Quantum Model of Memory

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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. The process was not by no means a mechanical deduction of the consequences of some basic postulates. For instance, the understanding of the relationship between geometric and subjective time developed through several erratic models and only a formulation of quantum TGD led to a quantitative formulation.

The new view about time has deep implications concerning the understanding of memory.

a) 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.

b) 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. 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.

Macro-temporal quantum coherence is further important piece of the model. The understanding of how macro-temporal 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. Macro-temporal quantum coherence making possible supercomputer like activities becomes possible.

The spin glass degeneracy associated with the join along boundaries bonds (the space-time correlates for the bound state formation) lengthens the lifetimes of the bound states dramatically and solves thus the basic objections against quantum consciousness. The spin glass degeneracy is due to 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.

This picture was not yet quite enough. A generalization of quantum theory based on the introduction of a hierarchy of Planck constants realized in terms of generalization of the concept of imbedding space motivated by anomalies of astrophysics and biology led to a quantitative model for how macroscopic and macro-temporal quantum coherence could be realized in living matter. Also a quantitative view about memory emerges. A rather detailed neuro level model of long term memory is developed and the model conforms nicely 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 Geometric and subjective memories

The identification of moment of consciousness as quantum jump between histories implies two kinds of time developments, subjective and geometric, and therefore also two causalities and memories. By the 4-dimensional general coordinate invariance 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.

1.2 p-Adic physics as physics of intentionality

In purely real contex one ends up with the problem that there is no clear difference between memories and intentions: intentions are just memories about the geometric future. Why the memories/predictions of geometric future and past are so different? The solution of the problem came when I realized that p-adic physics is physics of cognition, imagination, and intention. p-Adic spacetime regions represent intentions and are about geometric future. In quantum jumps transforming intentions to actions p-adic regions are transformed to real spacetime regions representing geometric memories and inducing self-organization patterns giving rise to macroscopic actions. This amplification process is possible by the quantum criticality of TGD universe implying initial value sensitivity. Psychological time corresponds to the front of a p-adic-to-real phase transition proceeding to the direction of geometric future.

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 subself 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.

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 manner 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 subselves 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 timelike separation. This would be the mechanism of episodal memory, For non-episodal memories only the 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 manner. Any finite spacetime 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 spacetime 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 lightlikeness 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 subself of brain entangles with with the subself 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 subself 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 spacetime level in terms of p-adic or real spacetime 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 Biosupercomputers 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 spacetime level to a join along boundaries condensate. In this process the zero modes of the condensing spacetime 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 spacetimes 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 spacetime 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 reange 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.

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 spacetime 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 wellknown 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 [K3].

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, "phychological 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 subselves 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 rhytmic actions (such as micro tremor of eyes at 80 Hz frequency and muscle tremor) could generate a sequence of subselves with constant duration and thus a clock measuring subjective time.

[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.

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 mindlike spacetime sheets and the notion of the association sequence (3-surfaces consisting of a sequence of spacelike 3-surfaces with timelike separations providing a simulation of classical history) make possible geometric memories. A natural hypothesis is that the macroscopic spacetime 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 mindlike spacetime 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 is indeed possible to predict rather reliably what will happen in the solar system during the next decade. Geometric memories are a prequisite 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 spacetime 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 mindlike spacetime 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 spacetime history defined by, say, my body. Cognitive neutrino pairs would 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 spacetime 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 mimick other selves by building cognitive representations about them at their own spacetime sheets. This would make it un-necessary 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 mindlike spacetime 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 spacetime. 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 mindlike spacetime sheet as a basic prequisite 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 subselves, 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: mindlike spacetime 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 mindlike spacetime sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

The difference between intentions and memories remained a puzzle for a long time. The answer was finally provided by the view about psychological time as a value of the geometric time characterizing the position of the p-adic-to-real phase transition front propagating to the direction of the geometric future. The MEs representing intentions are p-adic whereas those representing memories are real.

2.1.4 What is the temporal extension of mindlike spacetime sheets?

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

2.1.5 Durations of mindlike spacetime sheets representing subselves

Sensory experiences seem to correspond to a well defined geometric now having perhaps duration of order .1 seconds. Thus it seems that mindlike spacetime sheets representing my sensory subselves 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 mindlike spacetime sheets gives the first guess for the duration of the mindlike spacetime 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 mindlike spacetime sheets associated with sensory subselves. The mindlike spacetime sheets representing subselves (mental images) can be located in geometric past or future so that multitime experiences with mindlike sheets of past and future contributing to the experience are possible.

The duration of .1 seconds is the duration of typical subselves representing our mental images. The geometric duration of the mindlike spacetime sheet representing our 'main self' should be much longger since it contains mindlike spacetime sheets distributed along entire life span.

The subselves which have fallen asleep, wake-up again generating new wave of sensory experience. For instance, mental images (after images) typically reappear 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 mindlike spacetime 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.

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 subselves 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 subselves means that subjective memories represented by subselves 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' mindlike spacetime 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 subselves are not conscious during sleep periods so that also multitime experiences in which sensory subselves 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 mindlike spacetime 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 subself 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 subselves forming a subjectotemporal sequence, 'film', could be experienced in the absence of the ordinary sensory input.

2.2 Habits, skills, associations

The universe of TGD is quantum spin glass [I1]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/asso- ciations are formed.

1. Mental images (in particular memories) correspond to subselves 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.

2.3 Spin glass model of learning and long term memories

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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 mindlike spacetime 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 mindlike spacetime sheets located in the geometric past. The probability that a newly created mindlike spacetime 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.

2.4 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.

2.4.1 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 mindlike spacetime 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 mindlike spacetime 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 mindlike spacetime 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 mindlike spacetime 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.

2.4.2 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 [K3] 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' subselves 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 lightlike 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 Z^0 MEs are involved at this stage. Thus MEs with lengths of order of light lifetime ($L = cT$) would be required. The answer presumably involves a transformation of Z^0 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 lightlike character of the boundaries of MEs making possible lightlike selves; spacetime 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 lightlike 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 [35]. 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 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 lightlike 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 Feynmann diagram realized as a generalized Bohr orbit. The Feynmann 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 manner 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 [I3] 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.

2.4.3 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 ageing 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 [N5] 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.

2.4.4 More complicated scenarios

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

1. Ensemble of mindlike spacetime sheets could generate continuously cognitive representations remaining in ideal case unchanged and memories as ability to re-experience would be carried by mindlike spacetime sheet when it wanders to the direction of future. This would require that mindlike spacetime sheets replicate just as material spacetime sheets (DNA, cells, members of species) do. If mindlike spacetime 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 antineutrino Z^0 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 manner 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.

2.5 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 [21]. 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 mindlike spacetime sheet corresponding to our subself forms join along boundaries bond with a lower level self so that lower level self fuses with the subself 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 join along boundaries bonds between our subselves and subselves of other persons. This is quite possible if our subselves indeed correspond to topological field quanta representing ELF photons associated with the EEG frequencies having size of even size of Earth. Formation of join along boundaries contacts 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 subselves 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!

2.6 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. mindlike spacetime 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 mindlike spacetime sheets would have larger probability to enter to the valley and give rise to memory. For instance, reverbrating nerve pulse patters in the memory circuits of brain would realize this repetition.

3 Quantum computation in biological length scales, Penrose Hameroff hypothesis, and mirror model of long term memory

Penrose and Hameroff have proposed that microtubules could act as quantum computers. The quantum states involved would be quantum superpositions of tubulin conformations and quantum gravitation would somehow make these quantum superpositions stable. Long enduring quantum superpositions of the conformations of (say tubulin) molecules would allow to perform a multiverse simulation for the conformational behaviour of the molecules and this would certainly have evolutionary value.

Penrose-Hameroff hypothesis is highly interesting from TGD point of view since TGD Universe is quantum spin glass in the sense that there is an infinite number of different configurations of spacetime sheets whose energies differ only by the gravitational interaction energy. Also the generation of coherent gravitatons by MEs might have a role to play in the quantum physics of living matter. Especially so because genuine quantum gravitational states are state functionals in the space of 3-surfaces, that is world of worlds: therefore they should correspond to higher abstraction level of consciousness than ordinary elementary particles. Furthermore, the gravitational constant associated with the energy of the induced gauge fields is by a factor 10^8 larger than the gravitational constant associated with elementary particles. The task is to put these pieces together.

In the following I will discuss Penrose-Hameroff hypothesis in more detail from the point of view of TGD.

1. TGD Universe indeed allows quantum computing under natural assumptions and the huge quantum spin glass degeneracy broken only by classical gravitation is crucial for the preservation of quantum coherence.

2. Quantum computation occurs optimally for irreducible selves which are in the 'state of oneness' and have no subselves (mental images) so that there are no dissipating subsystems. The paradoxal statement of mysticism that completely empty mind is source of infinite wisdom has therefore a precise content. Second prequisite is that all but center of mass zero modes of 3-surface representing say join along boundaries condensate of tubulin molecules (microtubule) transmute to quantum fluctuating degrees of freedom when 3-surfaces topologically condenses to a larger spacetime sheet. Otherwise a complete localization in zero modes meaning state function reduction would occur in each quantum jump and quantum computation would not be possible in time scales longer than CP_2 time about 10^{-39} seconds defining the average duration of a single quantum jump (quantum jump corresponds to 'elementary particle of consciousness' having duration of CP_2 time).

3. The problem is that standard physics predicts too short life times for the bound states so that quantum computations would still last for too

short time. The huge spin glass degeneracy associated with the join along boundaries bonds however implies that there is an immense number of bound states with almost degenerate energy. This means that the branching ratio for the decay to unbound states is reduced dramatically and bound state lifetime increases.

4. An unexpected connection with the mirror model of long term memories emerges: it is the topological correlates of gravitons which are mirrored from curved almost vacuum spacetime sheet. The reason why for gravitons is that they have so weak interaction with background. What is especially fascinating is that classical gravitational binding energies in the range spanned by the cell membrane thickness and cell length scale (all p-adic length scales in this range correspond to Gaussian Mersennes) correspond to time range 1 millisecond- 100 years, the span of human memories. In particular, microtubule conformations could code for declarative long term memories. Also a connection with the idea that so called $1/f$ noise (now gravitonic) is crucial for consciousness and long term memory emerges.

3.1 Is quantum computation possible at all in TGD universe?

In TGD framework each quantum jump can be interpreted as quantum computation performed by entire universe. Unitary process $\Psi_i \to U\Psi_i$, where Ψ_i is a prepared maximally unentangled state, corresponds to the quantum computation. Then follows state function reduction and state preparation involving a sequence of self measurements and given rise to a new maximally unentangled state Ψ_f.

The problem is that simplest estimate for the increment of the psychological time in single quantum jump is about 10^{-39} seconds from the idea that single quantum jump is a kind of elementary particle of consciousness and thus corresponds to CP_2 time. This would mean that 10^{39} quantum computations occur during single second and conscious experience is average over these quantum computations and the result of the computation would be averaged out completely. This would look like another manner to say that quantum computation is not possible.

That Nature would not allow quantum computation in time scales much above CP_2 time scale looks strange and there sould be ways to get out of the problem.

1. The estimate, which is just a dimensional guess, could be simply incorrect and the average increment of psychological time could be dynamically determined and be much longer. The question is about how long average time interval the p-adic-to-real phase transition front shifts towards geometric future in single quantum jump. There are good reasons to believe that this time interval is common for living organisms: otherwise one ends up with strange paradoxes. It seems however difficult to believe that this

interval is as long as say .1 seconds: we would not experience a continuous stream of consciousness if this were the case and 10 Hz would be natural time scale for the rate of all quantum transitions.

2. Situation changes if the quantum entanglement associated with the quantum computer is bound state entanglement stable against self measurements and if the quantum computer self is in a state of 'irreducible selfness' and therefore stable against self measurement. Paradoxally, in mystics this corresponds to the state of oneness without any mental images: the total emptiness of mind would be crucial for quantum computation which is the most effective manner to perform information processing! In this case quantum jumping could preserve bound state for quite a long time. The halting would be caused by an external perturbation destroying the bound state. The properties of the bound state plus interaction with environment would allow to estimate the typical duration of the quantum computation. This time would take the role of coherence time. This would suggest connection with the standard approach to quantum computation.

Irreducible selfness is not enough for quantum computation. Macrotemporal quantum coherence in the sense that zero modes for the three-surface cease to be zero modes under some conditions, is also necessary for quantum computation. The reason is that localization in the zero modes corresponds to state function reduction spoiling the quantum coherence.

One can imagine two alternative mechanisms transmuting zero modes to quantum fluctuating degrees of freedom.

1. Topological condensation transforms zero modes to quantum fluctuating degrees of freedom quite generally. In this case one would effectively have no zero modes at all. This looks utterly unphysical conclusion.

2. The formation of join along boundaries bonds between 3-D space sheets implies that only the 'center of mass' zero modes remain whereas relative zero modes become quantum fluctuating degrees of freedom. This option looks realistic and is very natural in the case of tubulins and water molecules, which indeed form join along boundaries condensates. The formation of join along boundaries bonds is indeed the basic mechanism for the formation of macroscopic quantum states and the correlate for bound state quantum entanglement. This would explain why water is so important for life.

Whether one can one approximate quantum jump sequence as unitary Hamiltonian time evolution in case of a bound state is an open question. Fractality of consciousness would suggest that one can in case of quantum coherence effectively treat long quantum jump sequence as a single quantum jump (just like one can treat molecules as pointlike particles in a reasonable approximation) so that Hamiltonian description might make sense. Hamiltonian time evolution would more or less correspond to a unitary operator resulting as a product of

the actions of the unitary operators U associated with the quantum jumps of the sequence. Discretized time development would emerge automatically in this framework. Schrödinger equation at infinitesimal level would not make sense but this is of course not a practical problem.

The fact that oxidative metabolism is anomalously low during a neuronal syncrony supports the view that neuronal synchrony might give rise to bound-state entangled multineuron states in 'state of oneness'(the liberated binding energy would be usable energy). The quantum computations performed by the neuronal groups might last the typical duration of 'feature', which is about .1 seconds, typical time scale of alpha rhytm.

3.2 Macrotemporal quantum coherence and molecular sex

The formation of bound states is a generic mechanism for generating new quantum fluctuating degrees of freedom and could make possible quantum computation like processes and multiverse states of consciousness containing large amounts of conscious information. At macrolevel sexual organism could be basic example of multiverse state of oneness generated by the formation of quantum bound state between partners. Neuroscientists use to talk about rewards and punishments and one might argue that life involves kind of sexual pleasure as a reward for the formation of bound states at all levels of hierarchy. Spiritual experiences would represent a more abstract experiences of this kind involving the formation of bound states of the field bodies by MEs serving as field bridges.

Some examples are in order.

1. The binding of molecules by lock and key mechanism is a fundamental process in living matter and could generate large number of quantum fluctuating degrees of freedom and generate conscious intelligence. This could explain why long linear macromolecules are so important for life. From the viewpoint of classical chemistry it is not obvious why DNA is arranged into long chromosomes rather than separate short threads. In TGD universe the reason why would be that for chromosomes the number of quantum fluctuating degrees of freedom and thus the amount of conscious intelligence is maximized.

2. The Ca^{++} ions binding to microtubules and molecules like calmodulin could act as switch like bridges between water clusters and microtubules and thus able to dramatically increase the number of quantum fluctuating degrees of freedom and initiate quantum computation like process. The de-attachment of Ca^{++} ions would halt the process.

3. The binding of the information molecules to receptors is a universal control mechanism in living matter. In TGD universe information molecule would initiate genuine quantum information processing lasting for the lifetime of the information molecule-receptor complex. In particular, neurotransmitters could induce molecular states of oneness in receptor-neurotransmitter complex or perhaps even in larger-sized structures. If neurotransmitters

have join along boundaries bonds to other neurons mediated by magnetic flux tube structures, they could act as conscious quantum links in quantum web and induce quantum computation like processes involving distant neurons just as link links in the web induce classical computations involving distance computers.

4. One could see information molecules and receptors as representatives of opposite sexes: information molecules being active quantum binders free to move from flower to flower whereas receptors would be the passive party attached to some structure. The binding of the information molecule to the receptor would be the analog of sexual intercourse. Usually the receptors are bound to larger structures such as cell membrane and also the zero modes for some parts of these larger structures could become quantum fluctuating in the process.

3.3 Do quantum superpositions of tubulin molecule conformations last for a time longer than CP_2 time?

In TGD quantum superpositions of molecular(say tubulin) conformations correspond quantum superpositions of 3-surfaces representing protein conformations and the question is whether they could last more than CP_2 time.

3.3.1 Naive argument: No

The first guess is that the conformational degrees of freedom of protein correspond in TGD framework to effectively non-quantum fluctuating zero mode degrees of freedom (zero modes do not contribute to the line element defining the metric of the configuration space of 3-surfaces). In each quantum jump a complete localization in the zero modes must occur by mathematical consistency. Standard quantum measurement theory results if there is entanglement between zero modes and quantum numbers associated with quantum fluctuating degrees of freedom: just like between spin of electron and its classical orbit in magnetic field in Stern-Gerlach experiment.

In each quantum jump the unitary process U generates a multiverse in which different protein conformations are in quantum superposition and state function reduction selects a quantum superposition of the spacetime surfaces such that zero modes have same values for all these surfaces and state looks completely classical. If the average increment of the psychological time in quantum jump is CP_2 time about 10^{-39} seconds, this means that the quantum superposition lasts only for 10^4 Planck times and is what standard quantum gravity would also suggest apart from 10^4 factor. Thus TGD would not support Hameroff-Penrose view if the simplest assumptions are correct.

3.3.2 Could gravitational interaction transform zero modes to quantum fluctuating degrees of freedom?

The situation changes if the interaction of the tubulin molecule with the external world, say other tubulin molecules, somehow transforms zero mode degrees of freedom characterizing the shape of free tubulin to quantum fluctuating degrees of freedom, or rather the relative shape degrees of freedom. The mechanism would be simply the formation of join along boundaries bonds between tubulins of microtubules which would transmute all but the overall 'center of mass zero modes' to quantum fluctuating degrees of freedom. I do not know whether molecular chemistry allows examples in which molecule can be said to be in quantum superposition of different conformations or whether molecules behave effectively classically as assumed in Born-Oppenheimer approximation for calculating electronic states. In translational degrees of freedom situation is certainly different.

Quantum fluctuations in the shape of the spacetime sheet belonging to a join along boundaries condensate characterized by prime p would be of the order p-adic length scale $L_p \propto \sqrt{p}$. The ratio of this length scale to the length scale of the larger spacetime sheet at which molecules are condensed topologically, would be typically a small power of 2: $\sqrt{p/p_1} \simeq 2^{(k-k_1)/2}$, k and k_1 primes or powers of prime. Typically the factor would be $1/2, 1/4, ...$ Interestingly enough, in biological length scales twin pairs $k, k_1 = k + 2$ of primes are very abundant: in this case the value of the factor would be $1/2$ so that quantum fluctuations in shape would be maximal. Perhaps this maximation of quantum fluctuations is something deep.

3.3.3 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 subselves 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 [24]. 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 decoherence time become much longer than predicted by standard physics.

2. If the join along boundaries bonds 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 decohering 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 [G1]. 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, join along boundaries bonds 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 spacetime 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 spacetime 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.

3.4 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 vacuum and and emitted 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 nonvacuum extremals, classical momentum conservation however requires that the topological graviton exchanges momentum with the background spacetime surface and thus is mirrorred 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.

5. Gravitonic MEs carry also classical em and/or Z^0 fields. The requirement that memory MEs interact weakly with the environment suggests that Z^0 MEs are in question.

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.

4 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.

4.1 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 timelike 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.

4.1.1 Mirror mechanism

Mirror mechanism is the simplest quantum mechanism of episodal memories and involves only a sharing of mental images by entanglement. 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 targed communications to the geometric past. The sizes of these loops would be measured in light years. Z^0 Mes and Z^0 magnetic flux loops associated with the personal Z^0 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 Z^0 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 requires only that gravitational/Z^0 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.

4.1.2 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.

A dramatic reduction of the phase velocity is required, and is also assumed to occur for Z^0 MEs in the model of nerve pulse and it could occurs for EEG MEs because of the interaction with brain. The phase velocities of EEG waves in brain provide a good estimate for the effective phase velocities of MEs. The mechanism reducing the velocity is quantal: positive energy ME drifts to the direction of geometric future quantum jump by quantum jump and this reduces the effective phase velocity. Thus it would seem that classical communications might rely on positive energy EEG and ZEG MEs in EEG frequency range. Z^0 cyclotron frequencies are quite generally in alpha band so that Z^0 MEs could be responsible for the communication of the long term memories using memetic code whereas EEG MEs might be responsible for various sensory representations

at the personal magnetic body and even magnetosphere. Note that the "features" of Freeman [17] having during of about .1 seconds are good candidates for the representation of the classical signals. If EEG MEs are involved, the modulation of hippocampal theta frequency is a candidate for the representations of classical signal.

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 and ZEG 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. Positive energy Z^0 MEs could directly generate membrane oscillations and nerve pulse patterns via the general mechanism of nerve pulse and EEG discussed in [M2]. EEG MEs could in turn induce cyclotron transitions at the magnetic flux tubes of the Earth's magnetic field and induce modulations of Z^0 MEs 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 spacetime sheet A can be transferred to a smaller spacetime 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 join along boundaries bonds 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 spacetime 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 spacetime sheets (say cell membrane spacetime sheet and cell exterior spacetime 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 spacetime 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 spacetime 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 "stucking" 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.

4.1.3 Negative energy Z^0 MEs as ideal entanglers with the geometric past

Gravitational, or equivalently Z^0-, 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 Feynmann 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 Z^0 transforming to a negative energy Z^0 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 pre-cognition 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.

4.2 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 em and Z^0 MEs as the model of biophotons involving in essential manner negative and positive energy MEs suggets. Of course, this statement must be take only in the spirit of fractality and wuold 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.

4.2.1 Synesthesia as a key to the mechanism of episodal memory

What forces brain region to send negative energy Z^0 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 [H3]). Perhaps the generation of the negative energy Z^0 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 Z^0 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 naive 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.

4.2.2 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.

4.2.3 NDEs and long term memories

That negative energy Z^0 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 the Z^0 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 entanglement by Z^0 (gravitational) 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 Z^0 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 dominating p-adic-to-real phase transition changing intentions to 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.

4.2.4 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 preceided 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 havin 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 Z^0 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.

4.3 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.

4.3.1 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 Z^0 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 Z^0 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 [18] 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 fudamental frequency associated with the negative energy ME if quantum entanglement is involved, and the length of magnetic loop and curvilinear negative energy Z^0 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 Z^0 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. Z^0 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 Z^0 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 Z^0 magnetic flux loop of a given astrophycal

length scale is associated with a microtubule of a given length.

4.3.2 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 [16]. 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. Glials 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.

4.3.3 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 the Z^0 cyclotron frequencies are around 10 Hz; that the frequency of neuronal synchronal firing is about kHz; and that there seems to be no direct electromagnetic counterpart for the synchronous firing.

Quite recently it became clear that TGD predicts counterpart of Tesla's scalar waves [I4, I5]. 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 spacetime 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 (and also zelectrets) 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 Z^0 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. Zelectret sequences would ultimately give atomic nuclei kicks in a direction depending on the value of the bit.

4.3.4 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. Naive 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 multibrained 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 invididual 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 istance, 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.

4.3.5 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 Z^0 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 erranous 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.

4.4 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 [23].

4.4.1 Anatomy of hippocampal system

The anatomy of hippocampus is discussed in [19]: 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, entorhinal and perirhinal cortex and uncus. The main body of the hippocampus consists of the detante 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.

4.4.2 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 toruslike 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 [18] 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 Z^0 (gravitonic) 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.

4.4.3 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 Z^0 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 timelike quantum entanglement of parts of the electrically stimulated structures with primary sensory areas with the mediary of these loops should be involved. If the stimulation is too strong, hallucinations result. In this case the sensory

representations in thhe 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.

4.4.4 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 [17].

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 [L1]. Positive energy em and Z^0 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 Z^0 magnetization direction for cognitive antineutrinos is a further candidate for realizing the symbolic repre-

sentations. This highest level representation adding context to the other data located in the geometric past would entangle via Z^0 MEs with the brain of the geometric now in case of episodal memories. The fact that hippocampus is thought to be involved with the trassfer of items in short term memory to long term memory in cortex conforms with the mirror mechanism.

Entorhinal cortex serves as somekind 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*→ *entorhinal* → *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.

4.4.5 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 timelike 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.

4.4.6 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 interpretthem in TGD framework. Memory consolidation means the strengthening of memories by 'replaying' them. Certainly a repetion 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 [25]. 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 replayd 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 intepretation of the hippocampal theta. There are two options.

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

2. Z^0 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 rhytms 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 consciusness without an organized view about space and time categories. This applies also to the non-REM verbal dreams. Furthermore, the desynchronization 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.

4.4.7 Relationship between cortical and hippocampal EEGs

Cortical desynchronization accompanies hippocampal synchronization and vice versa. The simultaneous desynchronization of cortical and hippocampal EEGs involves distractability and hyper-responsiveness 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 desynchorized, 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.

4.5 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 [22], 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 naive 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 signicantly than some subsub....subself level at the bottom of the self hierarchy might be expected to do.

4.5.1 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 [22] 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 [22].

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 mimick 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 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 timelikequantum entanglement. MEs generate coherent photons or gravitons according to the original definition of quantum antenna [J4]. 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 longlived holistic microtubular mental images and the generation of memory representations would not occur as they should.

4.5.2 How microtubuli could relate to declarative long term memories?

For several reasons microtubuli are taylor-made for the realization of long term declarative memories in TGD Universe (the structure of microtubuli is discussed in some detail in [H8], 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. Also cognitive neutrinos could be present. 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 spacetime 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 [H8] 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 spontaneus 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 spacetime 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 microtuble 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 amnesiae 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 Z^0 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 $L_0 = 10$ μm 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.

4.5.3 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 (otoacoustic 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 maximation 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. Notice that the continual regeneration of memories with say temporal distance of $T = 15$ minutes does not seem sensical since these memories would not be received by that part of the 4-D brain which corresponds to the p-adic-to-real phase transition front. 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 subselves would have microtubular selves as subselves: 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 Z^0 ME. The process would be preceded by the emission of a p-adic Z^0 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 naive guess inspired by the right/left–holistic/reductionic 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 ageing 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 subselves or subsub....selves. If the entangled microtubuli correspond to our subselves, the microtubuli belonging to different neurons should be able to entangle with each other. This requires the presence of join along boundaries bond 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.

4.5.4 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.

5 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 the period 2004-2006 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.

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

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

The quantization of Planck constants assignable to M^4 and CP_2 degrees of freedom as integer multiples of the ordinary Planck constant is strongly suggestive in this framework and the phases with large Planck constant are interpreted as a dark matter quantum controlling ordinary matter in living matter. The average geometric durations of quantum jumps are naturally quantized as multiples of the integer characterizing M^4 Planck constant. This allows the reduction

of the notion of self to that of quantum jump at higher level of hierarchy. A strong quantitative prediction for the preferred geometric durations of quantum jumps emerges.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled sub-systems. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a justification from the quantum measurement theory for hyper-finite factors of type II_1.

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

5.2 Dark matter hierarchy

The identification of dark matter as phases having large value of Planck constant [D6, J6, O5] 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 [O5]. 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.

5.2.1 Living matter and dark matter

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

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

macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

5.2.2 Jones inclusions and quantization of Planck constant

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

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [O5]. In particular, the notions space-time as a hyper-quaternionic four-surface of imbedding space emerges.

2. One can understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to M^4 and CP_2 and appearing as scaling constants of their metrics as integer multiples of standard value $\hbar_0$ of Planck constant: $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$. This in terms of a mild generalization of standard Jones inclusions [O5]. The emergence of imbedding space means that the scaling factor of these metrics given by the scaling factor of Planck constant have spectrum: their is no landscape as in M-theory. Also the fusion of real and various p-adic variants of imbedding space along common rational (algebraic) points is involved.

3. In ordinary phase Planck constants of M^4 and CP_2 are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2,C)$ and $SU(2)_L \times \times U(1)$ which also acts as a subgroup of SU(3). Space-time sheets are $n(G_b)$-fold coverings of M^4 and $n(G_a)$-fold coverings of CP_2 generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of M^4 and CP_2 Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings.

4. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases

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

5. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimick 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.

5.3 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 [J6, M3].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the most important hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump un-necessary. It is perhaps un-necessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

The averaging of conscious experience over quantum jumps would occur only

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

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

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

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

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Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. The integer $n = 2^{k11}$, $k = 0, 1, 2, ...$ seem to define favored values of Planck constant in living matter. This means a hierarchy in which time and length scales are zoomed up by a factor of 2048 in the transition to the next level of hierarchy. This integer represents also fundamental constant in TGD Universe [D6].

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

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

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

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.

5.5 How the arrow of psychological time emerges?

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.

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

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

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

   i) Why this drifting?

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

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

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

There are also other models but these two are the ones which represent basic types for them.

5.5.2 Arrow of time in zero energy ontology

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

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the

fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

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

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

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

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

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless

extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

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

5.6 Questions related to the notion of self

I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

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

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

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

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

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant.

Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

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

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

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within

quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

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

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

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

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

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

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

5.6.2 Does entanglement mean loss of consciousness?

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

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

5.6.3 What after biological death?

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

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

5.7 Remote metabolism, long term memory, and zero energy ontology

The notion of negative energy signals and time mirror mechanism 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.

5.7.1 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.

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 eigen modes of the modified Dirac operator appearing in the first principle formulation of quantum TGD are characterized by the eigenvalues λ, which are complex. $|\lambda|^2$ has interpretation as a conformal weight mathematically analogous to a vacuum expectation value of Higgs field. There are reasons to believe that the eigenvalues relate closely to the zeros of Riemann zeta and/or its generalizations. If the eigenvalue and its complex conjugate correspond to a state and its phase conjugate, crossing symmetry fails and would mean also breaking of time reversal symmetry.

5.7.2 Is zero energy ontology consistent with time mirror mechanism

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.

5.7.3 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 [29] assigned with the two arrows of time. I learned from the work of Fantappie in SSE conference held in Röros from Antonella Vannini [30] and Ulisse Di Corpo [31].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 [H2] 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 manner to build hot spots and diversity could be reduced to NMP or whether it should be regarded as something completely independent.

5.8 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.

5.8.1 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 join along boundaries bonds 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.

5.8.2 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.

5.8.3 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 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.

5.8.4 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 manner 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 [32].

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 [32] 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.

5.8.5 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.

5.8.6 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 depen-

dent) signal having 1/f spectrum in average sense [33] (I am grateful for Vesa Kiviniemi (who is also working in this field [34]) 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.

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