CaMKII is complementary to the microtubular hexagonal lattice so that CaMKII could take care of the phosphorylation of microtubulins: 6 tubulins at most would be phosphorylated at one side. The presence of Ca^{+2} or calmodulin flux flowing to the neuron interior during nerve pulse is responsible for self-phosphorylation of CaMKII: one can say that CaMKII takes itself care that it remains permanently phosphorylated. I am not sure whether this stable phosphorylation means complete phosphorylation.

It is however difficult to imagine how Ca^{+2} and calmodulin flux could contain the information about the bit sequence and how this information could be coded in standard manner to phosphorylation pattern of legs. The only possibility which looks natural is that phosphorylation is a random process and only the fraction of phosphorylated legs depends on Ca^{+2} and calmodulin fluxes. Another possibility would be that the subsequent process of phosphorylation MT by completely phosphorylated CaMKII manages to do it selectively but it is very difficult to imagine how the information about codon could be transferred to the phosphorylation state of MT.

For these reasons my cautious conclusion is that phosphorylation/its absence cannot represent bit. What has been however found is a mechanism of phosphorylation of MTs, and the question is what could be the function of this phosphorylation. Could this phosphorylation be related to memory but in different manner? The 6+6 structure of CaMKII certainly suggests that the analog of genetic code based on 6 bits might be present but realized in some other manner.

5.1.1 What does one mean with memory?

Before proceeding one must make clear what one means with memory in the recent context. The articles of New Scientists with - almost as a rule - sensationalistic titles, do not pay too much attention for the fact this kind of proposals are always based on some philosophical assumptions which might be wrong.

1. What one means with "memory" in the recent context? The memory in question is behavioral memory. Conditioning producing reflect like reaction is a typical example of behavioral memory and need not have anything to do with conscious memory such as episodal memory in which one literally re-lives an event of past. Electric stimulation of some regions of temporal lobes can indeed induce this kind of memories. The idea about coding would suggest the identification of this memory with a highly symbolic computer memory based on "carving in stone".

2. The proposal is inspired by the idea of brain or cell as computer and can be criticized. There is no pressing need for coding since behavioral memory can be reduced to the formation of associations and associative learning by computers is standard example of this kind of behavioral memory. One can of course consider the coding for declarative and verbal memories and genetic code provides an attractive candidate for a universal code. This kind of code might be behind the natural languages as a kind of molecular language.

3. Behavioral memories can be defined as changes of behavior resulting from a continued stimulus. The understanding of behavioral memory relies on the notions of synaptic strength, synaptic plasticity, and long term potentiation. Synaptic strength tells how strongly the postsynaptic neuron responds to the nerve pulse pattern arriving along pre-synaptic axon and mediated by neurotransmitter over the synaptic gap. For instance, glutamate acts as excitatory neurotransmitter and binding to receptor. At neuronal levels long term potentiation means increase of the synaptic strength so that post-synaptic neuron becomes "more attentive" to the firing of pre-synaptic neuron.

   Hebb's rules [J2] (see `http://tinyurl.com/y7q2gueo`) - not established laws of Nature and plagued by exceptions - state that the effectiveness of synaptic receptors increases, when the two neurons fire simultaneously: it is important to notice that these firings need not have any causal connection with each other. The simultaneous firing activates NMDA receptors in the post-synaptic neuron and generates Ca^{+2} flux which correlates with the increase of the synaptic strength. NMDA obeys same chemical formula $C_5H_9NO_4$ as glutamate: in fact, glutamate and asparagin the two acidic amino-acids. It is also known that the presence of CaKMII is necessary for the increase of the synaptic strengths.

4. There is however an almost-paradox involved with this view about memory if assumed to explain all kinds of memories - in particular episodal memories. Long term conscious memories can be lifelong. Synaptic structures are however highly unstable since the synapses and proteins involved are cycled. To my view this argument is somewhat naïve. There could be a flow equilibrium. The flow pattern of fluid flow in flow equilibrium can be stable although the fluid is replaced with new one all the time. The proposal of authors is that memories are

stored to some more stable structures and that microtubules are these more stable structures making possible short term memories. Post-synaptic microtubules, which differ from presynaptic microtubules in several ways are indeed stabilized by MAPs. Authors also propose the thin filaments associated with the cytoskeleton are responsible for long term memories.

Authors believe on computationalism and they apply standard view about time so that their conclusion is that long term memories are stored elsewhere and remain able to regulate synaptic plasticity. In this framework the notion of memory code is very natural.

5.1.2 LTP and synaptic plasticity

From Wikipedia one can read that synaptic plasticity [J6] (see `http://tinyurl.com/cn7724o`) means possibility for changes in function, location and/or number of post-synaptic receptors and ion channels. Synapses are indeed very dynamical and synaptic receptors and channel proteins are transient, which does not seem to conform with the standard view about long term memory and indeed suggest that the stable structures are elsewhere.

Long term potentiation [J4] (see `http://tinyurl.com/djmhrp`), briefly LTP, involves gene expression, protein synthesis and recruitment of new receptors or even synapses. The mechanism of LTP is believed to be following. The glutamate from pre-synaptic neuron binds to post-synaptic receptors, which leads to the opening of Ca^{+2} channels and influx of Ca^{+2} ions to dendritic spines, shafts and neuronal cell body. The inflow of Ca^{+2} induces activation of multiple enzyme including protein kinase A and C and CaMKII. These enzymes phosphorylate intra-neuronal molecules.

It is known that the presence of CaMKII is necessary for long term potentiation. This supports the proposal of authors that microtubules are involved in an essential manner in memory storage and processing and regulation of synaptic plasticity. The observation about the correspondence between the geometries of CaMKII and microtubular surface is rather impressive support for the role of MTs. To my opinion, the hypothesis about memory code is however un-necessary.

5.1.3 Microtubules

Quite generally, microtubules (MTs) are basic structural elements of cytoskeleton. They are rope like polymers and grow as long as 25 micrometers long. They are highly dynamical. The standard view identifies their basic function as maintaining of cell structures, providing platforms for intracellular transport, forming the spindle during mitosis, etc..

Microtubules [J5] (see `http://tinyurl.com/ya6rm9r`) are extremely rich in eukaryotic biology and brain neurons. They are believed to connect membrane and cytoskeletal levels of information processing together. MTs are the basic structural elements of axons and MTs in axons and dendrites/neuronal cell bodies are different. Dendrites contain antiparallel arrays MTs interrupted and stabilized by microtubule associated proteins (MAPs) including MAP_2. This difference between dendritic and axonal microtubules could be relevant for the understanding of the neuronal information processing. Microtubules are associated also with long neural pathways from sensory receptors, which seem to maximize their length.

For these reasons it would not be surprising if MTs would play a key role in the information processing at neuronal level. Indeed, the more modern view tends to see microtubules as the nervous system of the cell, and the hexagonal lattice like structure of microtubules trongly suggests information processing as a basic function of microtubules. Many information processing related functions have been proposed for microtubules. Microtubules have been suggested role as cellular automatons and also quantum coherence in microtubular scale has been proposed.

The proposal of the article is that short term memory is realized in terms of a memory code at the level of MTs and that intermediate filaments which are much more stable could be responsible for long term memory.

5.1.4 CaMKII enzyme

According to the proposal the key enzyme of memory would be Calcium/calmodulin-dependent protein kinase II: briefly CaMKII [J1] (see `http://tinyurl.com/6x4toa3`). Its presence is known to be necessary for long term potentiation.

In passive state CaMKII has snowflake shape. The activated kinase looks like double sided insect with six legged kinase domains on both sides of a central domain. Activation means phosphorylation of the 6+6 legs of this "nano-insect". In the presence of Ca^{+2} or calmodulin flux CaKMII self-actives meaning self-phosphorylation so that it remains permanently active.

There are however grave objections against phosphate=1–no-phosphate=0 coding.

1. Only the fluxes of Ca^{+2} and/or calmodulin matter so that it is very difficult to imagine any coding. One would expect that the fraction of phosphorylated legs depends on these fluxes in equilibrium but it is very difficult to image how these fluxes could carry information about a specific pattern of phosphorylation for legs. If all legs are phosphorylated the coding to microtubular phosphorylation would require that 6 bits of information is fed at this stage by telling which leg actually gives its phosphate to tubulin. This does not look two plausible but one must be very cautious in making too strong conclusions.

2. Since metabolic energy is necessary for any information processing, the more plausible interpretation would be that phosphorylation makes bit active. Bit itself would be represented in some other manner. The 6+6 leg structure of CaMKII is very suggestive of a connexion with 6 incoming bits and 6 outgoing bits - possible same or conjugated. The interpretation in terms of DNA codon and its conjugate is what comes first in mind.

One should not however throw away child with the wash water. The highly interesting discovery discussed in the article [J13] (see `http://tinyurl.com/7dcgjwf`) is that the spatial dimensions, geometric shape, and electrostatic binding of the insect-like CamKII and hexagonal lattices of tubulin proteins in microtubules fit nicely together. The authors show how CaMKII kinase domains can collectively bind and phosphorylate MTs. This alone could be an extremely important piece of information. There is no need to identify bit with phosphorylation state.

5.2 TGD View About The Situation

TGD based view about memory could have been developed by starting from the paradox related to long term memories. Memories are long lasting but the structures supposed to be responsible for their storage are short-lived. TGD based solution of the paradox would be based on new view about the relationship between geometric time and experienced time.

1. According to this view brain is 4-dimensional and primary memories are in the time-place, where the neural event took place for the first time. In principle there would be no need to store memories by "carving them in stone". To remember would be to see in time direction: this view is indeed possible in zero energy ontology. Time-like entanglement and signalling to the geometric past using negative energy signals would be the basic mechanisms of memory.

2. Stable memories require copies also for another reason. The negative energy signal to geometric past is not expected to allow a precise targeting to a one particular moment of time in past. To circumvent the problem one must make the target large enough in time direction. The strengthening of memory would mean building up large number of copies of memory. These copies are produced in every conscious memory recall and learning would be based on this mechanism. The neuronal mechanism would produce large number of copies of the memory and one can ask whether CaMKII indeed generates phosphorylated sections of MT somehow essential for the representation of long term symbolic memories as names for experiences rather than experiences themselves.

3. Metabolism must relate also to conscious memory recall. Since negative energy signals are involved, there is great temptation to assume that de-phosphorylation liberating metabolic energy corresponding to the absorbed negative energy accompanies memory recall. Large $\hbar$ for the photons involved would allow very low frequencies -expected to characterize the time span of memory recall - and make communications over very long time intervals possible. This would mean that the original memory representation is destroyed in the memory recall. This would conform with the spirit of quantum no-cloning theorem [**?**] (see `http://tinyurl.com/2dhl4oe`). Several copies of the memory representation would be needed and also feed of metabolic energy to generate new copies. In this framework conscious memory recall would

be dynamical event rather than stable bit sequence in accordance with the vision about quantum jump as moment of consciousness.

5.2.1 Braiding as a universal model for memory

This leaves a lot of freedom to construct more detailed models of symbolic memories.

1. Braiding of magnetic flux tubes would make possible not only topological quantum computation [K1] (see `http://tinyurl.com/ybyscdpt` but also a universal mechanism of long term memory. In the model of DNA as topological quantum computer) the flux tubes connect DNA nucleotides and lipids of cell membrane. It turned out that the flux tubes carrying dark matter - identified as ordinary particles but with non-standard value of Planck constant [K12] - could connect all kinds of biomolecules and that braiding and reconnection could serve as basic quantum mechanisms in the functioning of biomolecules. Flux tubes could also connect the tubulins of microtubules and lipids of axonal or dendritic membrane.

2. Two kinds of braidings are present: the lipid flow defines braiding in time direction as the analog of dance and the fact that lipids are like dancers with threads from shoes the wall - now microtubule surface - so that the dance induce braiding of these threads storing the dynamics of the dance to memory. The presence of both space-like and time-like braiding and the fact that they are in well-defined sense dual has become central idea of quantum TGD itself. Originally it was however discovered in the model for DNA as topological quantum computer [K1].

3. Both active memory recall by sending negative energy dark photon to geometric past and spontaneous memory recall by receiving a positive energy photons from geometric past require metabolic energy. Therefore the presence of phosphate in braid strands is necessary. The flux tubes defining braid strands can be therefore assumed to be active only if they have phosphate at the other end. A more appropriate TGD based interpretation is that this makes possible negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book), which is one of the basic predictions of the number theoretic vision about life. High energy phosphate bond would thus a signature of negentropic entanglement, which could serve as a correlate for the experience of understanding. One could relate ATP-ADP process as a basic process of life directly to cognition. The presence of phosphate would tell that there is magnetic flux tube - actually pair of them- beginning from the molecule.

5.2.2 TGD variant of the microtubular model for memory

The finding of the authors inspires a more detailed formulation for the vision for how memories could be realized at microtubular level.

1. The phosphorylation of tubulins would generate active braids strands and their presence would make possible memory recall. Note that memories as such could be stored to the braiding in any case if the microtubule-lipid flux tubes are present always. Every nerve pulse pattern would induce a flow of lipids at neuronal membrane if the membrane is in a phase corresponding to 2-D liquid crystal. This flow pattern would be stored to the braiding of the flux tubes.

2. In the model of DNA as topological quantum computer one assigns to braid strands connecting DNA nucleotides to lipids 4 different states representing the nucleotides A, T, C, G. In the original model the A, T, C, G were mapped to four states defined by quarks u, d and their antiquarks at the ends of braid strands. This proposal can be of course accused of being quite too science fictive. TGD however predicts the possibility of scaled up variants of QCD type physics even in the scale of living matter and there are some indications for this.

   A more down-to-earth realization of the genetic code proposed quite recently [K15] is that braid states correspond to pairs of magnetic flux tubes. To the ends of both flux tubes one assigns electron so that the electrons form spin triplet and spin singlet state defining 3+1 states representing A, T, C, G. This gives also a connection with electronic super-conductivity

which is fundamental assumption in the model of nerve pulse based on Josephson currents: nerve pulse corresponds to a simple perturbation of the ground state in which all Josephson current along axon are oscillating in the same phase. Mathematically the phase difference behaves like gravitational pendulum [K26].

The 6=2+2+2 legs could correspond to flux tube pairs and each flux tube pair would represent DNA nucleotide in terms of the spin state of electron pair. Phosphorylation would activate the braid strand by making possible negentropic entanglement and information storage and recall. This conforms with the fact of life is that metabolic energy is needed for all kinds of information processing including also information storage.

If all 6 tubulins to which bits are assigned are indeed phosphorylated in the active state and if the memory recall involves use of metabolic energy as proposed, then the reading of the memory would mean complete de-phosphorylation of 6-tubulin sequences. The prediction would be the presence of phosphorylated 6-tubulin sequences at microtubular surface and their disappearance in memory recall. I do not know whether there is any manner to test these predictions.

3. For this proposal LTP would involve a generation of active braid strands. The post-synaptic neuron would be in "wake-up" state and would pay attention to the nerve pulse patterns arriving from the pre-synaptic neuron. This activation would be induced by simultaneous firing of post-synaptic and pre-synaptic neurons. As a consequence, the lipid flow would generate braidings providing memory representations and defining in temporal domain quantum computation like processes.

4. This does not yet explain why CaMKII is necessary for LTP. There is a high temptation to regard the increase of the synaptic sensitivity as a property of synaptic connection. One can imagine several mechanisms.

   (a) For instance, active flux tube connections between presynaptic lipids and postsynaptic microtubuli could be generated by phosphorylation, and the flux tubes might increase the flow of glutamate between pre- and post-synaptic neurons and in this manner increase synaptic strength. Flux tubes might make possible a continual flow of dark particles between pre- and post-synaptic neurons. They could also make possible negentropic entanglement between the two neutrons binding the neurons to single coherent quantum whole.

   (b) The strength of this connection could be affected also by the presence of active braid strands making possible quantum memory and topological quantum computation. Also more complex processes assigned with LTP would become possible since microtubules might be seen as conscious intelligent structures able to modify their nearby environment.

6 How subjective memories are realized in TGD inspired theory of consciousness?

We remember our conscious experiences: also as re-experiences and not just as learned, often unconscious, behaviors that reduce to associations. In the following the notion of memory is discussed from the points of view of computer science and neuroscience, of quantum theories of consciousness, and of TGD inspired theory of consciousness.

6.1 Memory as challenge in computer science and neuroscience

The notion of conscious memories is highly problematic both in computer science and neuroscience.

1. Computers completely lack subjective memory if they are what they are believed to be, that is to obey the Turing paradigm. Computers are also believed to be deterministic, either in the sense of classical physics or of statistical quantum mechanics. Since non-determinism is the basic aspect of conscious entities, computers are expected to lack conscious experiences. One can of course challenge the Turing paradigm and this is done in [**?**].

2. In neuroscience, memory is often interpreted as mere learned behaviors This view is a remnant of behaviorism. Associations provide a mechanism of memory and association is also the basic mechanism of the now fashionable large language models. This interpretation does not explain at all the episodic, experiential memories that we also have. Some of us have very intense sensory memories. All of us have dreams involving memories and the electric stimulation of the parietal brain regions can induce lively sensory memories of the past events.

   Memories must be stored in some sense. In neuroscience, the finiteness of the memory space becomes a basic problem. If memories are "carved in stone", a large number of stones are needed and their number is increasing all the time. It might be necessary to give up some memories, most naturally the oldest ones. Computationalist would say that new data is written over the older data. What happens is just the opposite: the last memories to disappear are the childhood memories. The strong emotional content of these memories is certainly one reason for this. They are also remembered many times and this produces many copies of them, which makes it easier to recall them. This might be used as a neuroscience explanation for their stability.

   The understanding of the reading of memories, that is having a conscious experience providing information about the memory, remains an unsolved challenge in the neuroscience context: this would require a genuine theory of conscious experience.

6.2 Memory as a key challenge for quantum theories of consciousness

Any theory of consciousness, including quantum theories of consciousness, should be able to explain the basic mechanism of conscious memory. A basic element of subjective memory is its temporality. Its content corresponds to the events of the past.

1. An attractive idea is that, by their non-determinism which is a basic behavioral feature of conscious entities, quantum jumps determine the development of consciousness. Subjective memory recall would therefore represent information about the previous quantum jumps. The quantum states should represent information about what was experienced in the past.

2. The information of the conscious experience, if determined by the quantum jump, must be about the initial and the final states of the quantum jump and the transition between them. It should be encoded into the final state of the quantum jump. In the standard ontology of quantum theory this is not possible. According to the standard quantum theory, quantum states 3-D time=constant snapshots and do not remember anything about the previous quantum jumps.

   Therefore, theories of consciousness based on standard quantum mechanics cannot explain subjective memory, which is from previous conscious experiences, i.e. quantum jumps. For some reason, this fact seems to have been overlooked.

The understanding of subjective memories is therefore a hard challenge for the theories of consciousness.

1. If one accepts only the statistical view of quantum theory, a natural question would be that in some sense the characterization of quantum statistical time evolution corresponds to some kind of Markov chains. Stronger condition would be quantum states are replaced by sequences of 3-D quantum states. This would require a failure of strict determinism but standard quantum theory does not allow this.

2. The failure of strict classical determinism is however a valuable guideline and would mean that quantum states are in some sense "slightly" 4-dimensional so that also the brain would be "slightly" 4-dimensional. The zero energy ontology (ZEO) of TGD indeed predicts this. Quantum states are superpositions of 4-D classical time evolutions obeying almost deterministic holography so that they are not quite 3-dimensional.

3. In TGD, the zero energy ontology (ZEO) combined with holography=holomorphy vision suggests a universal mechanism of this kind. In the sequal the general TGD based mechanism of memory storage is discussed. By its universality, the proposed mechanism applies also to

matter which is usually regarded as "dead" (since it looks dead in the time scales of our perceptive abilities).

6.3 TGD view of subjective memory

We have memories about the conscious experiences of the past. How are these memories formed? Zero energy ontology (ZEO) [**?**] [K33] suggests a rather concrete model for the representations of the memories in terms of the geometry of the space-time surface.

6.3.1 ZEO briefly

Consider first a brief summary of ZEO.

1. The basic notions of ZEO are causal diamond (CD), zero energy state, and state function reduction (SFR). Zero energy state be seen as a pair of ordinary 3-D quantum states at the light-like boundaries and as a superposition of space-time surfaces inside $CD = cd \times CP_2$ obeying holography [**?**]. Here cd is the intersection of future and past-directed light-cones of M^4. There are two kinds of SFRs: "small" SFRs (SSFRs) and "big" SFRs (BSFRs).

2. A sequence of SSFRs is the TGD counterpart for a sequence of repeated measurements of the same observables: in wave mechanics they leave the state unaffected (Zeno effect). Already in quantum optics, one must loosen this assumption and one speaks of weak measurements. In ZEO, SSFRs do not affect the 3-D states at the "passive" boundary of CD but change the 3-D states at the active boundary, this gives to the flow of consciousness and defines a self as a conscious entity. In the TGD framework, SSFRs give rise to a flow of consciousness, which defines self as a conscious entity.

3. BSFR is the counterpart of the ordinary SFR. In the BSFR the arrow of the geometric time changes. BSFR means death of self and to a reincarnation with an opposite arrow of geometric time. Death and birth as reincarnation with an opposite arrow of time are universal notions in the TGD Universe. Falling asleep and biological death are examples of BSFR. Since TGD predicts quantum coherence in arbitrarily long scales, the arrow of time can change in even cosmological scales.

6.3.2 The classical representation of the information of subjective memories

Consider now the classical representation of the information of subjective memories.

1. Zero energy states can be regarded as pairs of 3-D many-fermion states at the opposite light-like boundaries of the CD. Second view of zero energy state is as a superposition of space-time surfaces obeying holography and therefore analogous to Bohr orbits. This picture is made more complex by the hierarchy of CDs.

2. It is essential that the holography is almost deterministic. holography=holomorphy principle allows the explicit construction of space-time surfaces as holomorphic minimal surfaces, and they are analogous to Bohr orbits when one interprets 3-surface as a generalization of a point-like particle. Already 2-D minimal surfaces fail to be completely deterministic (a given frame can span several minimal surfaces). This non-determinism forces ZEO: otherwise one would have ordinary ontology with 3-D objects as basic geometric entities.

   The failure of complete determinism makes 4-dimensional Bohr orbits dynamical objects by giving them additional discrete degrees of freedom. They are absolutely essential for the understanding of memory and one can speak of a 4-dimensional brain.

3. The 3-D many-fermion states and the restriction of the wave function in WCW to a wave function to the space-of 3-surfaces as the ends of Bohr orbits at the passive boundary of CD are unaffected by the sequence of SSFRs. This is the counterpart for the Zeno effect.

   This requires that a given SSFR corresponds to a measurement of observables commuting with the eigen observables at the passive boundary. The simplest option is that these observables are associated with the discrete degrees of freedom due to the classical non-determinism.

4. The 3-D states at the opposite, active, boundary of CD are however affected in SSFRs and this gives rise to self and flow of consciousness. Also the size of CD increases in a statistical sense. The sequence of SSFRs gives rise to subjective time correlating with the increase of geometric time identifiable as the temporal distance between the tips of the CD. The arrow of time depends on which boundary of CD is passive and the time increases in the direction of the active boundary.

5. In TGD, ordinary SFRs correspond in TGD to BSFRs. Both BSFRs and SSFRs are possible in arbitrarily long scales since the h_{eff} hierarchy makes possible quantum coherence in arbitrary long scales.

   The new element is that the arrow of geometric time changes in BSFR since the roles of the active and passive boundaries of CD change. BSFR occurs when the set of observables measured at the active boundary no longer commutes with the set of observables associated with the passive boundary.

   The density matrix of the 3-D system characterizing the interaction of the 3-surface at the active boundary with its complement is a fundamental observable and if it ceases to commute with the eigen observables at the passive boundary, BSFR must take place.

   The degrees of freedom characterizing the classical non-determinism are crucial for memory. Since they commute with the eigen observables at the passive boundary, they naturally belong to the degrees of freedom measured in SSFRs.

6.4 Memory recall and memory storage in ZEO

Consider now what memory recall could mean in this framework. There are two views of memory recall: classical and quantal.

1. The classical view is that active memory recall requires what might be regarded as communications with the geometric past. This requires sending a signal to the geometric past propagating in the non-standard time direction and absorbed by a system representing the memory locus (part of the brain or of its magnetic/field body). The signal should be generated in a BSFR of some subsystem. In ZEO this is possible since BSFRs change the arrow of the geometric time.

   The signal must be received by a system of the geometric past representing the memory. The signal would be received at a quantum critical memory location by a resonance mechanism, and a second BSFR would occur, resulting in a response that would propagate to the future brain. This pair of BSFRs corresponds to the TGD counterpart of quantum tunnelling.

2. The second way to see the memory recall relies on time-like quantum entanglement between memory locus and the system which remembers. Memory recall would be state function reduction reducing the entanglement and essentially a quantum measurement.

How are the memories coded geometrically?

1. This can be understood by asking what happens in SSFR. What happens is that from a set of 3-D final states at the active boundary some state is selected. This means a localization in the "world of classical worlds" (WCW) as the space of Bohr orbits. The 3-D surfaces at the active boundary of the CD represent the outcome of quantum measurement. The final state as a zero energy state represents classically the quantum transition to the final state! This is not possible in the standard ontology.

2. The findings of Minev et al [**?**] [**?**] that in quantum optics quantum jumps correspond to smooth classical time evolutions leading from the initial state to the final state. This provides direct support for the ZEO view. The interpretation works for SSFRs and also for the transitions of atoms as pairs of BSFRs having interpretation as quantum tunnelling events.

6.4.1 Is consious experience associated with SSFRs assignable to the classical non-determinism?

ZEO therefore gives a geometric representation of a subjective experience associated with the SSFR. One obtains conscious information of this representation either by passive or active memory recall by waking up the locus of non-determinism assignable to the original conscious event. The slight failure of determinism for BSFRS is necessary for this. The sequence of SSFRs is coded to a sequence of geometric representations of memories about conscious events.

This is how the Universe gradually could develop representations of its earlier quantum jumps to its own state. Since the algebraic complexity of the Universe can only increase in a statistical sense the quantum hopping of the Universe in the quantum Platonia defined by the spinor fields of WCW implies evolution.

It is tempting to think that cognitive and sense-awareness, or at least memory, correspond to regions of the space-time surface (minimal surface), where quantum jumps between the different classical alternatives are possible. These "hot spots" would be analogous to the frames spanning the soap film and as quantum critical systems serve as seats of memories.

1. At least for SSFRs associated with remembering, classical non-determinism and quantum non-determinism would correspond to each. Could this be the case also for sensory and cognitive SSFRs, in fact all SSFRs? Could the classical-quantum correspondence fail only for BSFRs as counterparts of the "ordinary" SFRs.

2. The "memory locations" at the space-time surface, especially in the 4-dimensional brain, correspond to the loci of non-determinism (and of quantum criticality).

3. Memory recall would require a signal to the geometric past propagating in the non-standard direction of geometric time. The signal would be generated in a BSFR of some subsystem. The signal would be received by the quantum critical memory location by a resonance mechanism, and a second BSFR would occur, resulting in a response that would propagate to the future brain.

6.4.2 Memory and TGD inspired quantum biology

Can one say anything more concrete?

1. TGD predicts that any system can have a self as a sequence of SSFRs. Therefore there is an entire hierarchy of systems, which can be conscious and the question is what level in the hierarchy biological consciousness corresponds to. In the case of the brain, the quantum critical slightly non-deterministic hotspots of the 4-D space-time surface representing the brain could be associated with DNA, microbuli, neurons, axons, and larger structures constructed from them.

2. Perhaps the most natural identification for the seat of our conscious experience is associated with the field bodies (magnetic and electric) of these systems. The reason is that they contain dark variants of the ordinary particles characterized by a very large value of effective Planck constant h_{eff}, which serves as a measure for algebraic complexity, representative capacity, and intelligence.

3. Gravitational Planck constant $\hbar_{gr}$ and electric Planck constant characterize the gravitational [**?**, **?**] electric bodies [**?**, **?**]. Both DNA, microtubuli, and DNA have large electric charges and the gravitational magnetic bodies of the Earth and Sun are excellent candidates for the field bodies involved.

   Water is an essential part of the living matter and expected to be crucial for our conscious experience. The proposal is that the monopole flux tubes accompanying the ordinary basic biomolecules carry sequences of dark protons providing a fundamental representation of the genetic code, which is universal and possible in all scales.

4. The notion of dark DNA leads to a proposal that the genetic code, realized in terms of a completely unique icosa tetrahedral tessellation of the hyperbolic 3-space H^3 [**?**], would be

crucial in the communications based on multi-resonance mechanism as selector of the receiver and frequency modulation as the way to represent information.

This mechanism, associated with the EEG and its possible fractally scaled copies at longer and shorter time scales, would be essential also for the memory recall. Dark photons obtained from ordinary photons have period and wavelength scaled up by h_{eff}/h. Large values of h_{eff} long time scales. The larger the value of h_{eff} the longer the time span of the memory.

REFERENCES

Cosmology and Astro-Physics

[E1] Freeman PE et al. Examining the Effect of the Map-making Algorithm on Observed Power Asymmetry in WMAP Data. *Astrophys J*, 638, 2006. Available at: `https://arxiv.org/abs/astro-ph/0510406`.

Biology

[I1] Gariaev P et al. *The DNA-wave biocomputer*, volume 10. CHAOS, 2001.

Neuroscience and Consciousness

[J1] CaMKII. Available at: `https://en.wikipedia.org/wiki/CaMKII`.

[J2] Hebbian theory. Available at: `https://en.wikipedia.org/wiki/Hebbian_theory`.

[J3] Hippocampus . Available at: `https://en.wikipedia.org/wiki/Hippocampus`.

[J4] Long term potentiation. Available at: `https://en.wikipedia.org/wiki/Long-term_potentiation`.

[J5] Microtubules. Available at: `https://en.wikipedia.org/wiki/Microtubules`.

[J6] Synaptic Plasticity. Available at: `https://en.wikipedia.org/wiki/Synaptic_plasticity`.

[J7] Vannini A. Advanced Waves, Retrocausality, and Consciousness. 2007. textnormalAvailable at: `https://www.scientificexploration.org/`.

[J8] Nanopoulos DV. Theory of Brain function, Quantum Mechanics, and Superstrings, 1995. Available at: `https://arxiv.org/abs/hep-ph/9505374`.

[J9] Ackerman E. *Biophysical Science*. Prentice Hall, 1962. Available at: `https://en.wikipedia.org/wiki/Electroencephalography`.

[J10] Giuditta A et al. The sequential hypothesis of the function of sleep. *Behavioural Brain Res*, 69, 1995.

[J11] Kiviniemi V et al. Comparison of methods for determining non-deterministic BOLD fluctuation in fMRI. *Magn Reson Imaging*, 22, 2004.

[J12] Raichle ME Fox MD. Spontaneous fluctuations in brain activity observed with functional magnetic resonance imaging. *Nature Reviews/Neuroscience*, 8:700, 2007. Available at: `https://www.nature.com/reviews/neuro`.

[J13] Hameroff S Graddock T, Tuszynksi A. Cytoskeletal Signaling: Is Memory Encoded in Microtubule Lattices by CaMKII Phosphorylation? *PLoS Comput Biol*, 8(3), 2012. Available at: `https://www.ploscompbiol.org/article/info:doi/10.1371/journal.pcbi.1002421`.

[J14] Fantappie L. *Teoria Unitaria del Mondo Fisico e Biologico*. Di Renzo Editore, Roma, 1942.

[J15] Squire LR. Memory and the Hippocampus : A Synthesis From Findings With Rats, Monkeys, and Humans. *Psychol Rev*, 99(2):195–231, 1992.

[J16] Fordahl M. Scientists trigger neuron regeneration in mouse brain, 2000. Available at: https://www.nandotimes.com.

[J17] Tegmark M. The importance of quantum de-coherence in brain processes, 1999. Available at: https://arxiv.org/abs/quant-ph/9907009.

[J18] Daneman M Mericle PM. Memory for unconsciously perceived events: evidence for anesthetized patients. *Conscious & Cognition*, 5:525, 1996.

[J19] Goldman-Rakic PS. The "psychic" neuron of the cerebral cortex. *Ann N Y Acad Sci*, 868:13–26.

[J20] Corpo Di U. The conflict between entropy and syntropy: the vital needs model. 2007. Available at: https://www.scientificexploration.org/.

[J21] Eastman KE Vertes RP. The case against memory consolidation in REM sleep. *Behav & Brain Sci*, 23(6).

Books related to TGD

[K1] Pitkänen M. DNA as Topological Quantum Computer. In *Quantum - and Classical Computation in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdcomp.html*. Available at: https://tgdtheory.fi/pdfpool/dnatqc.pdf, 2015.

[K2] Pitkänen M. Anomalies Related to the Classical Z^0 Force and Gravitation. In *TGD and Fringe Physics. https://tgdtheory.fi/tgdhtml/Bfreenergies.html*. Available at: https://tgdtheory.fi/pdfpool/Zanom.pdf, 2023.

[K3] Pitkänen M. Are dark photons behind biophotons? In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/biophotonslian.pdf, 2023.

[K4] Pitkänen M. Biological Realization of Self Hierarchy. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/bioselfc.pdf, 2023.

[K5] Pitkänen M. Criticality and dark matter: part I. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark1.pdf, 2023.

[K6] Pitkänen M. Criticality and dark matter: part II. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark2.pdf, 2023.

[K7] Pitkänen M. Criticality and dark matter: part III. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark3.pdf, 2023.

[K8] Pitkänen M. Criticality and dark matter: part IV. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark4.pdf, 2023.

[K9] Pitkänen M. Dark Forces and Living Matter. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/darkforces.pdf, 2023.

[K10] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/eegdark.pdf, 2023.

[K11] Pitkänen M. Did Tesla Discover the Mechanism Changing the Arrow of Time? In *TGD and Fringe Physics. https://tgdtheory.fi/tgdhtml/Bfreenergies.html*. Available at: https://tgdtheory.fi/pdfpool/tesla.pdf, 2023.

[K12] Pitkänen M. Does TGD Predict a Spectrum of Planck Constants? In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/Planck, 2023.

[K13] Pitkänen M. General Theory of Qualia. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/qualia.pdf, 2023.

[K14] Pitkänen M. Genes and Memes. In *Genes and Memes: Part I. https://tgdtheory.fi/tgdhtml/Bgenememe1.html*. Available at: https://tgdtheory.fi/pdfpool/genememec.pdf, 2023.

[K15] Pitkänen M. Macroscopic Quantum Coherence and Quantum Metabolism as Different Sides of the Same Coin: Part I. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/metab.pdf, 2023.

[K16] Pitkänen M. Many-Sheeted DNA. In *Genes and Memes: Part I. https://tgdtheory.fi/tgdhtml/Bgenememe1.html*. Available at: https://tgdtheory.fi/pdfpool/genecodec.pdf, 2023.

[K17] Pitkänen M. Meditation, Mind-Body Medicine and Placebo: TGD point of view. In *TGD Inspired Theory of Consciousness: Part III. https://tgdtheory.fi/tgdhtml/Btgdconsc3.html*. Available at: https://tgdtheory.fi/pdfpool/panel.pdf, 2023.

[K18] Pitkänen M. Negentropy Maximization Principle. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/nmpc.pdf, 2023.

[K19] Pitkänen M. Number theoretic vision, Hyper-finite Factors and S-matrix. In *Quantum TGD: Part I. https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://tgdtheory.fi/pdfpool/UandM.pdf, 2023.

[K20] Pitkänen M. p-Adic Physics as Physics of Cognition and Intention. In *TGD Inspired Theory of Consciousness: Part II. https://tgdtheory.fi/tgdhtml/Btgdconsc2.html*. Available at: https://tgdtheory.fi/pdfpool/cognic.pdf, 2023.

[K21] Pitkänen M. Quantum Antenna Hypothesis. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/tubuc.pdf, 2023.

[K22] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/qastro.pdf, 2023.

[K23] Pitkänen M. Quantum Control and Coordination in Bio-Systems. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/qcococII.pdf, 2023.

[K24] Pitkänen M. Quantum Control and Coordination in Bio-systems: Part I. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/qcococI.pdf, 2023.

[K25] Pitkänen M. Quantum gravity, dark matter, and prebiotic evolution. In *Evolution in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdevolution.html*. Available at: https://tgdtheory.fi/pdfpool/hgrprebio.pdf, 2023.

[K26] Pitkänen M. Quantum Model for Nerve Pulse. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/nervepulse.pdf, 2023.

[K27] Pitkänen M. Quantum Theory of Self-Organization. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/selforgac.pdf, 2023.

[K28] Pitkänen M. Self and Binding: Part I. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/selfbindc.pdf, 2023.

[K29] Pitkänen M. Semi-trance, Mental Illness, and Altered States of Consciousness. In *Magnetospheric Consciousness. https://tgdtheory.fi/tgdhtml/Bmagnconsc.html*. Available at: https://tgdtheory.fi/pdfpool/semitrancec.pdf, 2023.

[K30] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/astro.pdf, 2023.

[K31] Pitkänen M. Unified Number Theoretical Vision. In *TGD as a Generalized Number Theory: Part I. https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/numbervision.pdf, 2023.

[K32] Pitkänen M. Was von Neumann Right After All? In *TGD and Hyper-finite Factors. https://tgdtheory.fi/tgdhtml/BHFF.html*. Available at: https://tgdtheory.fi/pdfpool/vNeumann.pdf, 2023.

[K33] Pitkänen M. Zero Energy Ontology. In *Quantum TGD: Part I. https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://tgdtheory.fi/pdfpool/ZEO.pdf, 2023.