Quantum Model for EEG: part II

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Abstract

In the previous chapter the overall TGD based view about EEG was discussed. According to this view, the basic function of EEG is to induce cyclotron phase transitions at the magnetic body and thus to produce what might be called higher level sensory qualia identified as emotions and cognitions. In this chapter the relationship between EEG and nerve pulse patterns is discussed in TGD framework.

The relationship between nerve pulse patterns and EEG (also ZEG) is one of the basic challenges of the theory. The question is whether nerve pulse patterns could give rise to EEG patterns and vice versa, and what could be the underlying mechanisms. The deep difference between TGD and the conventional neuroscience is the presence of the hierarchy of magnetic bodies, cyclotron transitions, and MEs. This makes possible to consider alternatives for the identification of EEG resonance frequencies as resonance frequencies of nerve circuits.

Nerve pulses generate EEG MEs and the frequency of the nerve pulses determines the rate at which EEG MEs are generated rather than the frequency of EEG MEs. Pendulum metaphor suggests how spike patterns amplify EEG waves at frequencies, which appear as resonances in the autocorrelation function of the spike sequence: when the pendulum is kicked at correct half of its period its oscillation frequency remains unchanged but amplitude and phase suffer discontinuous changes. The EEG waves generated by subsequent nerve pulses tend to interfere constructively resulting in amplification if the EEG frequency corresponds to a resonance frequency of the spike autocorrelation function.

1. Generalization of the model for sensory receptor and new view about hearing

The relationship between nerve pulse patterns and EEG (also ZEG) is one of the basic challenges of the theory. The question is whether nerve pulse patterns could give rise to EEG patterns and vice versa, and what could be the underlying mechanisms. In TGD framework on ecan consider alternatives for the identification of EEG resonance frequencies as resonance frequencies of nerve circuits and dark matter hierarchy challenges the earlier speculative TGD inspired models for sensory qualia and sensory organ. An updating of the capacitor model of the sensory receptor by replacing the capacitor with Josephson junctions between sensory organ and its magnetic body must be considered. The question arises whether sensory organs define not only sensory, but also corresponding cognitive and emotional representations. The fact that nerve pulses tend to destroy the temporal coherence of cognitive and emotional representations encourages the identification of glial cells and their magnetic bodies as carriers of higher level cognitive and emotional representations. The model of hearing leads to further ideas. For instance, the transformation of the sensory input to signals propagating along axonal microtubuli could make possible to feed sensory input into brain and possibly back to sensory organs at least in the case of vision and hearing.

2. Features

Walter Freeman has identified spatially amplitude modulated synchronous but non-periodic EEG patterns serving as correlates for conscious percepts. The identification as MEs is possible and the spectrum of durations for the synchronous time patterns encourages the interpretation of these patterns as an electromagnetic realization of genetic code words. A compression of memetic code words defined by the nerve pulse patterns giving rise to abstraction and classification would be in question. The representation would be achieved by the amplitude modulation of the alpha waves by higher harmonics of alpha frequencies. In the case of hearing the contraction seems to be un-necessary and memetic code could perhaps be realized also at the level of features. This would explain the completely exceptional role of the language in cognition.

3. Synchronization

Synchronization in and between various cortical areas is known to occur with millisecond precision. Also disjoint brain regions can be in synchrony. This is difficult to understand without synchronizing agent oscillating at kHz frequency. In TGD framework magnetic body is the natural agent inducing the synchrony and MEs could induce the synchronization. Synchronization would naturally occur at the frequency corresponding to a duration of the bit of the memetic code.

4. Stochastic resonance

Concerning the mapping of EEG frequencies to nerve pulse patterns, stochastic resonance promotes itself as a basic mechanism. In bistable systems stochastic resonance allows to amplify very weak periodic signals by utilizing white noise. Stochastic resonance is known to be relevant also at the neuronal level as demonstrated by the autocorrelation functions for spike sequences exhibiting peaks at the harmonics of the signal frequency. Neuron is however far from being bistable system, and this raises the question whether bi-stability might be present at some deeper quantal level.

5. Temporal codings

The conventional view that the information content of conscious experience is determined completely by rate coding from nerve pulse patterns does not seem plausible in TGD framework. Indeed, p-adic cognitive codes define an entire hierarchy of binary codes associated with the p-adic frequencies and frequency coding would apply only to the average intensity of the sensory input. For high stimulus intensities the duration of the bit of the p-adic cognitive codeword tends to become shorter. This is comparable to the increase of the speech rate during a high state of arousal, and conforms with the observed shift of EEG towards higher frequencies in this kind of situation. There is a lot of experimental evidence supporting the existence of various kinds of temporal codings, and these codings are discussed in TGD framework.

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1 Introduction

In previous chapter the overall TGD based view about EEG was discussed. According to this view, the basic function of EEG is to induce cyclotron phase transitions at the magnetic body and thus producing what might be called higher level sensory qualia identified as emotions and cognitions. In this chapter the relationship between EEG and nerve pulse patterns is discussed in TGD framework.

1.1 Generalization of the model for sensory receptor and new view about hearing

The relationship between nerve pulse patterns and EEG (also ZEG) is one of the basic challenges of the theory. The question is whether nerve pulse patterns could give rise to EEG patterns and vice versa, and what could be the underlying mechanisms. In TGD framework one can consider alternatives for the identification of EEG resonance frequencies as resonance frequencies of nerve circuits and dark matter hierarchy challenges the earlier speculative TGD inspired models for sensory qualia and sensory organ. An updating of the capacitor model of the sensory receptor by replacing the capacitor with Josephson junctions between sensory organ and its magnetic body must be considered. The question arises whether sensory organs define not only sensory, but also corresponding cognitive and emotional representations. The fact that nerve pulses tend to destroy the temporal coherence of cognitive and emotional representations encourages the identification of glial cells and their magnetic bodies as carriers of higher level cognitive and emotional representations. The model of hearing leads to further ideas. For instance, the transformation of the sensory input to signals propagating along axonal microtubuli could make possible to feed sensory input into brain and possibly back to sensory organs at least in the case of vision and hearing.

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Nerve pulses generate EEG MEs and the frequency of the nerve pulses determines the rate at which EEG MEs are generated rather than the frequency of EEG MEs. Pendulum metaphor suggests how spike patterns amplify EEG waves at frequencies, which appear as resonances in the autocorrelation function of the spike sequence: when the pendulum is kicked at correct half of its period its oscillation frequency remains unchanged but amplitude and phase suffer discontinuous changes. The EEG waves generated by subsequent nerve pulses tend to interfere constructively resulting in amplification if the EEG frequency corresponds to a resonance frequency of the spike autocorrelation function.

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Before continuing some words about terminology are in order. Earlier I have used to talk about em and Z^0 MEs and em MEs. This terminology would make sense in standard gauge theory framework but is misleading in TGD context

where classical fields are extremely tightly correlated so that it is not possible to have a situation in which only em or Z^0 field is present as a classical field. Same neutral ME carries both em, Z^0, and color fields and whether it looks like em, Z^0 ME, or color ME or some combination of them depends solely on the gauge charges of the particles interacting with it. One implication is that the earlier assignment of em MEs with sensory perception and Z^0 MEs with motor actions must be given up. Note however that in TGD framework p-adic and dark matter hierarchy predict hierarchy of copies of standard model physics so that also Z^0 and color interactions are predicted to be important in living matter.

2 Generalization of the model for sensory receptor and new view about hearing

Dark matter hierarchy defines a well-come challenge for earlier speculative models of sensory qualia and sensory organ, and leads to a considerably more detailed view about how sensory qualia, emotion, and cognition are related. An updating of the capacitor model of the sensory receptor by replacing the capacitor with Josephson junctions between sensory organ and its magnetic body must be seriously considered. The question arises whether sensory organs define not only sensory, but also corresponding cognitive and emotional representations. Nerve pulses tend to destroy the temporal coherence of cognitive and emotional representations, and this encourages the identification of glial cells and their magnetic bodies as carriers of higher level cognitive and emotional representations. The model of hearing leads to further concrete ideas: in particular, the transformation of the sensory input to signals propagating along axonal microtubuli could make possible to feed sensory input into brain and possibly back to sensory organs at least in case of vision and hearing.

2.1 General ideas

Consider first general ideas about sensory qualia and capacitor model of the sensory receptor stimulated by the application of dark matter hierarchy.

2.1.1 Modification of the capacitor model of sensory qualia

From the time scale of sensory experience it seems obvious that all qualia are realized at the level of dark matter. .1 seconds defines a unit of time for sensory experience which suggests that EEG relates closely to sensory qualia.

A modification of the original capacitor model of sensory receptor must be considered. In the original model the capacitor discharge was associated with the sensory receptor. The time scale .1 seconds characterizing sensory mental images would support the view that the capacitor discharge producing the sensory qualia should be assigned to the Josephson junctions at $k_{em} = 3$

level of dark matter hierarchy rather then cell membrane which corresponds to $k_{em} = 0$ level in the hierarchy of selves.

Charge entanglement by W ME would induce non-local capacitor discharges which can be regarded also as exchanges of virtual W bosons inducing exotic ionization leading to dark plasma oscillation patterns inducing various kinds of physiological activity such as Ca^{2+} waves. .1 seconds could be seen as a period of recurring plasma oscillations. Sharing of mental images by entanglement would result as a by product.

2.1.2 Selection of percepts in state function reduction

State function reduction reducing charge entanglement could give rise to the selection of percepts involved for instance with binocular rivalry involving of magnetic body in the scale of brain. This selection means that only single alternative percept need to be realized in a given branch of the multiverse. This makes possible metabolic economy: for instance, the synchronous firing at kHz frequency serving as a correlate for the conscious percept requires a lot of energy since dark photons at kHz frequency have energies above thermal threshold. Similar selection of percepts could occur also at the level of sensory receptors but quantum statistical determinism would guarantee reliable perception.

2.1.3 Also the magnetic bodies of sensory organs carry cognitive and emotional representations

Fractality forces the conclusion that also the magnetic bodies associated with the sensory organs carry cognitive and emotional representations. The level of cognition and emotion would be only lower than the cortical level and correspond to $k_{em} = 3$ most naturally. For instance, physical pain and psychological pain would correspond to emotions at different levels of the dark matter hierarchy.

An interesting possibility is that emotions and cognitions correspond to neutral gauge fields (em and Z^0 gauge fields and neutral color gauge fields) whereas sensory qualia or at least part of them would correspond W gauge fields and color charged gluon fields. Quite generally, cognition and emotions would have neutral Lie-algebra (or Kac-Moody algebra) generators as correlates whereas charged generators would correspond to sensory qualia.

2.1.4 The new view about the role of sensory receptors and glial cells

The starting point is the 4-dimensional view about gradual build-up of 4-dimensional percept as an evoked potential representing genetic, memetic or more general codon or single "note" depending on whether one considers cognitive or emotional representation.

Quite generally, sensory receptor neurons do not fire and the primary sensory input is represented as an evoked potential. That this must be the case is easy to understand if sensory receptor neurons generate cognitive and emotional

representations at their magnetic bodies based on modulations of $k_{em} = 3$ frequencies by EEG frequencies. The reason is that nerve pulse would spoil the temporal coherence of the cognitive and emotional representations by cyclotron transition patterns by taking Josephson frequency through zero to a large negative value and back to the original value. This would be like playing entire piano scale from right to left and back inducing cyclotron phase transition sweeping through a large portion of the magnetic body.

This applies also in the case of higher level emotional and cognitive representations and the only reasonable conclusion seems to be that glial cells which do not fire correspond to these representations. I have already earlier suggests this but on different grounds. Glial cells would not be mere metabolic storages but receive the metabolic energy directly because they are primary users of it utilizing it to build generalized EEG and ordinary EEG. T

he leakage of Ca^{2+} ions through sensory receptor cell membrane induced by a plasma oscillation pattern gives rise to temporal patterns of evoked membrane potential. Plasma frequency would correspond to the frequency of recurrence for these patterns. The temporal characteristics of plasma wave patterns should correlate with various codes, in particular memetic code. The same picture would apply at the level of glial cells. Neurons would us much less metabolic energy since supra currents through the cell membrane would not use much of the metabolic energy, and ionic channels and pumps would actually play the role of sensory receptors at neuronal level [J3].

2.1.5   Hearing *resp.* vision $\leftrightarrow$ electro-weak *resp.* color interactions

Hearing-vision dichotomy and weak interaction-color interaction dichotomy could correspond to each other. The sensation of hearing could correspond to the change of weak isospin resulting in W exchange. Sound-silence dichotomy ($\Delta I_3^w = \pm 1$) would be completely analogous to white-black dichotomy assignable to color isospin ($\Delta I_3^w = \pm 1$). Similar pairing should occur at the level of cognitions and emotions accompanying auditory and visual percepts and correspond to neutral weak gauge bosons and neutral color bosons.

2.1.6   The assignment of scaled up EEG with sensory organs

The assignment of $k_{em} = 3$ variant of EEG to sensory organs suggests itself. In the case of ordinary sensory qualia the scaled up 5 Hz Josephson frequency of ordinary EEG would be 10^4 Hz. If magnetic field strength associated with DNA is scaled up to .1 Tesla for these representations, alpha band is mapped to 2×10^4 Hz. Delta band for right/left brain DNA cyclotron transitions at .5 Hz/1 Hz is mapped to 1 kHz/2 kHz. Hence the identification of the 1 kHz synchronization frequency of neural firing as the scaled up cyclotron frequency of DNA must be considered.

The frequency range $20 - 2 \times 10^4$ Hz of frequencies audible by humans overlaps with the spectrum $0 - 10^4$ Hz of sferics known to correlate with consciousness. This coincidence has a natural interpretation in this picture since the $k_{em} = 3$

Josephson junctions (scaled up cell membrane thickness) would correspond to size scale of 80 m and scaled up cell size to the scale 160 km assignable to lito-ionosphere complex in the general model of EEG [M3]. Therefore hearing and also other sensory qualia cold be accompanied by low level cognitive and emotional representations resulting as EEG modulations of the frequencies above kHz: sensory organs would feel and cognize to some extent.

2.2 TGD based model for hearing

It is very difficult to understand how neural processing could cope with the fast temporal gradients of the auditory input. The basic difficulty is that the time scale of nerve pulses is below millisecond whereas the highest audible sounds correspond to frequencies of about 200 kHz for some sea mammals [25]. Also bats hear very high frequencies. The frequencies below kHz are known to be coded to spike interval distributions [49] but for higher frequencies this is not possible. The mystery is how brain receives the information about higher frequencies.

If sensory representations are realized at the level of sensory organs the problem becomes much easier. Without feedback from cortex one would however end up with difficulties: for instance, the phenomenon of missing fundamental could not be understood. Microtubular communications of sound to and from brain would allow to transform sound waves to signals propagating along axonal microtubuli. Feedback along microtubuli makes possible an active construction of percept so that phenomena like missing fundamental can be explained as being caused by spike interval distribution of nerve pulse patterns associated with feedback. The outcome is a more concrete view about hearing at the level of ear. This aspect have not been discussed in the earlier model which has concentrated on an attempt to understand the cognitive aspects of hearing [M6].

2.2.1 The anatomy of cochlea

The ear of mammals involves outer and inner hair cells [25, 26]. Outer hair cells have no axons to brain but there are efferents from cortex to them. The usual interpretation is that outer hair cells act as pre-amplifiers. They make possible feedback from cortex allowing to build sensory percepts already at the level of ear. This makes reasonable the idea that acoustic representations are indeed constructed at the level of sensory organs.

The cochlea for which piano keyboard is a good but not complete metaphor represents the phoneme as a spatio-temporal pattern. The input at a given frequency presses various keys with maximum activation at a key characterized by this frequency. The magnetic body of the entire cochlea experiences the sounds as spatial patterns of cyclotron transitions. Lower level emotional and cognitive components could emerge already here and correspond to rhythm and pitch. Meaning emerges at higher level as phonemes integrate to words and speech and associations are formed.

2.2.2 The coupling of hair cells with neurons

The coupling of hair cells with neurons mediating neuronal signals to brain is poorly understood [25, 26].

1. The transmission of neurotransmitters to postsynaptic neuron from the hair cell should be uncannily fast. The existence of unidentified very fast neurotransmitter is postulated.

2. Hair cell contains near presynaptic cleft mysterious structure with ring like shape known as presynaptic dense body. The function of this structure is not known but is believed to be crucial for the transmission of the neural transmitter.

3. There is chronical Ca^{2+} leakage to hair cell. This is also believed to be crucial for the transmission of mystery transmitter.

2.2.3 TGD based model for hearing

TGD based model hearing is inspired by the attempt to understand the meaning of the strange findings just listed.

1. It is known whether and it is difficult to understand how the audible frequencies above kHz can be coded by nerve pulse patterns. The representations based on $k_{em} = 3$ scaled up EEG suggests a solution to the problem. The fundamental sensory representations and also low level emotional and cognitive representations are realized at the level of cochlea so that there would be no absolute need to code for high frequencies by nerve pulse patterns. The representation at the level of sensory organs means that the loss of accuracy of representation due to communications with brain can be avoided. The speech and song type representations based on phonemes and sequences of notes with pitch would be realized at the level of cochlea. The feedback from cortex to the outer hair cells is essential and explains phenomena like hearing the missing fundamental.

2. The extreme rapidity of the transfer of the postulated unidentified nerve transmitter from the hair cells to the nerve axons is a mystery. The transmitter is not needed at all if microtubuli mediate the information about evoked potentials at hair cell membrane to brain as microtubular conformal patterns and/or acoustic/electric waves. Acoustic and electric waves would be both present since microtubuli are electrets.

   The transfer of auditory information from hair cells to postsynaptic neuron could occur via acoustic transmission meaning that the time lag spent in this step would be of order $\sim .1$ ns only. The reported extreme sensitivity of of the axonal signal to the evoked potential (the resolution is about $\Delta V \sim .1$ mV) [25] conforms with the view that evoked potential provides a representation of the sensory input.

The representation and communication of acoustic signals at microtubular level could induce the coding of frequencies sufficiently below 1 kHz to spike interval distributions [49]. The obvious critical question is how badly nerve pulse disturbs microtubular communications. One might argue that these perturbations do not affect conformational waves. As proposed earlier, the microtubular conformational wave patterns could be responsible for long term memories for instance. Acoustic waves could fulfill the same function.

3. The chronic leakage of Ca^{++} believed to relate to the transfer of the postulated fast transmitter. The TGD inspired interpretation would be that Ca^{++} wave is induced by the temporal plasma wave pattern and represents auditory percept cognitively/emotionally. The presynaptic dense body would be involved with the transformation of the temporal pattern represented by the time pattern of Ca^{2+} leakage to a signal propagating along the microtubule. Coupling to the microtubular conformational waves/acoustic signals could be also mechanical and the dense body could generate acoustic oscillations representing the temporal pattern of Ca^{2+} waves.

4. Mammals have two kinds of hair cells [26, 25]: inner hair cells are possessed also by lower life forms and outer hair cells only by mammals. Outer hair cells are thought to act as pre-amplifiers but TGD suggests that the deeper function of outer hair cells is to mediate auditory feedback from cortex. There are indeed efferents from cortex to outer hair cells making possible cortical feedback which sometime can create sounds audible even from outside (otoacoustic sounds).

   The feedback makes possible the realization of the experienced auditory percepts at the level of cochlea. This would explain various phenomena interpreted usually as a support for the hypothesis that sensory qualia are produced by neuronal activity. Consider only the emergence of pitch not present in the primary sensory input such as the missing fundamental when only its harmonics appear in the auditory input [49]. This feedback would of course occur also at the level of other sensory organs and rapid eye movements during REM sleep could be interpreted as being induced by the feedback from visual cortex.

The emergence of the outer hair cells increases the span of audible frequencies. For sea mammals 200 kHz which corresponds to 100 Hz for ordinary EEG. This would be just what would be needed for the representation of memetic codons or EEG patterns as amplitude modulations. This would mean emergence of a new symbolic level distinguishing mammals from lower levels in the evolutionary hierarchy. For frequencies below few kHz, say 3 kHz only pitch representation makes sense. Single formant vowels for which formant frequency is sufficiently below 1 kHz would have representation also as nerve pulse patterns.

Hair cells communicate with cortex using sequences of "phonemes" or "notes" defining amplitude modulations of frequencies above few kHz. At this limit

modulation preserves the pitch so that durational and pitch representations are mutually consistent. This explains the unexpected finding that same brain regions, prevalently in right hemisphere, are responsible for the analysis of pitch and durational patterns [27]. Only frequency representation would be realized at the lower frequencies so that the presence of cognitive and emotional amplitude modulations at the level of cochlear would distinguish mammals from lower life forms.

2.2.4 Why microtubuli are needed?

The time pattern represented by Ca^{2+} leakage to the inner hair cell could be transferred to the postsynaptic axon and transformed to a signal propagating along the axonal microtubuli. An interesting hypothesis is that left brain utilizes phoneme sequences and right brain note sequences. Also the signals from auditory cortex to the outer hair cells would propagate along axonal microtubuli.

The signals would propagate with a velocity which could be faster than the conduction velocity of nerve pulse and constant to a very high degree unlike the conduction velocity of nerve pulse. The measurement of a time lag of order millisecond for signals arriving to the right and left ear using co-incidence detectors in the brain stem (medulla oblongata) allows to determine the direction of the sound source. The typical time interval between nerve pulses varies and is somewhat more than millisecond, and is not at all clear whether nerve pulse conduction can preserve the time differences accurately enough to allow their meaningful comparison. If the signals from cochlea to brain stem propagate along microtubuli the situation could improve.

2.2.5 Memetic code, and genetic code as a representation of phonemes?

The average duration of phonemes is about 140 ms, which is by a factor $\sqrt{2}$ longer than the duration .1 seconds of the memetic codon. Durations vary in the range 60-300 ms. Note that the 250-300 Hz rhythm associated with speech organs defines the pitch of speech but phonemes can be recognized even in the absence of the fundamental. The basic pitch of about 250 Hz implies that the number of memetic codons associated single single period is at most 2.

Phonemes can be classified by the vocal tract mechanism generating them and phonemes can be also recognized by their spectral decomposition.

1. Formants [23, 24] correspond to vowels, approximants (say (r,l) and (j,w)) , and nasals (m and n). Only few resonant frequencies are needed to characterize the formant. Lowest formant is below 1 kHz but higher formants above kHz and frequencies up to 3 kHz are possible. It is easy to understsand that for vowels the frequency distribution does not depend on time for approximants and nasals it does.

2. Fricatives (hiss, buzz). Fricatives lack the formant structure. Both correspond to a repeated time amplitude peak and frequency distribution involves wide range of frequencies with same intensity.

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3. Plosives (such as p,b and t,d) correspond to a single peak in the time domain and constant frequency distribution.

All sensory input might be transformed by a feedback circuit to sequences or notes/memetic codons represented as a modulation of the membrane voltage providing a universal cognitive/emotional representations. Also ordinary phonemes and notes would be represented in this manner. Sensory organs correspond naturally to $k_{em} = 3$ level of dark matter hierarchy since .1 seconds represents the basic unit of sensory time. Therefore memetic codons modulating scaled up EEG at $k_{em} = 3$ level would be a good guess for how the sensory input is represented cognitively.

Also other p-adic codes are possible. Phonemes, the number of which is 41 in American english, could correspond to a sub-code reducing to a genetic code with 64 codons. It is important to notice that the temporal distance between memetic codons does not matter. Other memetic codons could code for recognizable sound patterns not representing phonemes and could have meaning at some other levels of self hierarchy.

One can argue that the representations as "notes" and "phonemes" should carry roughly the same amount of information. For frequency representation as sequence of "notes" 10 octaves represents upper limit for the modulation frequencies. For high modulating frequencies the representation tends however to fail since slow modulation is not anymore in question. This would mean that the number of distinguishable "notes" is below $10 \times N$, where N is the maximum number of distinguishable frequencies inside octave. $N = 12$, the number of half notes in octave, would give 120 different "notes", which is not far from 127 and corresponds to M_7 allowing $2^7 - 1$ different codons making almost 7 bits with bit duration of 67 ms. Since the first codon in pulse-no pulse representation must be always pulse to tell that the codeword starts, this leaves 6 bits and genetic code. Codons can have varying but long enough pauses between them and the average duration .14 s of phonemes allows this. The association of genetic or memetic codons to characteristic spectrograms of phonemes as a function of time and frequency would result by cortical feedback.

p-Adic cognitive codons could be also 2-adic fractals in the sense that the octaves of the fundamental p-adic frequency $f(n, k)$ would correspond to the frequencies coding for bits. This would give rise to a very robust representation. In the case of memetic code this would mean that the frequency range $10 - 10^3$ Hz dictated by the time scale 1 ms of nerve pulse activity would contain 6 octaves meaning an effective reduction of the memetic code to 6-bit genetic code. The prediction would be that the frequencies 10,20,40,80,160,320,640 Hz are in a special role in neural dynamics.

2.3 Some examples about deficits of color vision as a test of the model for cognitive representations

The article "Quining the Qualia" by Daniel Dennett gives [31] a good view about the difficulties encountered as one tries to understand qualia as a philosopher.

Dennett's reaction to the problems is to give up the notion of qualia altogether. To me this is like denying the causal role of consciousness just because we do not have mathematical and conceptual tools to describe it. This is however not the main point now. Dennett lists some fascinating empirical findings related to deficits in color vision, which serve as excellent tests for any theory of qualia.

It is instructive to consider these examples in the framework provided by the model of cognitive representations just discussed. For this purposes let us list the basic general assumptions of the model in the case of color vision.

1. Assume that color capacitor discharges occur between cones/rods and the corresponding magnetic body. The paradoxical fact that receptor cells hyper-polarize rather than depolarize as they receive light is consistent with the requirement that incoming light must increase the color voltages between cone system and its magnetic body in order to generate color discharge. Rods would differ from cones in that the full color algebra $SU(3)$ to its sub-algebra $SU(2)$ so that only the increments of color isospin I_3 would be perceived and would give rise to black and white as primary qualia. Thus only charged $SU(2)$ gluons are exchanged between the magnetic body associated with the rod system.

   In the case of cones the most natural assumption is that all 3+3 colors (black and white are counted as colors) are perceived and correspond to increments of color isospin and two generators carrying hyper charge. Single cone could be specialized to produce up the increment of color quantum numbers corresponding to a particular primary color. The increment of color quantum numbers should always have the same sign in the ideal situation (only quale which is red or green, blue or yellow, black or white is produced if the highest weight or lowest weight states of the representation of color algebra (or color Kac-Moody algebra) define the ground state of the system.

2. Cortex is assumed to participate actively to the coloring of the sensory map by using back projections to retina and the experienced color map is an outcome of a complex information processing.

3. The magnetic bodies of retina would contain regions where colors are cognitively represented as an analog of color circle so that the over all color sensation generates cognitive and emotional representations as a "somatosensory" experience at the magnetic body realized as cyclotron phase transition patterns. Pure colors would correspond to patterns localized at single point of the magnetic body whereas mixed colors would correspond to delocalized patterns.

2.3.1 First example

Objects to the right of the vertical meridian appeared to be of normal hue, while to the left they were perceived only in shades of gray, though without distortions of form... He was unable to recognize or name any color in any portion of the

left field of either eye, including bright reds, blues, greens and yellows. As soon as any portion of the colored object crossed the vertical meridian, he was able to instantly recognize and accurately name its color.

This finding could reduce the plausibility of the hypothesis that sensory organs are seats of sensory qualia and of primary cognitive and emotional representations. The hypothesis passes the test. Retina decomposes to nasal and temporal retina. This corresponds to the decomposition of the visual field of retina to right and left hemifields [32]. The inability to recognize and name colors in the left visual could be simply due to the fact that cones sensitive to color are not functioning properly or at all in the left temporal and right nasal retina. A more complex situation would results if parts of cortex responsible for the back projections to the left visual field want to "see the world as grey" and actively reduce the color map to the shades of grey.

2.3.2   Second example

The patient failed in all tasks in which he was required to match the seen color with its spoken name. Thus, the patient failed to give the names of colors and failed to choose a color in response to its name. By contrast, he succeeded on all tasks where the matching was either purely verbal or purely nonverbal. Thus, he could give verbally the names of colors corresponding to named objects and vice versa. He could match seen colors to each other and to pictures of objects and could sort colors without error.

What was remarkable that the patient was not aware of any deficit.

There is an obvious analogy with the phenomenon of absolute ear. Almost anyone can tell whether two notes have the same pitch but only people with absolute ear learn to name the heard note. In the case of color vision almost all of us have "absolute eye" in the sense that we can recognize the perceived color and name it but in the above described case this ability would be lost. The analogy is weakened by the fact that musicians not possessing absolute ear are quite well aware of their "deficit".

Accepting the analogy, the TGD based model for absolute ear generalizes as such to the recent situation. The model of absolute ear is based on a comparison in which reference dark photon signal is sent from the temporal planum [29] to the magnetic body assignable to the cochlea. Recognition relies on the constructive interference of the dark photon signals from cochlea and temporal planum enhancing the rate for the cyclotron phase transition. This model generalizes to a general model for how conscious pattern recognition occurs at the level of the magnetic body and applies in the case of vision too.

1. There should exists a region of visual or associative cortex analogous to the temporal planum sending a dark photon signal to the magnetic body of retina ($k_{em} = 3$ corresponds to the level of dark matter hierarchy also now).

2. That the patient is not aware of the syndrome suggests that the reference signal representing given name of color as actual color is sent but goes to a

"wrong address" at the magnetic body and is not compared with the real signal. If the cognitive "color circle" correspond to a small portion of the magnetic body as the general model for cognitive representations suggests, the resonance could indeed occur at wrong position of the magnetic body receiving different kind of cognitive input.

2.3.3 Third example

One morning in November 1977, upon awakening, she noted that although she was able to see details of objects and people, colors appeared "drained out" and "not true." She had no other complaint... her vision was good, 20/20 in each eye... The difficulty in color perception persisted, and she had to seek the advice of her husband to choose what to wear. Eight weeks later she noted that she could no longer recognize the faces of her husband and daughter... [So in] addition to achromatopsia, the patient had prosopagnosia, but her linguistic and cognitive performances were otherwise unaffected. The patient was able to tell her story cogently and to have remarkable insight about her defects.

This case could be understood as the failure of the back projection mechanisms making possible coloring of the percept and the generation of the caricature like percept allowing recognition of faces. Also the recognition of faces could rely on the resonance mechanism in which signal is sent from cortex to an appropriate magnetic body.

These examples should demonstrate that the TGD based notion of qualia combined with the general model for cognitive and emotional representations can easily explain the findings discussed in [31].

3 Features and synchronization

The model for sensory receptor discussed in the previous section is inspired by the general vision for how magnetic body controls biological body and receives information from it. The model generalizes straightforwardly to a model of features. What is new that features would most naturally be induced by W MEs affecting glial cell groups which in turn would induce the synchoronous neuronal firing.

Cyclotron phase transition at appropriate magnetic body induced by cyclotron and Josephson radiation generated by the corresponding biological body defines the feature. The cyclotron frequency in associated with scaled up EEG at $k_{em} = 3$ level of hierarchy for which alpha band is mapped to 2×10^4 Hz. The modulated cyclotron frequency could place code a position of the representation at magnetic body representing some geometric quantity, say the distance of the object of perceptive field. The temporal modulation pattern of the amplitude of cyclotron radiation by some EEG frequency in turn would define the feature assigned at this position. One can distinguish between speech and song like features responsible for cognitive and emotional aspects of perception. Also spatial modulation is present but temporal pattern is same at all points of feature.

Genetic and and perhaps even memetic codons with duration of .1 seconds are good candidates for the "phonemes" of speech like features. Recurring feature corresponds to a plasma oscillation with frequency below 10 Hz generated by the charge entanglement by W ME inducing exotic ionization. Ca^{2+}, Mg^{2+} and possibly also other bosonic ion waves are physiological correlates of the features.

1 kHz synchronization frequency reduces in this picture to DNA cyclotron frequency associated with the scaled up variant $\lambda B \simeq .02$ Tesla of the magnetic field $B = B_{end}/2 = .1$ Gauss assignable to the right brain hemisphere and having cyclotron frequency .5 Hz and carrying single flux quantum $h_5 = 5h_0$. Also 2 kHz synchronization frequency is highly suggestive. The dark photons of this radiation could result as DNAs drop to excited cyclotron states at the magnetic flux sheets traversing through the sequences of DNA double strands defining lines of a page of a book represented by the flux sheet. The text line has an interpretation as a supergene expressed collectively during synchronous firing.

Also fractally scaled up variants of features with duration of short term memory and realized as modulations of EEG frequencies are predicted with alpha band taking the role of 1 kHz synchronization. Scaled up variants of memetic/genetic codons would code for information now. In this case the size scale of the features would be $\lambda \times .02 = 40$ m suggesting that collective mental images involving several brains are in question.

3.1 Features

The notion of p-adic cognitive representation seems to have an impressive explanatory power. These representations are however local in the spatial degrees of freedom, and the further challenge is to understand how the p-adic codons from various points of cortex are combined to more complex features/symbolic mental images. The work of Freeman with odor perception gives valuable guidelines in this respect [36]. The findings of Freeman suggests that neurons in a given cortical area define temporally synchronous patterns, features. The temporal synchrony would mean that all spatial points correspond to the same p-adic codon in the temporal domain. There is however an arbitrary dependence of the feature on the two transversal coordinates of the cortical surface for a given time value. Hence the situation is 3-dimensional but the third dimension is time rather than space.

Also for MEs it is possible to choose arbitrarily the behavior of the field pattern on the coordinates of the 2-D transversal cross section of ME. Temporal coherence in turn corresponds to the arbitrary but synchronous dependence of the field pattern on the temporal coordinate at this cross section. Thus MEs are ideal for the communication of the information contained by features to the magnetic body. The following discussion is restricted to the memetic code but generalizes to all p-adic codes in an obvious manner.

3.1.1 Features as AM modulated EEG patterns

The coherence lengths for EEG inside cortex are in general much shorter than on the surface of the skull and complex patterns are encountered. In particular, synchronous cortical EEG patterns with coherence length of order 1-2 cm appear (size of Brodmann's areas). Freeman identifies these patterns as basic units, "features", of perceptual activity (the activity related to subjective experience rather than sensory input) [36], and calls these patterns mesoscopic activity as opposed to the microscopic activity represented by nerve pulse patterns. According to Freeman these patterns are observed besides olfactory bulb also in visual, auditory and somatic cortices.

These synchronous EEG patterns have a non-periodic time dependence which does not depend on position: this would be consistent with the frequency coding of the time span of declarative memory. The amplitude is spatially amplitude modulated. The AM patterns are measured at two-dimensional surface so that the question whether the spatial amplitude modulation is 3-dimensional or 2-dimensional remains open. The patterns are recurring 2-7 times per second, which corresponds to theta band in frequency space. This conforms with the assumption that memories are coded by the same features as direct experiences and that carrier frequency is in theta range unlike for purely symbolic representations of sensory experiences for which it is in gamma range. The duration of the patterns is $T = 80 - 120$ ms.

3.1.2 MEs as AM patterns representing features

W MEs as realizers of the generalized motor actions of the magnetic body inducing plasma oscillations and ionic waves are excellent candidates for inducers of AM patterns. They would have transverse cross section of about 1-2 cm. Note that 2 cm corresponds to the scaled up thickness of the lipid layer of cell membrane at $k_{em} = 2$ level of dark matter hierarchy. On the other hand, the thickness for the magnetic flux sheet with field strength of .05 Tesla implied by the identification of 1 kHz frequency as cyclotron frequency of DNA is $L(149) = 5$ nm and corresponds the thickness of the lipid layer.

MEs allow arbitrary direction and magnitude of transversal polarization and arbitrary time dependence which does not depend on position. 2-dimensional instead of 3-dimensional AM patterns are predicted. Note that MEs in question are like light fronts going through the two-dimensional surface where the measurement is performed. One might argue that the character of MEs as topological field quanta of classical radiation means that they are not sufficiently general to model the nearby ELF fields in brain. This might be the case. On the other hand, the solution ansatz defining MEs is extremely general [J4]. In geometric optics picture this means that paths of light rays inside MEs can be also curvilinear light like curves expressible as gradient lines for a Hamilton Jacobi functional S whereas the transverse polarization is defined by a gradient of a polarization function E.

3.1.3 Genetic code and odors

The interpretation of AM patterns as sub-selves representing standardized mental images is natural. The average duration of these sub-selves is of 100 ms which is the duration of the memetic codeword [L1]. According to Freeman, the time dependence of AM patterns is chaotic: this does not however mean that it is random. That also time coding is involved looks plausible because both temporal and spatial patterns of nerve pulses are crucial for the neural coding of odors [46].

The first thing to come in mind that temporal patterns correspond to memetic code words having length of almost 127 bits ($2^{127} - 1$ patterns are possible) with bits represented by a pulse or absence of it. The presence of pulse would correspond to some minimum intensity of field. The first bit would be always 1 to signify the beginning of the codon which would give 126 bits. Also a formal representation as superpositions of Fourier components with frequencies $f_n = n/T$, $n = 1, ..., 127$ with coefficients can be considered but would not be so natural than pulse representation.

There are however some objections against this identification.

1. p-Adic length scale hypothesis would predict duration of 100 ms for AM patterns representing memetic code words. The length variation for MEs is however possible and 100 ms MEs predicted by p-adic length scale hypothesis could be interpreted as resonant MEs in this picture, ELF frequency counterparts of on mass shell particles whereas other durations would correspond to off-mass shell 'virtual' MEs. This interpretation is consistent with the generalization of the ideas of Jaynes [N5, N6].

2. That memetic code could be represented also in terms of MEs conforms with the computer metaphor which suggests myriads of representations of the memetic code. On the other hand, the highest frequency involved would be of order kHz and outside EEG range. Furthermore, AM patterns should represent abstraction and classification of temporal nerve pulse patterns associated with the memetic code words.

The simplest thing one can imagine is that a compression of the $2^{127} - 1$ neuronal memetic codewords to genetic code words having length of 7 bits giving 127 code words occurs: in this case the the highest frequency would be in the range $58.3 - 87.5$ Hz which relates very naturally to the EEG frequency range and is above the 40 Hz band and various lower bands related to the place coding. One can argue that just as at DNA level only the 64 mutually consistent Boolean statements amongst the $2^7 - 1 = 127$ Boolean statements are realized physically.

Genetic code could be also realized as nerve pulse patterns. This option looks natural in the case of rate coding with almost random time intervals between nerve pulses. If stochastic resonance forcing the autocorrelation function of the nerve pulse pattern to have peaks at the multiples of the forcing frequency is involved, then the number of distinguishable code words would be also around 64. Also the discrete values of the pulse rate varying from 0 to 64 pulses per .1 seconds could define genetic codons.

3.1.4 Magnetic representation of the genetic codewords

Genetic code for odors is consistent with the assumption that the modulation frequencies are in the range $20 - 80$ Hz. The cyclotron frequencies of all biologically important ions including DNA are above 1 kHz so that amplitude modulations at EEG frequencies are slow.

The modulated cyclotron frequencies would naturally represent carrier waves coding for some geometric data, for instance the distance of the object of perceptive field on the sensory magnetic canvas. This prediction could be tested by looking whether the attention directed to a moving object is accompanied by a shift of some cyclotron frequencies.

EEG waves with well defined frequencies would have interpretation in terms of frequency coding by sequences of "notes" whereas chaotic EEG waves such as beta waves might be assignable to the speech like representation. For "note" representation trivial code word would correspond to a mere alpha wave modulation. Alpha wave begins to dominate when eyes are closed which suggests alpha wave modulation represents "no sensory input". In the case of vision alpha wave would assign the color quale black and the mental image "darkness" to the region of the perceptive field. In the case of hearing the trivial codeword would represent the experience of silence, something different from the absence of auditory experience.

3.1.5 Data compression as frequency cutoff and threshold coding

Some comments about the compression process and about the plausibility of the representation of Boolean statements at the level of conscious experience are in order.

1. The compression process simply drops away the bits corresponding to the frequencies above 80 Hz. This kind of frequency cutoff is precisely what is carried out in quantum field theories when the effective action for low energy theory is constructed. Technically this means functional integral over the frequencies and wavelengths above the cutoff frequency and cutoff wavelength. Thus brain would apply the counterpart of the same procedure as quantum field theorist or statistical physicist uses to build simplified models applying in time and length scales above the inverse of the cutoff frequency and cutoff wavelength.

2. The values of the EEG potentials need not be discrete to yield bit representation at the level of the conscious experience if magnetic quantum phase transition is induced only if the intensity of the oscillatory magnetic perturbation defined by ME is above certain threshold value. Threshold coding is actually what is expected since phase transitions should occur as a kind of domino effect. There is also an upper bound for the harmonics of the cyclotron frequency which can be amplified to a macroscopic quantum phase transition. This yields automatically frequency cutoff even in absence of a frequency cutoff for EEG waves.

3.2 Synchronization

Cognitive functions like perception, memory and language are based on parallel and highly distributed information processing. One of the major unresolved questions of brain science is how the information can be integrated and how coherent representational states can be established. Temporal binding has been suggested as a mechanism making this possible. The synchronized neuronal firing has been proposed as an underlying mechanism of temporal binding inside and between various cortical areas. The assemblies of neurons firing synchronously could even define neuronal correlates for objects of perceptive field. Synchrony mechanism would apply also to motor actions and allow selection of perceptually and behaviorally relevant information. Temporal binding has been proposed by Crick and Koch as a necessary and sufficient condition for the generation of conscious percepts.

In TGD framework the synchronously firing neuronal assemblies are excellent candidates for sub...selves. Synchrony should result from the presence of a TGD counterpart of a computer clock ticking with a frequency of order kHz associated with the memetic code.

3.2.1 Temporal binding by synchronization

The article of Engel *et al* [37] provides an excellent representation about the development, motivations and the recent empirical status of temporal binding by neuronal synchrony. The article contains also references to the original work and the references to the results represented below can be found from this article and are not separately mentioned.

There are many reasons why for binding by synchronization.

1. Synchrony provides the counterpart of computer clock making possible a precise presynaptic summation of the neural inputs in turn implying fast and precise and fast neural processing. Synchrony makes also possible coordinated changes of the synaptic efficacies: this is of obvious importance for the associative learning at synaptic level. Also the robustness of neural processing is implied: army does not need single man.

2. Synchronized neuronal assemblies define natural candidates for the neural correlates of conscious percepts and synchronization might be a basic mechanism of attention.

3. The information processing in brain is known to be highly parallel and distributed: for instance, there are about 30 distinct visual areas in monkey brain. Synchronization between various sensory, motor and associative areas has been proposed as a candidate for the mechanism generating coherent gestalts.

4. Synchronization has been proposed as key element for functions like learning and short term memory. Quite generally, it seems that non-synchronized

brain regions are analogous to a computer without a global computer clock and thus seats of neural chaos.

5. Synchronization has been also suggested by Crick and Koch to be a necessary and sufficient condition for conscious experience to occur. From the TGD point of view and on general philosophical grounds this hypothesis seems to be too far-fetched. Rather, synchronization seems to provide the counterpart of computer clock in TGD framework feeding order in neuronal chaos. Synchronized regions define however natural correlates for sub...selves.

3.2.2 Empirical evidence for synchronization

Neuronal synchronization is by now a well established phenomenon (see [37] and references therein).

1. Synchronization inside and between sensory, motor and associative areas has been established. Synchronization has been observed also inside subcortical structures such as lateral geniculate nucleus, superior colliculus and brain stem and even in retina [37]. Synchronization has also found even between areas belonging to different hemispheres.

2. Synchronization in visual system predicts synchronization inside visual areas and between areas icro-ss large cortical distances. These predictions have been verified. For instance, two neurons fire synchronically only if they respond to the same visual object but not otherwise. It has been found that the basic criteria for the gestalt formation (such as continuity and coherent motion), shown to support by perceptual grouping, are also important for the formation of a synchrony between the neurons of the visual cortical. Synchronization has been studied also in non-visual modalities: synchronization in the olfactory systems of various vertebrate and invertebrate species has been found and both auditory and somatosensory cortex has been demonstrated to show precise synchronization. Synchronization has been observed also in hippocampus and frontal cortex.

3. Synchronization has been observed in motor areas and between areas of sensory and motor system. For instance, the study of cats performing visuomotor tasks has shown that the synchronization between visual and parietal as well as visual and motor areas occurs in those task epochs where the animal processes attentively information to direct the required motor response.

4. Synchronization seems to serve as a neural correlate for conscious percepts [37]. For instance, in binocular rivalry, the neuronal activity in V1 does not change when the consciously perceived stimulus changes. However, highly synchronous firing is what distinguishes the perceived stimulus from the non-perceived one.

In TGD framework this would mean that the entanglement with magnetic body serving as the correlate for the directed attention would have synchronization as a neural correlate. The interpretation would be that without synchronization no coherent cognitive or emotional mental image is formed at the magnetic body.

Charge entanglement involving W MEs makes possible superpositions of several sensory percepts and state function reduction would select one of them. The possibility to build quantum superpositions of alternative percepts means metabolic economy since only single percept need to be realized in a given quantum parallel universe. The selection of percepts in binocular rivalry might be a basic example about state function reductions at the level of perception. Information processing resembling quantum computing could be realized using quantum superpositions of nerve pulse patterns. Same picture applies also to motor action. When a large number of similar systems (say sensory receptors) is involved, quantum statistical determinism guarantees reliable perception.

EEG and MEG studies demonstrate that high frequency components of sensory evoked potentials exhibit precise neuronal synchrony in the awake state but disappear in deep anesthesia [37]. The interpretation would be that 1 kHz frequency results as generalized motor actions absent during anesthesia induce the dropping of ions to magnetic flux sheets carrying .05 Tesla magnetic field.

Also gamma synchronization is enhanced during arousal and focused attention as well as during a conscious perception of distinct auditory events and of coherent visual stimuli during attentive visual search. The interpretation would be that this synchronization is related to the next level of the dark matter hierarchy, that is to the modulations of ordinary EEG amplitudes by $k_{em} = 5$ level EEG representing short term memories. In particular, the synchronous firing at 40 Hz frequency would correspond to this level and a hopefully testable prediction is that the modulations of 40 Hz frequency code for cognitive and emotional content.

3.2.3 What is the dynamics of volition and thought?

The proposed simplified view leaves open some fundamental questions which basically relate to how the geometric correlate of intentional action identified as p-adic–real transformations for space-time regions takes place at brain level. There are two basic questions.

1) How the dynamics of thought generation is realized?
The understanding of the feedback from the sensory (real) level to the cognitive (p-adic) level is required. More precisely, how sensory (real physics) input is transformed to cognition if the latter indeed involves the generation of p-adic MEs? There are also questions related to the role of neutrinos. What is the role of the spin flips of real cognitive neutrino pairs proposed to represent memetic codewords in this process [M6] but not discussed in this chapter at all? Are also cognitive neutrino pairs needed? Recall that cognitive neutrino-antineutrino pair is identified as neutrino and antineutrino located at the opposite throats of a wormhole contact. The throats are quite generally identified as light-like 3-surfaces carrying parton quantum numbers. The question is basically about

whether this kind of nearly zero energy particles existing simultaneously at two space-time sheets are important for the understanding consciousness and living matter.

2) How the dynamics of volition is realized?

Typically, the transformation of p-adic W MEs representing intentions to real ones connecting magnetic body to some part of the cortex, presumably glial cell group, induces synchronous neural firing exciting or inhibiting some other regions. In excitatory case this should somehow lead to a cascade in which lower level p-adic MEs of excited regions are transformed to real ones. The basic question is what mechanism induces the transformation of the p-adic MEs to real ones.

p-Adic length scale hypothesis suggests that some kind of a resonance dynamics possible at kHz resonant frequency and involving a feedback between p-adic and real physics is involved. This leads to the following view about what is involved with volitional action and in the generation of thought.

1. Volition would be volition of the personal magnetic body and induce a cascade of volitional acts transforming p-adic MEs to negative energy real MEs in shorter length and time scales. p-Adic-to-real transformation of negative energy W ME could occur with a high probability when p-adic W ME oscillates with a frequency which corresponds to the duration of the bit of the p-adic code word which is related to an appropriate dark matter level and p-adic length scale in a simple manner. When out of tune, p-adic negative energy ME would transform to a real ME with a low probability.

   This would suggest the realization of volition by frequency tuning. Tuning would mean that p-adic and corresponding real ME would have a maximum number of common rational points. Volition is involved also with the selection between percepts (not always by us however) in situations like binocular rivalry. The difference of an imagined almost real motor action and actual motor action would be that the imagined motor action is not induced by the negative energy ME entangling with motor organs but with some higher level of motor pathways. For sensory imagination entanglement would also occur with some higher level of sensory pathway than sensory organ.

2. One can wonder whether also real-to-padic phase transitions could occur and whether the dynamics of thought could the reversal for the dynamics of volition. Again synchronization and resonance condition would be important. p-Adic length scale hypothesis favors synchronization frequencies which correspond to p-adic length scales. If this picture is correct, volition and thought would be in well a defined sense time reversals of each other with respect to subjective time development.

3. The counter intuitive aspect of the p-adic topology is that p-adic space-time sheets having arbitrarily large size in real sense can be arbitrarily

small p-adically. Hence p-adic space-time sheet of infinitesimal size could have contact with systems separated by a real distance of the order of the size of the observable universe and even larger. If the energy of negative energy ME is by quantization argument of the order $E = 2\pi c/L$, negative energy ME of astrophysical size can result with very low energy costs as p-adic ME is transformed to a real one. These paradoxical aspects are however consistent with the view about the role of magnetic body and MEs for consciousness, and the attempt to deduce in detail the implications might be very rewarding.

3.2.4 A general view about the role of synchrony

The hypothesis that synchronization is due to the presence of MEs suggests the following general view about how conscious brain functions.

1. The basic states for the various areas of brain could represent more or less chaotic neuronal activity without synchrony. During sleep primordial neuronal chaos might be realized in the scale of the entire cortex.

2. p-Adic W MEs representing intentions and these would transform to real negative energy W MEs and represent desires inducing generalized motor actions. Negative energy W MEs would select from the sea of cortical chaos islands of order and generate objects of perceptive field or behavior (by sensory-motor analogy one might perhaps speak of "behavioral field") realized as sub-selves. W MEs would obviously feed negentropy to the neuronal primordial chaos and generate macro-temporal quantum coherence and thus sharp sub-selves lasting for a sufficiently long time to contribute significantly to the contents of consciousness and behavior (note the analogy with a social group: very short-lived member does not contribute significantly to the development of the social group).

3. The question whether there exist non-neuronal correlates for consciousness is definitely settled in this framework: they do exist and correspond to both p-adic and real charged and neutral MEs both in the sense of electro-weak and color interactions and the synchronous firing of neurons provides a direct experimental evidence for these correlates visible already at the primary sensory areas.

4. The mesoscopic feature level visible in EEG and reflecting the synchrony MEs could represent a higher abstraction level in which memetic code words are compressed to the genetic code.

Summarizing, this view combined with the general vision about the realization of the various representations represents a reasonably coherent vision about how magnetic body controls brain. There remains of course challenges even at the level of principle. The question whether p-adic-to-real transitions and their reversals really make sense and occur is one of them. The fact that inertial energy is not positive definite in TGD Universe makes in principle possible this kind of transitions.

4 Stochastic resonance and brain

This section begins with the review of the notion of the stochastic resonance. Also its applications to neuronal systems are reviewed. With motivations coming from conceptual difficulties of the proposed neuronal models, a reduction of the stochastic resonance to the quantum level, which is assumed to control the functioning of bio-systems, is developed by refining the quantum model for nerve pulse generation by specifying the interaction with MEs. Another key idea described in detail in [J2] is that bio-systems correspond to flow equilibria for ions in the many-sheeted space-time with atomic space-time sheets having the role of a controlled system and super-conducting space-time sheets taking the role of the controlling system. The possibility that MEs generate by stochastic resonance soliton sequences associated with Josephson currents, is discussed.

4.1 Stochastic resonance

Background noise is usually seen as a mere nuisance in communications but under certain circumstances it can in fact improve, rather than hinder the performance. The notion of stochastic resonance [18] was originally put forward by Benzi and collaborators [19] in seminal papers where they study the problem of the periodically recurrent ice ages. The same suggestion was raised independently by C. Nicolis and G. Nicolis [20]. The planetary glaciation sequence has a period of about 10^5 years which happens to be same as the period of the planetary gravitational perturbations with a typical time scale of 10^5 years inducing an extremely small (of about .1 per cent) periodic variation of the solar constant which as such cannot explain ice ages. The system is modelled by a bistable potential in which the two potential wells represent the ice-covered Earth and the normal climate. Short term climate fluctuations are modelled by white noise and if the intensity of the white noise is correct, the weak periodic variation of Earth's temperature is amplified to a synchronized hopping between cold and warm climates.

The notion of stochastic resonance has been considerably generalized to include a number of different mechanisms. The unifying features are the increased sensitivity to small perturbations and phase locking for an optimal noise level. Stochastic resonance like features have been reported also for autonomous systems. Also the quantum version of the stochastic resonance taking into account quantum tunnelling has been studied. Stochastic resonance has been also generalized to coupled (that is higher-dimensional) systems and to excitable systems allowing only single stable state and meta-stable states. The interested reader can find references to the rich literature about stochastic resonance in [18].

Stochastic resonance has been verified for a wide variety of system such as Schmitt trigger, bistable ring laser, electron paramagnetic resonance, and super-conducting quantum interference devices (SQUIDs) [18]. An especially important application is to neuronal systems [21].

4.2 Basic model for stochastic resonance

The archetypal model of stochastic resonance involves a one-dimensional system equivalent with a particle with mass m moving in a double potential well

$$V(x) = -ax^2/2 + bx^4/2$$

under a friction force $\gamma dx/dt$ proportional to velocity, a weak periodic external driving force $A(t) = A_0 sin(\Omega t)$, and a random force which can be modelled as a white noise $\xi(t)$ with vanishing mean and correlation function

$$\langle \xi(t_1)\xi(t_2) = 2D\delta(t_1 - t_2) \ .$$

Here the parameter D characterizes the noise level.

The noise could be also a more general colored Gaussian noise with ultra-violet frequency cutoff. The fluctuational forces cause transitions between the potential wells with a rate given by the Kramers rate [22]:

$$r_K \quad = \quad \frac{\omega_0\omega_b}{2\pi\gamma} exp\left[-\frac{\Delta V}{D}\right] \quad . \tag{1}$$

Here $\omega_0^2 = V''(\pm x_m)/m$ is square of the frequency of small oscillations at the bottom of well and $\omega_b^2 = -V''(x_b)/m$ is an analogous quantity estimated at origin which correspond to the maximum of the potential. ΔV denotes the height of the potential barrier separating the two minima.

If a periodic spatially constant force is applied to the particle, it induces a periodic variation in the shape of potential. At a given well the minimum of the potential barrier occurs periodically with frequency Ω and if the particle hops to second well when barrier height is minimum it experiences minimum height barrier in the second well after a half period. If the white noise is such that the rate r_K is twice the frequency Ω:

$$r_K \quad = \quad 2\Omega \ , \tag{2}$$

the rate for the jumps between potential wells is synchronized with the periodic variation of the external force. One can understand this relationship intuitively on basis of the previous simple observations.

Stochastic resonance is manifested as a phase locking of $x(t)$ to the external force and as maximum of the average amplitude as function of the parameter D characterizing the noise level when the resonance condition is satisfied. In linear response theory, which is appropriate when the condition $A_0 x_m << D$ is satisfied, the approximate expressions for the average amplitude and phase shift read as

$$\overline{x} = \frac{1}{m\gamma\omega\omega_b} \frac{A_0\langle x^2\rangle_0}{D} \frac{2r_K}{\sqrt{4r_K^2+\Omega^2}} \ ,$$

$$\overline{\Phi}(D) = arctan(\frac{\Omega}{2r_K}) \ . \tag{3}$$

$\langle x^2 \rangle_0$ denotes the variance for the unperturbed noisy system. The distribution of time intervals between hoppings has characteristic peaks at $T = 2\pi/\Omega$ and its integer multiples.

The phase averaged power spectral density $S(\omega)$ defined as the Fourier transform of the correlation function $\langle x(t+\tau)x(t) \rangle$

$$S(\omega) = \int_{-\infty}^{\infty} exp(-i\omega\tau)\langle x(t+\tau)x(t) \rangle d\tau \quad , \tag{4}$$

exhibits delta peaks at frequencies $(2n+1)\Omega$ superposed to a noise background $S_N(\omega)$ whereas even multiples of Ω correspond to dips. This reflects the reflection symmetry of the double potential well. The heights of the spectral spikes behave as A_0^{2n} and since the periodic perturbation is assumed to be weak, it is possible to restrict the consideration to the first spike ($n = 1$). In the linear response theory one obtains following expressions for the noise density $S_N^0(\omega)$, total spectral density $S(\omega)$, and signal-to-noise ratio:

$$S_N^0(\omega) = 4r_K \frac{\langle x^2 \rangle_0}{\sqrt{4r_K^2 + \Omega^2}} \quad ,$$

$$S(\omega) = \frac{\pi}{2}\overline{x}(D)^2 \left[\delta(\omega - \Omega) + \delta(\omega + \Omega)\right] + S_N(\omega) \quad , \tag{5}$$

$$SMR \equiv 2 \left[lim_{\Delta\omega \to 0} \int_{\Omega-\Delta\omega}^{\Omega+\Delta\omega} d\omega\right] / S_N(\Omega) = \pi(\frac{A_0 x_m}{D})^2 r_K \quad .$$

4.3 Stochastic resonance and neuronal systems

During the last decade stochastic resonance has become a well accepted paradigm in the biological and neurophysiological sciences [21]. This despite the fact that neuronal systems are excitable systems with only single stable ground state and a short-lived excited state with lifetime of order millisecond which can be short as compared to the typical driving frequency. The simplest models effectively assume that neuron is a bistable system. The most obvious functions of the stochastic resonance in neuronal systems are the amplification of weak periodic signals (such as the noise produced by a predator) and temporal coding (say in auditory nerve).

In TGD framework the natural question is whether the stochastic resonance really occurs at the neuronal level or at a deeper control level. If the latter option is correct, the simplest paradigm of bistable system might be enough to model the system.

4.3.1 Empirical evidence for stochastic resonance in neuronal systems

The encoding of acoustic information on the primary auditory nerve of mammals has been studied for a half century. It has been known that, in contrast to the

conventional theory, the information about the frequency of the stimulus is coded also to the inter-spike distribution of the spike sequence. This correlation between neuronal input and output is known as phase locking in neurophysiology and presents one particular form of temporal coding [49]. It is needless to emphasize that various forms of temporal coding and its reverse process are absolutely crucial in TGD based model of qualia.

Longtin, Bulsa and Moss [54] observed that inter-spike interval histograms of periodically stimulated neurons of a cat exhibit a remarkable resemblance to the return time distributions of a periodically driven noisy bistable system with Gaussian noise for which correlation function decays exponentially:

$$\langle \xi(t)\xi(t') \rangle = \frac{D}{\tau_c} exp\left(-\frac{|t-t'|}{\tau_c}\right) \quad .$$ (6)

Return time is defined as the time for the system to be kicked from one well to another and back again. With only one fitting parameter it was possible to achieve an excellent agreement. Neuron is definitely not a bistable system and this forces to ask whether the assumption about the underlying bistable system might make sense at some deeper, controlling level.

Moss and collaborators studied also the behavior of the mechanoreceptor cell of a crayfish [55] by stimulating it with an input consisting of a sum of single tone and noise. The spectral properties of the action potentials were analyzed, yielding a power spectrum typified by a background noise plus sharp peaks at multiples of the frequency of the stimulus. Also signal-to-noise ratio was studied and was found to resemble the shape of the corresponding curve for a bistable system although the resonance peak as function of the noise intensity does not decrease so fast as for stochastic resonance in a bistable system.

Stochastic resonance has been demonstrated to occur also in the hair cell of cricket [50]. In this case the function of the stochastic resonance is to help the detection of a weak periodic signal (a coherent motion of air created by say predator) from a huge noisy background.

4.3.2 Models of stochastic resonance based on standard neuroscience

Several phenomenological models reproducing the stochastic resonance for inter-spike interval distributions have been proposed.

1. Neuron firing and Poissonian spike trains

The simplest model is based on the idea that neuron emits uncorrelated sharp spikes at random times [51] The spiking rate $r(t)$ is however sinusoidally modulated and the specification of $r(t)$ defines the model. One can express the phase averaged spectral density $S(\omega)$ for the spike train as a sum of frequency independent white noise term $\bar{r}$ and sum of delta peaks at frequencies $\omega = n\Omega$:

$$S(\omega) = \bar{r} + 2\pi \sum_{n=1}^{\infty} |r_n|^2 \delta(\omega - n\Omega) \ ,$$

$$r_n = \frac{1}{T} \int_0^T r(t) exp(-in\Omega t) dt \ .$$

(7)

The rate theory for noise-induced barrier crossing in the presence of a periodic external force suggest the generalization of the Kramers rate formula for the hopping rate r_D between potential wells to

$$r(t) = \nu \times exp\left[-\frac{\Delta V}{D} - \frac{A_0 x_m}{D} cos(\Omega t)\right] \ .$$

(8)

Here ΔV is the barrier height in absence of forcing, D is noise strength, A_0 is the amplitude of the periodic driving force, and the scale factor x_m characterizes the position of the potential well. The pre-factor ν depends on the details of the process. This formula should make sense for sufficiently low frequencies Ω (adiabatic approximation).

By calculating the Fourier transform of $r(t)$ one obtains for the signal to noise ratio defined as the ratio

$$SNR = \frac{2\pi r_1^2}{\bar{r}} \simeq \frac{\pi x_m^2 A_0^2}{D^2} exp\left(-\frac{\Delta V}{D}\right) \ .$$

(9)

Signal-to-noise ratio shows a behavior characteristic for stochastic resonance. The comparison with the data from the mechanically modulated mechanoreceptors of a crayfish shows qualitative agreement with this prediction although the decrease of SNR for large noise levels is overestimated by this model. The parametrization of $r(t)$ is based on the assumption that system is effectively bistable: this is of course not true at the neuronal level.

3. Integrate and fire model

Integrate and fire model assumes that the input of the neuron consists of a spike train $i(t)$ (cortical neurons) or a continuous signal (sensory neurons) [52, 18]. The membrane voltage $u(t)$ is obtained by integrating the input $i(t)$ represented as a current through the membrane. By representing cell membrane as a capacitance C and resistance R the equation of motion for the membrane potential reads as

$$\frac{d}{dt}u = -\frac{1}{\tau_{RC}}u + \frac{i(t)}{C} + \frac{\xi(t)}{C} \ .$$

(10)

Here one has $\tau_{RC} = RC$. Gaussian white noise with a zero mean is assumed. In the case of a perfect integrator ($1/RC = 0$) the Fokker Planck equation for the probability distribution for the potential values as a function of time reads as

$$\frac{\partial P(u,t)}{\partial t} = -\left[i_0 + A_0 cos(\Omega t)\right]\frac{\partial P(u,t)}{\partial u} + D\frac{\partial^2 P(u,t)}{\partial u^2} \quad . \tag{11}$$

The equation states that probability is conserved for the flow in the phase space defined by u and velocity variable $\partial_t u$. Initial values are $P(u = b, t) = 0$ at threshold stating that particle is absorbed at $u = b$. The rate for crossing is given by $r(t) = dP(u = b, t)/dt$.

The distribution function for the inter-spike intervals is given by the mean-first-passage time distribution ρ which is essentially the probability $P(b \rightarrow b)$ that the random walk in the external driving force leads from the point $u = b$ representing the threshold for nerve pulse generation ends up for the first time back to $u = b$. This probability can be calculated using Wiener integral for a particle performing random walk in the external force field defined by the periodic perturbation at the half-line $u \geq b$. The first passage distribution shows a multi-peaked structure with higher peaks suppressed exponentially. For a sufficiently large stimulus the peaks are located at $t_n = nT$, $T = 2\pi/\Omega$. The heights of the peaks decay exponentially. The peaks heights run through a maximum as a function of the noise strength D.

This model is unrealistic for several reasons. For instance, the phase of the sinusoidal stimulus is reset after every spike so that the coherence of the stimulus is eliminated.

4. Neuron firing and threshold crossing

One can improve the integrate and fire model by allowing the resistance to be finite and modify it by assuming that the phase, rather than being reset, does not change at all in the emission of a nerve pulse [53, 18]. One can solve $u(t)$ from the previous equation in absence of the noise explicitly by assuming that the amplitude of the driving force is so small that the threshold is not crossed in the absence of the noise. This gives at large values of time

$$u_\infty(t) = i_0 R + \frac{A_0 R}{1 + \Omega^2 \tau_{RC}^2} sin(\Omega t - \phi_{RC}) \quad . \tag{12}$$

Here one has $tan(\phi_{RC}) = \Omega/t_{RC}$. The presence of the ohmic current induces the reduction of the threshold to $b - i_0 R$. Gaussian colored noise is assumed to cause the crossing and the generation of the nerve pulse, which is for simplicity idealized with a delta peak.

The problem of calculating the rate for the threshold crossing can be formulated mathematically as a random walk on half line $u \geq b$ in presence of an external force using a semiclassical approximation for the Wiener integral over all paths. This means a functional integration over small perturbations of an unperturbed solution to give the probability $P(t)$ that an arbitrary path of the particle leads to the threshold $u = b$ during time interval t. The rate $r(t)$ for the threshold crossing is given as $r(t) = dP(t)/dt$. In [53] $r(t)$ the threshold crossing

rate is estimated for a colored Gaussian noise and one finds stochastic resonance also now. The formulas are not reproduced here: the interested reader can find them in [18].

This model effectively assumes that the membrane potential is driven by an external driving force and that the phase of the membrane potential is not appreciably affected by the emission of the spikes. This is consistent with the idea that there is some deeper control mechanism giving rise to the stochastic resonance and that neural level is only the controlled level.

4.4 How neuronal stochastic resonance could be realized at quantum level?

There is no doubt that neuronal systems exhibit stochastic resonance. The excellent fit of the inter-spike interval distribution by a return time distribution for a bistable system in the case of the auditory nerve of a cat suggests that genuine bistable system might be somehow involved. It is however not at all clear whether it is possible to understand the emergence of the stochastic resonance without leaving the framework of the standard Hodgkin-Huxley theory.

1. Neuronal systems are excitable media rather than bistable systems and it is not at all obvious whether excitable media allow stochastic resonance.

2. The time scale for the return of a neuron to the resting state is of order milliseconds and can be much shorter than the period of the driving external force. Thus the intuitive picture behind stochastic resonance need not make sense at neuronal level. Perhaps one should turn the attention to a more fundamental level, and interpret nerve pulse activity as a result of quantum control with the bistable system to be identified acting as a control system.

The previous model for sensory receptor applied to hearing suggests that perhaps a plausible model of stochastic resonance could be obtained by including besides neurons also a system able to represent sensory input as evoked potentials giving rise to cognitive and/or emotional representations in the manner discussed. This system could be sensory receptor such has hair cell or an aggregate of glial cells (the possible role of astrocytes for brain functioning has been discussed earlier in [K6]).

As found, periodic signal and white noise affecting bistable system are the key factors in the stochastic resonance. Astrocytes would induce the spiking of nearby neurons whereas spike activity and/or microtubular input would generate perturbations of the astrocyte membrane potential which might perhaps idealizable as a white noise. In the case of sensory receptor the source of white noise could be neuronal and/or microtubular back projection.

The basic prediction is that the frequency of the stochastic resonance has an exponential sensitivity to $1/D$, where D characterizes the intensity of the white noise assumed to be generated by the neural activity. The noise level should correlate with the average firing rate if neurons are responsible for the

white noise. Also microtubular white noise could be induced by the neuronal firing. The intensity of the white noise should be under automatic or conscious control so that important frequencies could be spotted out from the sensory input by "tuning to the correct wavelength" by varying the level of (possibly neural) noise. The reduction of the resting potential generates higher level of spontaneous firing so that the level of alertness would correlate directly with the value of the spotted frequency for neural noise option.

In the case of sensory organ the oscillatory signal would be contained in the sensory input represented as an evoked potential. In the case of astrocytes the oscillatory signal would be contained to the sensory signal mediated by microtubuli inducing oscillating evoked membrane potentials V. For hearing V could represent electric counterpart of a sound wave with a well-defined frequency. V would affect also $k_{em} = 3$ level EEG since it would appear as an additive component in membrane potential besides membrane voltage. Stochastic resonance should transform a frequency associated with the sensory input V to a peak frequency in the autocorrelation function for spikes so that spike interval distribution would reflect the frequency of the sensory input and its harmonics.

The bistable system would consist of the astrocyte-aggregate and neuron group. Glutamine-glutamate cycle for astrocyte-neuron interaction could relate closely to the bi-stability. The first state of this system would correspond to a situation in which astrocyte aggregate activates glutamate-ergic neuron group and second state to a situation in which this neuron group activates the glutamine-ergic astrocyte aggregate. Quantum entanglement induced by W ME having W exchanges as correlate could mediate a transition between these two states.

Also sensory receptor could serve as a bi-stable system. The transition between the two states would proceed by charge entanglement induced by W ME and the two states would transform to each other by the exchange of W bosons and would have different exotic ionizations and weak or color charges.

5 Temporal codings

An impressive evidence exists for the temporal coding [49] despite the fact that the dominant view has for long time been that rate coding is all that is involved. The vision about MEs as quantum holograms suggests that nerve pulse patterns are coded to the pulse patterns of the light-like current along ME.

5.1 TGD based overall view about temporal codings

The following is a summary about TGD inspired attempt to build an overall view about temporal codings.

1. The prevailing neuro-scientific view is that the resonance frequencies of EEG can be assigned to resonances in neural circuits. In TGD inspired picture nerve circuits are not necessary and there are reasons to believe

that this kind of resonances are too wide to explain kHz resonances frequency or even sharp EEG resonances.

2. For neurons the rate coding for the intensity of the sensory input is certainly fundamental and would realize genetic code by allowing maximum flexibility. 10 Hz alpha rhythm would specify uniquely the time intervals containing the genetic codons. The discrete value of the firing rate expressed as the number of spikes per period of 10 Hz alpha wave would realize genetic codon as an integer $n \leq 63$.

3. The above discussed "note" and "phoneme" representations defining emotional and cognitive representations would be realized as temporal patterns of evoked potentials at the level of sensory receptors and glial cells. Also now genetic or even memetic code could be realized in case of speech like representations. For these representations the EEG at level $k_{em} + 1$ modulates the Josephson frequencies and thus generalized theta and beta frequencies at level k_{em} but not generalized alpha frequencies or their harmonics. Features include also spatial modulation patterns.
   i) At neuronal level temporal coherence allows only $k_{em} = 2$ representation modulated by $k_{em} = 3$ level for which the lowest modulating frequency is around 1 kHz so that nerve pulses do not destroy the modulation patterns.
   ii) Sensory organs would correspond to $k_{em} = 3$ Josephson frequency 2×10^4 Hz modulated by EEG frequencies.
   iii) The cortical representation of audible frequencies above 1 kHz requires representations using evoked potentials of glial cells and microtubular transfer of sensory input as acoustic/electric oscillations of microtubuli to the glial cells is a necessary prerequisite of this representation. The cortical feedback via outer hair cells expands the audible frequencies above 1 kHz in the case of mammals and makes possible the representations of EEG frequencies as modulations of the Josephson frequency 2×10^4 Hz of $k_{em} = 3$ EEG. The aggregates of glial cells would correspond to $k_{em} \geq 3$. Short term memories would correspond to $k_{em} = 4$ with 5 Hz Josephson frequency modulated in the time scale of short term memories. This representation would emerge in frontal lobes.

4. Also the coding of (say sound) frequencies based on spike interval statistics is supported by experimental findings and is possible for frequencies below 1 kHz. This representation might be induced from the above discussed representation at the level of glial aggregates and sensory receptors via stochastic resonance. Periodic signal and white noise affecting bistable system are basic elements of stochastic resonance. Astrocytes induce the spiking of nearby neurons whereas neuronal noise affects astrocytes. Suppose that astrocytes receive also sensory signals mediated by microtubuli inducing oscillating evoked membrane potentials V of astrocytes.

Stochastic resonance would transform V to a peak frequency in the autocorrelation function for spikes. Glutamine-glutamate cycle for astrocyte-

neuron interaction could define the neuron-astrocyte interaction. The bistable system would be the complex formed by the astrocyte-aggregate and neuron group. The first state of this system would correspond to a situation in which astrocyte aggregate activates glutamate-ergic neuron group and second state to a situation in which this neuron group activates the glutamine-ergic astrocyte aggregate. Quantum entanglement induced by W ME having W exchanges as correlate could mediate a transition between these two states.

5. Also spike patterns can affect EEG. Neuronal spikes would kick the penduli defined by the aggregates of glial cells. If the kick realized as a perturbation of the membrane potential tends to occur simultaneously and with the same phase as the extremum of the oscillatory voltage perturbation in Josephson current through astrocyte membrane, the corresponding oscillatory perturbation will be amplified.

6. That neural transmitters and modulators could control resonance frequencies in neural circuits is also a natural hypothesis in neuroscience context. Neural transmitters and modulators can affect average firing rates and also the intensity of neural activity experienced by glial cells as white noise and thus control the stochastic resonance frequency for glial cells. A selection of preferred frequencies by controlling the intensity of neural noise would be in question rather than the generation of resonance frequencies.

5.2   As if time really mattered

Not only physics, but also neuroscience is plagued by the tensions caused by the erratic identification of the subjective time with the geometric time. There are two views about how nerve pulses patterns code for the sensory data. The first, and still dominating, view is that firing frequency codes for the intensity of the sensory experience. Competing view is that temporal patterns of nerve pulses code for the sensory information (fore a review see [49]).

In TGD framework first approach can be seen as emphasizing the dynamics with respect to subjective time whereas temporal patterns with respect to geometric time are neglected. Both memetic code and spectroscopy of consciousness rely crucially on temporal patterns with respect to geometric time. Hence these approaches are in conflict with the standard view about time. The approach based on temporal coding in the framework of the classical field theory forgets the dynamics with respect to subjective time and concentrates on the dynamics with respect to the geometric time. One however ends up with philosophical paradoxes circulating around time-frequency uncertainty relation: it is difficult to understand how communication is possible at all in deterministic classical world.

Quantum jumps between quantum histories view fuses both of these approaches to a more general unified description. The excellent review article "As if time really mattered: Temporal strategies for neural coding of sensory information" by Peter Cariani about temporal coding will be referred to several

times in the following discussion. This article also reviews the difficult problems of frequency coding approach [49].

5.3   Rate coding contra temporal coding

Rate coding is the dominating view about the representation of the sensory data in neuroscience and most neural net models rely on this approach. The approach is based on three assumptions.

1. Rate coding is the whole story: the average rate of firing defined by an interval with duration of ten to few hundred milliseconds codes the intensity of the sensory input.

2. Everything is ultimately coded into spatial patterns and spatial rate differences somehow code all relevant sensory information. The standard coding relies on rate-place scheme: average firing rate increases along one-dimensional axis. In TGD this hypothesis is generalized in the sense that brain is assumed to build miniature virtual world model of the space-time and that magnetic transition frequencies code for the values of the spatial and temporal coordinates.

3. A further element is connectionism: in some manner the architecture of the neural pathways gives rise to qualia associated with it.

Geometric time is completely absent from rate-coding based model of brain. This is what mere quantum statistical determinism neglecting the notion of quantum history and the physics of the classical em fields associated with them would leads to. In particular, EEG is mere epiphenomenon in this approach. What makes the situation so problematic is that neural net models describing information as purely spatial patterns can always reproduce the observed behavioral patterns by brute force by introducing a sufficiently complex neural network. From modelling perspective this might be nice but need not have anything to do with how Nature does it. The situation has been however changing during the last decade. The observations about the correlations of EEG patterns with conscious experience, the successes of neurofeedback [45], the realization of the potential importance of 40 Hz coherent oscillations in binding, and a rigorous experimental proof for the temporal coding of odors [46], are forcing the view about brain as a system in which classical em fields are important.

Temporal coding provides alternative and much more general approach but, as already noticed, has also its problems which relate to the fundamental confusions about the relationship between geometric and subjective time. There is empirical evidence for the occurrence of temporal coding in virtually every sensory system [49]. One can imagine many temporal coding mechanisms but the most important ones rely on spike interval statistics and latency-place representations.

Temporal coding provides solutions to the three basic difficulties of the rate coding paradigm: contrast degradation problem, pattern recognition problem

and multiple object problem or "superposition catastrophe". Contrast degradation implied by the saturation of the firing rates at high stimulus intensities. Good example of pattern recognition problem is related to the perception of pitch. Same pitch can be generated in very many manners: by monochromatic sound; by a sequence of clicks; or even by a superposition of multiples of fundamental frequency not involving the fundamental frequency itself as in the case of periodic pitch phenomenon. It is very difficult to understand how the stimulus coded to a spatial representation based on mere firing rates could even contain the information needed to decode the pitch. For temporal coding these problems are almost trivial [49]. Superposition catastrophe is identity problem for different objects of perceptive field. For instance, how it is possible to identify the sound of a familiar person in large crowd of people or distinguish transparent object from a nontransparent one, and how it is possible to group sensory inputs to form objects of perceptive field? In temporal coding approach common temporal structures allow to define objects of perceptive field: for instance, points of perceptive field moving in the same direction or behaving synchronously belong to the same object.

5.4 Spectroscopy of consciousness favors spike-statistics coding

The idea about temporal coding by spike-interval distributions or by some other distribution of time scales associated with the nerve pulse patterns (say intervals between spike bursts) resonates strongly with the spectroscopy of consciousness idea.

5.4.1 Spike-interval statistics and EEG

Nerve pulse patterns are ideal for stimulating EEG waves with desired transition frequencies. This stimulation mechanism is rather robust since ELF selves can carry only harmonics of characteristic fundamental frequency and the only thing needed is that 'kicks' to the em pendulum are given at correct half period. It is not necessary that spike patterns associated with subcortical cells excite EEG waves: it could occur and probably occurs also at the level of cortex. Several experiments described in [49] however suggest that coding could occur also at subcortical level. If this is really the case and spectroscopy of consciousness makes sense, one could perhaps deduce the values of various transition frequencies by studying spike-interval distributions of nerve fibers from sensory organs. Also the identification of ions serving as candidates for various types geometric qualia becomes possible. The basic hypothesis could be also tested by electrical stimulation of sensory pathways by these frequencies and by finding how the change of these frequencies affects conscious experience.

5.4.2 Multiplexing

Superpositions of the harmonics of different transition frequencies would represent temporally orthogonal messages. It is known that EEG decomposes to sum of two parts: the part consisting of relatively few fundamental frequencies and their harmonics and the quasi-continuous part, 'noise'. Both the amplitudes of harmonics and fundamental frequencies fluctuate. The properties of spike interval distribution should be consistent with this decomposition.

5.4.3 Broadcasting

Broadcasting is possible: the same message or superposition of messages can be send as em or Z^0 waves and only those parts of brain which contain macroscopic quantum phases woken-up by the frequencies present in the message react to the message. This kind of communication mechanism would provide a mass media type communication mechanism depending only weakly on the connectivity of the neural circuitry. Brain as a neuron society metaphor indeed supports the view that besides neural chatting also mass communications are important. In particular, mass communications might be involved with the synchronous firing of the neuron groups. Combined with the possibility of simultaneous superposition of various data in EEG pattern, broadcasting mechanism replaces the rather poorly defined problem of computing the representation of the external world from spatial firing rate patterns by direct experiencing. The computational problem is transformed to understanding how experience of, say, motion is represented by magnetic quantum phase transitions. Of course, the very assumption that computation gives rise to conscious experience is completely ad-hoc hypothesis.

5.4.4 The role of transmitters and modulators in generating correct EEG frequencies?

The recovery periods for neurons vary from milliseconds to seconds. Recovery time can be affected by neurotransmitters as well as neuro-modulators. Many axons [49] show triphasic recovery period consisting of refractory period, super-excitable phase and depression phase. Clearly, neuron favors inter-spike intervals for which the next spike arrives in neuron during super-excitable phase. Many-levelled hierarchy of neuronal pathways could thus serve as a sequence of sieves selecting preferred frequencies. Emotions are known to affect strongly the information processing in brain but not to alter the information content. Neurotransmitters and neuro-modulators could control the frequency ranges favored by neurons and thus they would ultimately control the structure of EEG and thus also contents of consciousness. For instance, neuro-modulators realizing emotional modulation chemically could induce temporal scaling of the typical firing patterns generated by neuron but preserving frequency ratios. It is known that 'hippocampal theta frequency' varies in wide limits [43] and that its value correlates with the state of arousal [33].

5.4.5 Resonant generation of complex motor activities?

There is also the fascinating possibility that single EEG frequency generates complex field eigenmodes at relatively large space-time sheets and that these modes induce complex self-organization patterns giving rise to the basic building blocks of motor actions. If this is really the case, then EEG frequencies could serve as names for self-organization processes. This idea is of course not new and is expressed eloquently already by Ernst Mach [49].

Perhaps a more feasible option is that superposition of EEG frequencies each coding for a particular spatiotemporal position in the virtual world of brain excites neuron in that particular position and this leads to the generation of a complex spatiotemporal pattern amplified to motor action by puppet in string mechanism.

5.5 Objections against temporal coding can be circumvented in TGD framework

There are several objections against temporal coding which all involve in an essential manner the relationship between subjective and geometric time.

1. If t=constant snapshot represents the reality, as believed in standard quantum physics, the inclusion of frequencies and temporal patterns does not make sense except phenomenologically. In TGD approach the problem disappears since quantum states are quantum histories. The quantum jump sequence represented by a nerve pulse pattern corresponds to subjective time development as hopping between geometric time developments characterized by EEG patterns. Each nerve pulse affects slightly the EEG pattern.

2. The coding of nerve pulse patterns to EEG frequencies requires high regularities for the spike patterns but there is no guarantee that spike patterns are regular enough in the primary sensory cortex. Also this counter argument melts down. In TGD framework nerve pulse pattern as such does not characterize the EEG pattern but only helps to induce and amplify Fourier components at certain EEG frequencies. Nerve pulse patterns are like kicks to an oscillating pendulum resetting it. When the kick gives the pendulum impulse in the same direction as the momentum of the pendulum, it amplifies the motion but leaves oscillation frequency and harmonic character of motion unaltered in harmonic oscillator approximation (in the case of EEG harmonic approximation is excellent). All that is needed is that nerve pulse is in the half period of duration $T/2$ if T is period for the EEG wave to be stimulated. Thus the coding mechanism is extremely robust and explains why spike-interval statistics correlates so nicely with sensory experience generated by nerve pulse pattern.

3. The kick changes the phase of the pendulum and this means that the Fourier spectrum representing the motion of the pendulum receives higher

harmonics although the behavior after kick could be purely harmonic oscillation. This phase increment could be responsible for the observed loss of synchrony accompanying arousal. If the kick corresponds to quantum jump it could only replace EEG Fourier component with a new one such that phase shift occurs also in the geometric past: very limited number (if any) of higher harmonics would appear. EEG component would however suffer phase shift with respect to other EEG components and this would lead to the loss of synchrony. Loss of synchrony is indeed signature of conscious information processing in cortex. As already noticed, temporal phase shift of spike patterns with respect to hippocampal theta frequency has been observed in the hippocampus of rat and might code the motion of rat with respect to surroundings [43]: motion would be mapped to a sequence of kicks given to pendulum.

This raises the question whether EEG record represents the EEG spectrum associated with the space-time surface generated in the last quantum jump or whether it is some kind of an average over the EEG spectra over quantum jumps. If the recording of EEG is completely automatic process, it is updated in every quantum jump and represents EEG at the space-time surface generated in the last quantum jump and, rather paradoxically, is therefore changing all the subjective time. The experiments of Radin and Bierman support this view [56]. Also the experiments related to the timing in active aspects of consciousness suggest that the EEG of the past changes in the interval which is a considerable fraction of second [38] and long time scale compared to the millisecond time scale of nerve pulse patterns.

5.6 Spike interval coding

Spike interval statistics codes information in the temporal pattern. This information can be information about the temporal or spatial pattern of the sensory stimulus (audition, vibratory sense) or about the non-geometric quale (this might be the case in the case of color vision, tastes and odors).

Empirical data support following type of spike-interval coding. The dominating time interval ΔT in the spike sequence codes for the heard frequency below kHz: $f = 1/\Delta T$ in the case of audition. The intensity of experience is measured by the ratio of the power in dominant interval to the power in non-dominant intervals [49]. These relationship holds in more general case. This code gives frequency coding by averaging.

The nice feature of temporal coding mechanism is the possibility of multiplex coding: same nerve pulse pattern can contain simultaneously several messages represented by spike patterns which are mutually orthogonal with respect to the inner product defined by Fourier transform. For instance, information about color, shape and temporal pattern of illumination might be coded as a superposition of nerve pulse patterns. In the following some well established examples about this mechanism [49] are discussed.

1. *Hearing*

Hearing involves both spatial coding of frequencies in the sense that special points of cochlea are especially sensitive to frequencies around the center frequency. This is not however the whole story. Rather, it would seem that this frequency serves only as a carrier frequency for amplitude modulated messages generated by the pattern of nerve pulses. The spike sequences for nerve fibers specialized to a given center frequency contain spike intervals which code for various qualities of sound like pitch, timbre and phonemic identity. Rather remarkably, the spike distribution of single nerve fiber contains enough information about speech to make possible speech recognition [49].

In the phenomenon of periodic pitch superposition of the harmonics of fundamental frequency, which is not itself present in the superposition, generates experience of pitch at the fundamental frequency. Periodic pitch has also visual counterpart which can be understood as coding of the visual textures along lines to temporal patterns by scanning. Periodic pitch can be understood if one assumes coding of the temporal patterns to spike patterns. The point is that any superposition of Fourier components not containing constant term is periodic function with a period determined by the fundamental frequency and must have at least one zero in the period since the integral of this function vanishes and must therefore change its sign at least once in the period. Thus sensory stimulus vanishes at least once during the period which means that threshold crossing occurs periodically and generates spike train. This periodicity in turn implies that also EEG contains the fundamental frequency. In TGD framework this argument is not quite enough since nerve pulse patterns are not directly responsible for the experienced pitch. The feedback from cortex via outer hair cells to the inner hair cells is needed to generate fundamental frequency as artificial auditory input.

Two visual/auditory/tactile stimuli are experienced as separate if the time interval between them is longer than 25 ms/.01 ms/5 ms. For hearing the time interval is by a factor 1/100 shorter than the millisecond time scale of nerve pulse which suggests that nerve pulse patterns cannot code for the high frequency part of the auditory stimulus. The representations of the auditory stimulus as evoked potentials at hair cells and glial cells would resolve the problem.

2. Tactile senses

Humans can perceive vibrations applied to skin in the range $5 - 1000$ Hz. The so called rapidly adapting receptors code for 5-100 Hz frequency range whereas Pacinian corpuscle receptors code for 30-1000 Hz. There is evidence that this ability relies on or at least involves spike statistics coding. The temporal patterns of the vibratory stimulus are evident in the temporal discharge patterns of all units at all stations in the ascending somatosensory pathway. In TGD framework the spike patterns would reflect the deeper coding in terms of glial evoked potential patterns.

It is known that the ordering of the inter-spike intervals is disrupted by jitter along neural pathway to cortex. If inter-spike distribution is not changed too much, spike sequence can excite magnetic transitions inducing the emotional and cognitive representations at magnetic bodies associated with groups of glial

cells. Note that the loss of information about temporal ordering is not important for our sensory experience which is temporal average over quantum jumps over time interval of at least .1 seconds as suggested by the fact that temporal resolution of sensory experience is about .1 seconds. If the time separation between visual,auditory, or tactile stimuli is above 20 ms, their temporal ordering can be perceived correctly. It could be however that the reaction to the sensory input is associated with some lower level self and that at our level averaging over longer time scale occurs.

Spike interval codes has also been reported for pain, touch, temperature and nociception (for more details and references see [49]). These modalities are highly emotional which suggests that higher harmonics code for emotional content whereas fundamental codes for the basic quale.

3. Chemical senses

Odor discrimination relies on spatiotemporal coding of odors [46]. The facts about olfaction and gustation does not fit well with the hypothesis that connection structure of the neural pathway somehow codes for the quale. This hypothesis requires that the connection structure should be more or less static. Both taste buds and olfactory neurons have limited lifespans. Cells of taste bud move from center to boundary during the life cycles and are innervated by different axons during their life cycle. In TGD framework these problems disappear.

Taste discrimination experiments [49] have demonstrated that electrical stimulation using the spike patterns stimulated by odorant reproduce the emotional expressions following the perception of the real odor. When temporal pattern is changed by keeping firing rate same, emotional response disappears. This is consistent with the assumption that emotional representations experienced by us are realized at the level of glial cells and that neuronal spike patterns are enough to excited the frequencies involve with these representations. Second type experiments demonstrate that electrical stimulation of an individual taste bud generates taste experience. This would suggest that the frequency giving rise to taste quale is excited automatically by the sensory stimulus and that each cell of taste bud generates it own primary taste.

4. Vision

In the case of vision there is psychophysical evidence for the temporal coding of color, texture and form. Color sensations can be produced using achromatic temporal patterns. Any color can be induced by the appropriate pattern of luminal changes. Benham's top is a famous device used to achieve this. Also electric stimulation of retina can directly induce color sensations. In TGD framework the color sensation should result from the back projection from glial cells to the sensory receptors induced by the achromatic temporal pattern communicated to glial cells and would involve genuine generation of photons which could be also dark photons. One can also imagine that the de-coherence of $k_{em} = 4$ dark EEG photons at frequency range 27-47 Hz could generate color stimuli (wavelengths in the range 400-700 nm). 10 Hz dark EEG photons could be assignaed

to the so called dark current oscillating at 10 Hz frequency and present even in darkness and giving rise to neural activity: in this case de-coherence would generate infrared light.

In TGD framework color qualia could be seen as coding spatial gradients of the illumination at a particular wavelength (in consistency with the color constancy phenomenon) to subjective experience. The saccadic motion of the eye would code a spatial change in the illumination to a subjecto-temporal gradient represented by the increments of appropriate color quantum numbers in quantum jump. This phenomenon is related to the color sensations stimulated by suitable frequency patterns of achromatic illumination [49]. What would happen that some colors present in the achromatic illumination would be amplified more than others. How precisely the coding of spatial illumination gradients to color qualia occurs is a challenge for TGD approach but it seems obvious that classical color gauge fields accompanying always classical electromagnetic fields must be an essential element of this coding.

If color is indeed experienced and coded to modulations of $k_{em} = 3$ Josephson frequency by EEG frequencies in retina, also multiplex coding suggests strongly itself. Color could be coded to the pitch of the modulation of Josephson frequency.

Scanning and saccadic motion suggests itself as a fundamental mechanism generating at neuronal level temporal maps of the surface texture. Each line of the perceptive field scanned by the saccadic motion could give rise to spikes at those moments when the line is crossed by the saccadic line. Neighboring neurons would in turn code the direction of the line to the direction of a line in space-time-plane: line would be like space-time orbit of particle. There is empirical evidence for multiplex coding of information about visual form and color (for more detail and references see [49]). Also information about changing illumination seems to be coded into spike-statistics.

5.7 Latency-place representations

Latency-place representations use relative time-of-arrival differences to code information about the intensity of the sensory stimulus. Since latency typically decreases with intensity, the contrast degradation problem is circumvented. As absolute latencies decrease, so do the variances of latency distributions. Latency differences can be amplified more centrally by lateral inhibition since the impulses can excite inhibitory units which can inhibit regions surrounding the region with the shortest latency. This mechanism might be involved with the generation of space-time sheets representing objects of perceptive field. Variants of the latency-place representation can be involved with vision (motion perception), electroception, auditory, somatosensory, olfactory and gustatory systems.

Co-incidence detection is basic mechanism related with the formation of latency-place representations for position or direction. There is evidence that pyramidal neurons in cortex apply co-incidence detection [49]. In the case of hearing, which is the most studied case, co-incidence detection occurs in brain

stem. In many vertebrates, inter-aural time differences are used to deduce the azimuthal direction of the sound source at frequencies above kHz whereas at lower frequencies phase differences between waves entering into separate ears are used for this purpose. The general mechanism uses pathways from corresponding positions of right and left ear to an array of co-incidence detectors in brain stem such that the length difference for the pathways varies linearly with the array coordinate. Only that part of array fires for co-incidence for which the delay caused by the length difference between right and left pathways compensates the time lapse between signals to separate ears. The time difference for the arrival times of the signal to two ears is thus coded to spatial coordinate and this coordinate represents information about azimuthal angle characterizing the direction of the sound source.

It is interesting to notice that music metaphor reflects itself also at the level of brain anatomy [49]. Brain resembles piano in that distances along axes coding different temporal or spatial frequencies depend logarithmically on frequency ratios: this guarantees the invariance of the sensation with respect to the scaling of frequencies. It might have also something to do with the hallucinatory states in which objects of the external world are perceived as gigantic or miniature sized: perhaps hallucinatory state leads to anomalous frequency-scales for some objects of the perceptive field.

In TGD the comparison of parallel supra-currents representing sensory inputs to be compared makes possible co-incidence detection at quantum level. When two identical supra currents flowing in parallel super conductors and forming Josephson junctions enter at same time they are in the same phase, resonant Josephson current is generated and wakes up sub-self giving rise to mental image about co-incidence and also generates nerve pulse activity giving rise to further experiences.

5.8 Why ELF MEs are scanning the cortex?

Alpha waves are known to move along the skull in the anterior-posterior direction with a velocity of about 7 m/s, whereas the alpha waves along the surface of the cortex propagate with a velocity of about 14 m/s [47]. There is evidence that also 40 Hz EEG waves propagate in a similar manner along cortex. The intuitive guess is that this motion corresponds to a scanning analogous to the saccadic motion. A fractal hierarchy of scannings with varying time and length scales is indeed what one might expect. The findings of Revonsuo [39] show that the increase of the intensity of 40 Hz EEG wave is associated with the appearance of a new mental image (holistic pattern of an auto-stereogram in the experiments of Revonsuo) rather than with the mere presence of the mental image. A possible underlying mechanism was discussed in [M1].

In the case of saccadic motion the scanning detects spatial and temporal gradients in the texture and illumination and transforms them to the increments of zero modes and of quantum numbers so that geometric and sensory qualia result. Perhaps the scanning of the cortex is in some sense a scaled up version of the saccadic motion. The scanning would detect geometro-temporal gradients

implied by the appearance of a space-time sheet representing a new symbolic representation, and yield a sensation of surprise as the simplest outcome. The scanner could be our personal magnetic magnetic body. The scanning would involve MEs inducing membrane oscillations and/or nerve pulse patterns in turn inducing EEG MEs at cyclotron frequencies.

A possible mechanism of scanning is based on the variation of time dependent classical W field in direction transversal to W ME (and parallel to cortex) inducing a transverse motion of surfaces at which W field intensity is constant. Also the propagation of Ca^{++} waves and nerve pulse conduction could rely on this mechanism.

5.9 p-Adic transition frequencies and EEG

The generalization of the fundamental p-adic length scale from $l \simeq 10^4$ Planck lengths to a hierarchy $\lambda^k \times l$, where λ depends on the p-adic length scale logarithmically and satisfies $\lambda \simeq 2^{11}$ for electron's p-adic length scale ($p = 2^{127} - 1$), means that not only p-adic time scales but also their dark variants define fundamental time scales as natural durations of cognitive codons. Dark matter hierarchy implies also that small-p p-adicity becomes possible even in macroscopic length and time scales and might help to explain why the periods associated with population dynamics tend to be prime multiples of year.

It is quite possible that these time scales can be also realized as cyclotron periods. The realization of genetic codons as the number of spikes per period of alpha wave would represent example of this. The time intervals between cognitive codons can however vary as long as the beginning and/or end of the codon is specified using some kind of start/end bit(s). This would conform with the extreme flexibility of human language. The model for p-adic cognitive codes assumes that also the time scales $T(n, k)/k$, k prime, of the p-adic timescales define fundamental time scales. Note that 2-adic fractality suggests that p-adic cognitive codons corresponds to octaves of the p-adic frequency $f(n, k) = \hbar/T(n, k)$.

There are several numerical coincidences suggesting that the p-adic length scales associated with $k = 5_2^3, 251, 2^8$, $127_2, 257, 131_2$ defining fundamental p-adic time scales in EEG range are directly involved with our consciousness. The dark variants of these time scales are not discussed here but might also be important. The table 2 of section 2 listing various primary p-adic time time scales helps to follow the discussion.

In the following all cyclotron frequencies correspond to $B_{end} = .2$ Gauss assignable to dark $k = 169$ flux sheets with $\hbar = 5\hbar_0$ and carrying magnetic flux $2h_5 = 10h_0$. The radius of tubular flux sheets of this kind would be 25 μm, the size of a large neuron.

1. The level $k = 5_2^3 = 125_2$ corresponds to the frequency $f = 40$ Hz defining the thalamocortical resonance frequency which is of central importance for sensory consciousness in wake-up state. For $k = 251$ the frequency 28.3 Hz associated with $k = 251$ level corresponds to the lower end of gamma

band. It is also the resonance frequency of dog's cortex stimulated by sinusoidal light wave [47].

2. The secondary time scale $T_2(127) = .1$ seconds corresponds to $f = 10$ Hz which is average alpha frequency and defines fundamental biological clock. This frequency is also the fundamental associated with the memory recall and storage circuits involving hippocampus and it has been suggested that .1 seconds serves as time quantum in memory circuits [48]. Also harmonics of 10 Hz are present in EEG spectrum: in particular, the fourth harmonic 40 Hz.

3. $k = 2^8$ corresponds to $f = 5$ Hz. Josephson frequency $f_J = 5$ Hz at $k_{em} = 4$ level of dark matter hierarchy explains the narrow EEG resonances at 3,5,7 and 13,15,17 Hz [47] as satellites of cyclotron frequencies in alpha band [M3]. It is known that during mental calculations 5 Hz theta frequency is activated [47]. A possible interpretation is in terms of the scaled down cyclotron frequency 10 Hz assignable to the magnetic flux sheets traversing genomes in right hemisphere and carrying magnetic field $B = B_{end}/2 = .1$ Gauss [M3]. $4-5$ Hz frequency band is indeed known to be important frequency band in EEG and could correspond to the scaled down alpha band. Also the cyclotron frequency of Co_+ ion is 5 Hz.

4. $k = 257$ correspond to the basic frequency $f = 3.5$ Hz which is the lower end of the (hippocampal) theta band. There are intriguing coincidences supporting the hypothesis is that this level corresponds to a transpersonal level of consciousness.

   i) Second harmonic of this frequency is about $f_2 = 7.1$ Hz and corresponds to the upper end of the (hippocampal) theta band. $n = 3$ harmonic corresponds to $f_3 = 11.0$ Hz. Quite recent experiments of Mark Germine [57] provide evidence for the notion of ELF self and associated collective memory. What was studied was the evoked EEG response to a series of random quantum stimuli which consisted of series of identical sound stimuli with randomly located deviant stimulus. Two subject persons, A and B, were involved. In the case that A observed the differing stimulus 1 second before B, the evoked EEG response of B became incoherent. Since evoked stimulus was oscillation at EEG frequency of about 11 Hz in the case that A had not observed the stimulus, one could understand the mechanism as a direct evidence for transpersonal $k = 257$ 'ELF ME' interacting with brains of both A and B. When transpersonal ELF ME had already heard the stimulus once, it did not react to it in similar manner.

   ii) $n = 4$ harmonic $f_4(257) = 14.1$ Hz is the frequency associated with sleeping spindles. $f_4(257)$ should have same role for the sensory processing at transpersonal level as $n = 4$ harmonic $f(127, 2) = 40$ Hz has at the level of sensory processing at personal level. A possible interpretation is that the activation of these frequencies is associated with the shift of attention from bodily sensory input to transpersonal 'sensory input'. This suggests

that sleep state is a state in which attention is shifted to the transpersonal $k = 257$ level. The fact that $k = 257$ fundamental frequency is at the lower end of theta band is consistent with the fact that theta waves dominate during sleep.

iii) Meditative and creative states of consciousness involve enhanced alpha and theta activity. A fascinating question is what happens in physical death. If we are really selves with at least the size of Earth, physical death could mean only that attention is redirected from body level to higher transpersonal levels or to some other form of bio-life so that there would not be actually no real death (note that several selves can direct their attention to the same physical body and same self could even share its attention between several physical bodies!)

5. The secondary time scale $T_2(131) = 1.6$ s corresponds to the frequency .63 Hz which could be identified as lower end for delta band. Rather interestingly, the development of child involves gradual shift of the peak frequencies from delta band to alpha band during first ten years of life: as if the development of individual would mean gradual shift of attention from higher transpersonal levels of consciousness to lower levels. Of course, this shift could also reflect the fact that higher harmonics associated with transpersonal levels begin to dominate of lowest harmonic. Perhaps reincarnation occurs gradually!

5.10   Do brain areas correspond to particular EEG resonance frequencies?

The scaling law of homeopathy inspires the guess that the information processing hierarchy, which starts from the primary sensory organs and contains besides sub-cortical nuclei also primary, secondary, etc... sensory areas, corresponds to a hierarchy of increasing EEG resonance wavelengths. This is consistent with the idea that primary, secondary and higher sensory areas of the cortex correspond to the periods of the periodic table in increasing order such that gamma band corresponds to the primary areas. Similar hierarchy should be realized at the motor areas.

This hierarchy should be realized dynamically by resonantly amplifying the EEG MEs with fundamental frequencies near the resonance frequency associated with a particular brain area. Neural circuits generating nerve pulse patterns, whose autocorrelation function contains the resonance frequency, could form a part of the mechanism. Alfven resonance could be even more important. If the magnetic flux loops associated with the magnetic body of a given brain area have a particular length L, one expects that the ELF MEs passing around the magnetic loop acting as a wave guide are amplified, when the fundamental frequency of the ELF ME satisfies certain resonance condition. This passage might involve several reflections but one might hope that only single curvilinear ME parallel to the magnetic flux loop acting as an Alfven wave guide is needed.

In this case the length L of the magnetic flux tube would correspond to the resonance frequency $f = c/L$.

The generalization of this argument to the case of super-canonical resonance frequencies would suggest the following scenario.

1. Primary sensory areas correspond to tertiary excitations of $k = 5_2^3$ algebra with the fundamental frequency of 40 Hz to primary excitations of $k = 251$ with fundamental frequency of 28 Hz. It is also possible that $k = 83_3$ excitations with frequency 56 Hz are associated with primary sensory areas and subcortical areas.

2. Secondary sensory areas correspond to secondary excitations of $k = 127$ with fundamental frequency of 10 Hz, average frequency in alpha and fundamental frequency associated with memory.

3. Tertiary association areas turn correspond to $k = 2^8 = 256$ with fundamental frequency 5 Hz belonging to theta band.

4. Unimodal association areas correspond to $k = 257$ with fundamental frequency of 3.5 Hz, the upper end of delta band.

5. Multimodal association areas would correspond to secondary excitations of $k = 131$ with fundamental frequency .63 Hz.

Of course, one could shift the positions of p-adic length scales along cortex but the assignment of 40 Hz to primary sensory cortex suggests that the identification could be correct. The mirror mechanism of long term memories suggests that an analogous hierarchy is realized at much lower frequency scales in terms of MEs and Z^0 magnetic flux loops.

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