About TGD View of Neuron

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Abstract

The realization that saltation as a conduction over the myelinated portions of the axon is still poorly understood phenomenon inspired a careful reanalysis of the earlier TGD inspired visions of nerve pulse conduction, EEG and of brain based on the new view about space-time, the notion of the magnetic body carrying $h_{eff} > h$ phases behaving like dark matter, and the zero energy ontology (ZEO) based quantum measurement theory extending to a theory of consciousness.

The TGD view about nerve pulse replaces nerve pulse as a wave assignable to a generalized Josephson junction formed by lipid layers of the cell membrane for which Josephson frequency f_J is replaced by the sum $F_J = f_J + \Delta f_c$, where Δf_c is the difference between cyclotron frequencies for transversal flux tubes at the different sides of the axon. What propagates is the deviation of membrane potential below the critical value for the generation of action potential. There would be no action potential in the myelinated portions of the axon and it would be generated only in the non-myelinated portions of length about 1 μm and gives rise to chemical effects and also communicate a signal to the magnetic body if the notion of generalized Josephson junction is accepted.

An interesting challenge for the model is the discovery that the density of the voltage gated ionic channels in the dendrites of neurons is considerably lower for humans than for mammals. The general model suggests that the spatiotemporal patterns of Josephson radiation emitted by segments between nearby ionic channels or pumps define analogs of sentences of language having nerve pulse as a punctuation mark analogous to the stop codon for DNA, then these sentences would be longer for humans, which could relate to the emergence of the human language capacity.

1 Introduction

The inspiration for looking again at the TGD view about nerve pulse conduction [K4] came from email discussions with Jouko Alanko. I learned about the conduction of action potentials in the myelinated portions of axons, where ion fluxes assignable to the action potential do not seem to be possible, remains a mystery although 71 years has passed since the proposal of the Hodkin-Huxley model of nerve pulse conduction (`https://cutt.ly/ATvjVHD`).

J. W. Jacak proposes a model of saltatory conduction [J3] (`https://cutt.ly/cTvj0db`) according to which action potential could propagate in plasmon-polariton condensate and the myelinited portions of length about $L = 100$ μm could behave like electric dipoles. This requires coherence in scale L and one might ask whether quantum coherence of plasmon-polariton condensed might be involved.

What makes this idea interesting is that plasmon-polaritons are known to form BEC condensates in the presence of energy feed as laser light. In the TGD framework this particular BEC formed in the presence of an external energy feed would represent one example of a much more general phenomenon in which the metabolic energy feed increases the values of h_{eff} for the system and keeps their distribution stationary. This would not be a stationary BEC but a BEC analogous to flow equilibrium. For instance, metabolic energy feed would give rise to a forced bio-superconductivity. An exciton-polariton condensate could be also present. However, to me the answer to the question whether this can give rise to an action potential remained unclear to me.

This inspired a careful reanalysis of the earlier TGD inspired visions of nerve pulse conduction [K4], EEG [K1, K5, K2, L7] and of brain based on the new view about pace-time, the notion of the magnetic body carrying $h_{eff} > h$ phases behaving like dark matter, and the zero energy ontology (ZEO) based quantum measurement theory extending to a theory of consciousness.

The TGD view about nerve pulse assumes that nerve pulse is a secondary phenomenon induces by a voltage modulation wave assignable to a generalized Josephson junction formed by lipid layers of the cell membrane for which Josephson frequency f_c is replaced by the sum $f_c + \Delta E_c$, where ΔE_c is the difference between cyclotron frequencies from transversal flux tubes at the different sides of the axon.

What propagates is the deviation of membrane potential, possibly below the critical value for the generation of action potential. There is no action potential in the myelinated portions and it is generated only in the unmyelinated portions of length about 1 μm and gives rise to chemical effects and would also communicate a signal to the magnetic body (MB) if the notion of generalized Josephson junction is accepted.

The model survived the Occam's razor with small modifications and became much more precise and led to more explicit formulation of the speculative generalization of the genetic code [L8].

An interesting challenge for the model is the discovery that the density of the voltage gated ionic channels in the dendrites of neurons is considerably lower for humans than for mammals. The general model suggests that the spatiotemporal patterns of Josephson radiation emitted by segments between nearby ionic channels or pumps define analogs of sentences of language having nerve pulse as a punctuation mark analogous to the stop codon for DNA, then these sentences would be longer for humans, which could relate to the emergence of the human language capacity.

2 Neuron and brain according to TGD

The TGD view of the brain has evolved during the last 30 years and differs from the neuroscience based view in several aspects. The notion of MB carrying $h_{eff} \geq h$ phases behaving like dark matter and zero energy ontology (ZEO) predicts time reversal in ordinary ("big") state function reductions (BSFRs). BSFRs would be counterparts for motor actions and "small" SFRs following unitary time evolutions would be counterparts for sensory perception.

Josephson radiation communicates information from the biological body (BB) to MB and gives rise to EEG and possibly also its scaled variants. BSFRs at MB produce cyclotron resonance peaks, which would generate a feedback signal to the central nervous system (CNS) via genome and/or microtubules. These signals in turn induce oscillatory perturbations of the soliton sequence leading to secondary nerve pulses. This gives rise to a closed control loop BB-MB-BB.

The generalization of Nottale hypothesis [E1] states that one can assign to gravitational flux tubes gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where G is Newton's constant, M is large mass - say Earth's mass or solar mass -, and m is mass of particle, and $v_0 \leq c$ is a velocity parameter [L2, L7, L11, L10] [K7]. The Nottale hypothesis, in particular the dependence of $\hbar_{gr}$ masses (more generally charges) is discussed from the point of view of Yangian symmetry implying polylocal conserved charges in [L9].

Nottale hypothesis conforms with the Equivalence Principle and implies universality in several senses. The cyclotron energies $E_c = \hbar_{gr} ZeB/m = ZeGMB/v_0$ for charged particles and gravitational Compton length $\Lambda_{gr} = GM/v_0$ are independent of the particle mass m. Cyclotron frequencies do not depend on h and Josephson frequency $f_J = ZeV/h_{gr} = ZeVv_0/(2\pi GMm)$ is inversely proportional to mass m just like f_c so that the ratio f_c/f_J is also universal in that it does not depend on the mass of the charged particle. Also the generalized Josephson frequency $F_J = \Delta f_c + f_J$ is universal.

Cell membrane as a (generalized) Josephson junction is an essential element and its ground state corresponds to a propagating soliton sequence. A perturbation reducing the membrane potential below the critical value for the generation of action potential replaces nerve pulse as a fundamental phenomenon and the soliton sequence would be present in all cell bodies but would not propagate as it does in the axons and dendrites. Neither would it generate a nerve pulse. The modulation is universal and the same for all charged particles. Frequency scale is however inversely proportional to the particle mass m and highest for electrons.

If the modulation is small, the cyclotron frequencies define the frequency scale and corresponding natural time scale for events at the MB. In the "endogenous" magnetic field $B_{end} \simeq 2B_E/5$, where $B_E \simeq .5$ Gauss is the nominal value of the Earth's magnetic field, tentatively interpreted as monopole flux part of the Earth's magnetic field the cyclotron frequencies of proton and electron are $f_c(e) = 6 \times 10^5$ Hz and $f_c(p) = 300$ Hz (assignable to the rotating shaft of ATPAse). Ions have cyclotron frequencies in the EEG range. For protons, a modulation by a nerve pulse of duration of few milliseconds would represent rather slow frequency modulation in the the scale of $f_c(e)$. For protons and ions, the modulation would be a short ripple and presumably of no significance. Hence the nerve pulse could be significant only for the representation of the system provided by dark electrons.

This suggests that generalized Josephson radiation for B_{end} appears in various frequency scales characterized by cyclotron frequencies of electron, proton, and biologically important ions and that one can assign flux tubes of the gravitational part of magnetic body with various kinds of ions with characteristic frequency and time scales but universal cyclotron energies. Besides B_{end} also other values of B can be considereed and the model of bioharmony suggested that approximately

correspond to frequencies of 12-note scale [L1, L3, L6, L8].

One can assign to elementary particles also a p-adic secondary time scale and for electrons this scale corresponds to .1 second assignable to the alpha band of EEG. Intriguingly, for u and d quarks this time scales if of the order of the millisecond time scale assignable to nerve pulse.

2.1 TGD based view about nerve pulse conduction

In the TGD framework, nerve pulses would be induced by more fundamental dynamics of the neuronal membrane acting as a possibly generallized Josephson junction between superconductors associated with the lipid layers of the membrane. Also the ordinary cell membrane would give rise to this kind of Josephson junction. The sequence of Sine-Gordon solitons propagating along the axons would represent the resting state of the axon and its perturbations would define the fundamental dynamics. An interesting question is, how this sequence relates to the time crystals now in fashion.

At the microscopic level, this Josepson junction would decompose to Josephson junctions associated with the membrane proteins acting as ion channels.

1. In the microscopic picture, the axon is analogous to a sequence of penduli associated with the membrane proteins acting as Josephson junctions and during nerve pulse as ion channels.

   The Sine-Gordon soliton sequence is mathematically analogous to a sequence of rotating penduli such that the phase difference between subsequent penduli is constant. This gives rise to a constant phase velocity v. Perturbation corresponds to the local transformation of the rotation to oscillation so thay frequency parameter is reduced. The perturbation propagates with the same velocity as the solitons of the soliton sequence.

   If the perturbation takes the membrane potential below critical value, action potential is generated and in myelin free regions the optimum velocity v is identifiable as the conduction velocity v_c of the nerve pulse. For $v \geq v_c$, the physiology is too slow to react to the perturbation.

2. There is no need for action potentials in the myelinated regions. This would lead to considerable energy savings reducing the energy feed by factor 1/100 as the ratio of the lengths of Ranvier nodes and myelinated portions.

   The perturbation of the soliton sequence could propagate freely since it would not be forced to move at the same velocity as the action potential restricted by physiological constraints. This would increase the propagation velocity and apparent conduction velocity by a factor of order 100 and give rise to the dramatic difference between vertebrates having myelinated axons and invertebrates without them.

3. Action potentials would be generated only in the unmyelinated Ranvier nodes of length about 1 mm between myelinated portions of length about 100 μm. This allows considerable savings in metabolic energy. Overcritical modulation would generate an action potential at positions of voltage gated ion channels inside the Ranvier node.

4. The TGD based model would solve the still-unsolved problem about how action potentials are conducted in the myelinated portions of axon. Saltation is the proposed mechanism but is plagued by many blatant conflicts with empirical facts [J3] (`https://cutt.ly/GTvjEJo`). For instance, the thickness of myelinated axons is not enough to guarantee high enough conduction velocity.

   The fact that the splitting of the axons does not prevent the transfer of the action potential between myelinated portions, which suggests that there is a deeper propagation type phenomenon involved. In the article it is proposed that the saltation could be understood as a wave packet in plasmon-polariton condensate and that the entire myelinated portion effectively acts as a dipole.

   In the TGD framework there would be no conduction of nerve pulses inside myelinated regions but propagating waves in plasmon polariton type condensates (Ca waves?) could induce perturbations of propagating soliton sequence assignable to cell membrane as a generalized Josephson junction allowing communication of chemical "sensory" data to magnetic body (MB) of the system.

2.1.1 What is the function of neurotransmitters?

In the standard picture, the neurotransmitters would make possible propagation of a membrane voltage modulation through synaptic gap by building a bridge. This picture looks rather reasonable in the context of standard neuroscience.

What the function of neurotransmitters could be in the TGD framework? TGD allows several guesses for what happens at synaptic contact.

1. Flux tubes, or rather, the massless extremals (MEs) [K3, K6]) associated with them act as wave guides for classical gauge fields. Neurotransmitters at the synaptic contacts would connect pre- ja postsynaptic flux tubes to longer flux tubes. This would make classical communications possible inside the brain and generate classical coherence. There would be no quantum coherence at the level of ordinary matter but the classical coherence would be induced by the quantum coherence at the level of MB.

   At the level of MB the neurotransmitters would induce the increase of the scale of quantum coherence and h_{eff} could increase. h_{eff} and therefore the scale of quantum coherence tend to be reduced spontaneously so that it can last for some average time τ. Therefore $L = v \times \tau$ gives an upper limit for the average coherence scale at the level of CNS. The higher the conduction velocity v, the larger the size of the coherence regions. For $v = 100$ m/s and $\tau \simeq 1$ ms, one would have $L = .1$ m, the size scale of the human brain hemisphere. In the TGD view, the high conduction velocity would not be a prerequisite for high rate of communications in the brain but for the formation of large enough coherence regions.

   TGD also suggests that the bridges at junctions serve as relays making possible communications to the MB of a system consisting of pre- and postsynaptic neurons.

2. In this framework, the difference between vertebrates and invertebrates would not reflect the different rates of information processing but the different sizes of coherence regions and of the associated quantum coherence regions at the level of MB, which should be for vertebrates roughly by a factor 100 larger than for invertebrates.

   Note however that octopus (see `https://cutt.ly/cTvh3yD` and `https://cutt.ly/zTvh5Ir`) is is a highly intelligent invertebrate. In particular, it also has EEG. Octopus CNS has several centers analogous to the brain but there are no somatotopic mappings of sensory data providing a representation of the entire organism or even part of it. These features could be understood as reflecting the smaller size of the coherence regions at the level of the CNS.

3. The (possibly generalized) Josephson radiation communicated to MB from both unmyelinated and myelinated portions of the axon would create a sequence of cyclotron resonance peaks at flux tubes of MB. Resonance is obtained when the frequency modulated (generalized) Josephson frequency coincides with the cyclotron frequency at the flux tube of MB which can vary along the flux tube.

   The sequence of resonance peaks transforms the Josephson radiation to an analog of nerve pulse sequence and yields a feedback communicated via genomes and/or microtubuli to the postsynaptic neuronal membrane by transversal flux tubes. The outcome would be oscillations of the membrane potential perturbing the soliton sequence and possibly generating nerve pulses so that a closed control loop would be obtained. This communication to MB would correspond to EEG and possibly existing fractally scaled analogs of EEG.

   The communication of Josephson radiation followed by SSFR or BSFR is analogous to Fourier transform. The continuous temporal pattern of Josephson oscillations is transformed to a sequence of resonance peaks analogous to a sequence of nerve pulses defining a sequence of time differences.

4. This picture suggests that the information processing occurs at the level MB. How the response of MB to this sensory input is generated? The simplest option is that it is realized as a BSFR inducing time reversed time evolution just like raising the finger in the experiments of Libet. No specific mechanism would be needed.

5. For the ordinary Josephson junctions, the quantum coherence would be lost during action potential and the idea about small modulation of Josephson frequency does not make sense. This need not be the case for generalized Josephson junctions. The generalized Josephson frequency F_J is the sum $F_J = \Delta f_c + f_J$ of terms consisting of the difference Δf_c of cyclotron frequencies for transversal flux tubes at both sides of the membrane and of Josephson frequency f_J , which would be small correction giving rise to modulation which is larger than in absence of nerve pulse.

   If only ordinary Josephson junctions are present, the role of nerve pulse would be passive and purely chemical. Nerve pulse activity would affect the chemistry and would be essential in motor actions and in the long term modulation of brain structure and of function and behavior, say by inducing long term potentiation.

   If MB is there, it would look natural for it to participate also in the long term modulation of brain function and behavior so that the communication of nerve pulse patterns to MB requiring generalized Josephson junctions looks a more attractive option.

2.2 Brain as a factory of standardized mental images

According to an earlier view, the brain would be a factory of standardized mental images. They would be produced by a quantum counterpart of pattern recognition involving virtual sensory input to sensory organs. How does the new view relate to this picture?

2.2.1 Earlier view

TGD leads to the proposal that nerve pulses do not transfer information inside the brain. The information about nerve pulse pattern could be communicated to MB if the notion of generalized Josephson junction makes sense as a modulation of the frequency F_J of generalized Josephson radiation containing a contribution proportional to membrane potential. This does however not seem absolutely necessary.

1. The starting point of the TGD based model of the brain is the idea that biophotons are ordinary photons produced from dark photons. There are indeed indications for the role of biophotons in brain functioning. This leads to the idea that dark photons and classical em fields propagating along massless extremals (MEs) parallel to magnetic flux tubes in the scale of brain are essential for the communications inside brain and that nerve pulses serve as relays connecting pre- and postsynaptic flux tubes to larger structures.

2. Also connections to much larger MBs are possible and could even give rise to communications allowing to exceed the limitations due to finite speed of light since signals could be time reflected by BSFR from very distant objects. The occurrence of BSFR is assumed quite generally in the new view.

3. Even BSFRs, the fact that light velocity dramatically exceeds the velocity of nerve pulse conduction would make possible virtual sensory input from the brain (or from MB via brain) to sensory organs as ordinary dark photon signals. This would make possible iteration producing standardized mental images. REM dreams serve as a support since they could be regarded as reflecting virtual sensory input from MB.

The open problem of this picture is that detailed mechanisms for the information processing at cortex or MB and for the generation of virtual sensory input are missing. Zero energy ontology (ZEO) [L5] [K8] could automatically provide these mechanisms.

2.2.2 The modified view

In the new view the signalling between parts A and B of brain (and body) would always occur in scales via an appropriate layer of MB as A$\rightarrow$ MB $\rightarrow$ B rather than directly as A$\rightarrow$B and involve BSFR at MB.

The BSFR at the level of MB would be followed by the step S$\rightarrow$ MB (S denotes sensory organ) inducing a virtual sensory input MB$\rightarrow$S via a signal via genomes of neurons of axon or microtubuli.

1. Genomes and/or microtubuli would receive the cyclotron radiation induced by a sequence of resonance peaks at MB and by stochastic resonance would transform this sequence to oscillations affecting the membrane potential. The step MB→S would be a time reversal for the transformations of the Josephson photon signal to resonance peaks in the step $S \to MB$.

   Remark: This picture explains why we can remember our dreams although we remember nothing about the sleep state. The natural assumption is that the sleep state corresponds to a change of the arrow of time by BSFR and that we cannot remember anything about this period. We remember dreams and this can be understood as a partial wake-up of the brain by another BSFR giving rise to the standard arrow of time. The change of the arrow of time at MB for a part of the brain would give rise to a virtual sensory input at some sensory organs and to REM dream.

2. MB has a layered onion-like structure involving several scales and the communications in shorter scales as communications $BB \to MB \to MB$ occurring via BSFR would be fast and have the same effect as classical communications. In longer scales involving layers of MB of size of order Earth, light velocity would become a problem, and the time reversal of BSFR could overcome this problem. One can even consider sizes of MB so large that the barrier due to finite light-velocity is overcome.

3. Brain can be seen as a factor of standardized mental images also in this picture. Communication steps between brain (and possibly MB of brain) and sensory organs are only replaced with the steps S→ MB → S.

   One can also consider the possibility $S_1 \to$ MB→ S_2 making possible quantal associations and synesthesia. Also sensory motor associations as an analog of synesthesia becomes possible.

2.2.3 Is the new picture consistent with the earlier view?

Is the new view about the brain as a factor of mental images consistent with the earlier view? Zero energy ontology (ZEO) implies that classical physics is an exact part of quantum physics so that also BSFR must have classical correlates.

In ZEO, zero energy state is a superposition of classical deterministic time evolutions - space-time surfaces which are preferred extremals - having 3-D ends at the boundaries of a causal diamond (CD).

1. The passive boundary of CD is not affected during the sequences of "small" SFRs (SSFRs) and also the 3-D states at it are unaffected (analog of Zeno effect). The active boundary of CD is shifted and the size of CD increases at least in statistical sense during the sequence of SSFRs. Also the states at the active boundary are affected in SSFRs.

2. In BSFR, the roles of boundaries of CD are changed and the new zero energy zero energy state as pair 3-D states (or perhaps their superposition) is a superposition of time reversed time evolutions beginning from the final state in 3-D sense (note that holography is almost exact). The strange looking experimental findings of Minev et al [L4] and Libet [J1] support this picture [L4]. This implies that BSFRs look like deterministic classical time evolutions for times assignable to the final state in 3-D sense.

3. Quantum classical correspondence is an essential element of TGD and implied by ZEO. Classical signals defined by what I call topological light rays (massless extremals, MEs) propagating with light velocity define a subset of classical correlates for what happens in BSFRs. The MEs would be parallel to flux tubes and signals would propagate along them to sensory organs and effectively give rise to the virtual sensory input.

   The next BSFR would re-establish the original arrow of time and give rise to the modified sensory input from sensory organ (S) to the brain as nerve pulse patterns and oscillations of membrane voltage. The iteration of the loop S→ MB → S would give rise to standardized mental images in analogy with the pattern recognition.

   Therefore one can say that the earlier picture is consistent with the new view if it is interpreted in terms of classical correlates.

There are several views about what memories are and one can invent an endless variety of representations of memories. As a matter, in the TGD framework one cannot separate representations of realities from the realities and conscious representations are everywhere.

2.3 How information is represented at the level of MB?

The basic question is how information is represented at MB. Computationalists assume analog of computer memory but in the TGD framework the representation as conscious repetitive processes looks more appropriate.

2.3.1 Memories as behaviors

Neuroscientists understand memories as behavioral patterns realized statistically as connections between neurons. Conditioning and associations as behaviors are realized in terms of strengthening of the synaptic contacts between post- and presynaptic neurons. This gives rise to neural networks.

In the TGD framework MB would realize these networks as flux tube networks at higher level and induce the counterparts of these networks at the level of BB (CNS). The connections A-B between nodes would be via MB as connections A-MB-B. If the generalization of Josephson junction is accepted, MB would actively control long term potentiations and development of behaviours.

The communication of the perturbations of propagating Sine-Gordon sequence associated with the axonal membranes and stationary Sine-Cordon lattice associated with the cell membrane would define one particular representation.

2.3.2 Memories as conscious mental images

Conscious information can be represented as conscious mental images defining temporal and spatial patterns.

1. Episodic and sensory memories are this kind of memories, kind of re-experiences. This kind of patterns would correspond in the TGD inspired theory of consciousness mental images as sub-selves, living entities having analogs of wake-up and sleep periods. After images provide a good example. They would be born in BSFR and die in the next BSFR and disappear from consciousness of self. They would however live with an opposite arrow of time during their sleep period.

2. Short term memories and perhaps also long term memories could be analogous to repeating after images. The loop BB-MB-BB from axon to magnetic flux tube and back could create a repeating nerve pulse pattern accompanying a similar repeating pattern of membrane potential oscillators modulating the frequency of the Josephson current. One can wonder whether this kind of representation applies for all time scales as memory spans.

2.3.3 Criticism of the computationalistic view about data representation and data storage

Computationalistic view about memory interprets memory as a sequence of symbolsm carved in stone. One can argue that the mathematical complexity of the sequence serves as a measure for the information carried by the sequence. This however does not tell anything about the information itself and a more approprite interpretation is as complexity.

As such the symbol sequence carries no conscious information. One can invent an endless number of various physical representations. How the physical realization is "read" to conscious experience remains however unsolved. Reading ordinary text induces a conscious experience in the reader and one could say that the experience tells what the information coded by the text is. The text has different meaning for different readers or no meaning at all.

Conscious information must be assigned to temporal dynamic patterns but they are not dynamical in the classical sense of the word. State function reduction (SFR) as a moment of consciousness would be the basic building brick for these patterns and since SFR replaces the quantum universe with a new one, one must give up the idea that deterministic dynamical patterns with respect to

geometric time could carry any information as such. One can assign to them a measure of complexity, say as the dimension and structure of extension of rationals associated with the space-time region, but no information.

2.3.4 TGD based model of the genetic code

The TGD inspired model of genetic code based on the notion of bioharmony allows quite a dramatic generalization of the genetic code and suggests a radically different view about representation of information and its communication and even about how living matter functions.

1. DNA is often regarded as a sequence of letters and the 64 codons represent 6 bits of information. In this view, genes would correspond to bit sequences and be analogous to computer programs. Transcription to mRNA translated to proteins would be reading and printing of this information.

2. In the TGD framework, the notion of genetic code generalizes. These entities have magnetic bodies carrying dark matter which provides the fundamental realization of the genetic code. Chemical code would be a secondary realization.

   The flux tubes parallel to DNA strands are assumed to realize genetic codons as states of dark proton triplets [L1, L6]. The communications between DNA, RNA, tRNA, and amino-acids are realized in terms of dark photon triplets also realizing genetic code as 3-chord music of light one might say. The three dark protons/photons form a single quantum coherent unit.

   Bioharmony would correspond to what might be identified as the holistic emotional aspect of intelligence not taken into account in computationalism whereas codons as 6-bits would correspond to a reductionistic local aspect of intelligence.

   This idea generalizes further. Also genes can be realized as quantum coherent units both in terms of dark N-protons and N-photons analogous to Bose-Einstein condensates.

3. The formation of dark N-protons and N-photons relies on a universal number theoretic mechanism for the formation of bound states by what I call Galois confinement. At the M^8 level the mechanism has a simple description. The momenta of quarks at the fundamental level are algebraic integers in the extension of rationals defined by 4-surface of M^8 mapped to H by $M^8 - H$ duality.

   This makes possible number theoretic universality, meaning that the momenta of quarks defining the quantum state and corresponding to a subset of points in $X^4 \subset M^8$ make sense also for the extensions of p-adic numbers defined by the extension of rationals. The subset of points of X^4 carrying quarks defines the physical set as a cognitive representation.

   Bound states of quarks would have by periodic boundary conditions momentum components, which are ordinary integers for a suitable momentum unit defined by the size scale of CD. This means Galois confinement. Fermi ball with each point with momenta having integer components is a maximal cognitive representation.

4. This gives rise to a hierarchy of Galois confinements in which the Galois non-singlets of a given level can form singlets at the next level. This generalizes also to wave functions in the space of momenta with algebraic integer valued components which would be Galois singlets for physical states.

   This would define a universal mechanism for the formation of bound states. Stability however requires that the energy of the bound state is smaller than the sum of the energies of composites. Dark N-codons and dark 3N-photons would represent special cases of these entities.

This picture also leads to a vision about communication and control and information processing in living matter.

1. 3N-(cyclotron)-resonance between dark proton N-triplet representing DNA, RNA, tRNA or amino-acids by dark photon N-triplet makes possible communications in which only identical

codon sequences get in contact. Frequency- and energy resonance are possible if the values of h_{eff} are the same and only energy resonance if they are different.

Resonant communication by dark photons, possibly transforming to dark photons with a different value of h_{eff} or to ordinary photons, gives rise to association sequences analogous to those appearing in computer language LISP.

2. Even this is not enough. In the TGD framework the spectrum of possible genetic code expands dramatically and DNA and basic biomolecules could be only a special case.

   The hyperbolic space realized as a mass shell at the level of M^8 would define an infinite number of tessellations [L8]. Perhaps the simplest tessellation, known as icosa-tetrahedral tessellation also involving octahedrons, realizes genetic code in the model of bioharmony. The projection of this tessellation induces a tessellation at 4-surface of H mapped to $M^4 \times CP_2$ by $M^8 - H$ duality. The induced tessellation is. analogous to the quasicrystal, which is also obtained as a projection of a higher dimensional lattice.

   This tessellation could assign variants of genetic code which can be, not only 1-, but also 2- and 3-dimensional. For instance, the cell membrane could provide a 2-D realization of genetic code. Genetic code could be present everywhere, even outside biology.

3. Could the generalized Josephson radiation consisting of dark 3N-photons have an interpretation as N-codons analogous to 2-D variants of genes so that the propagation of the perturbation of the soliton sequence would be like reading a "sentence" for MB serving as a listener? Could the myelinated portions of axons define this kind of generalized genes? Could the nerve pulse at Ranvier nodes define the analog of punctuation mark ending a "sentence"?

   This proposal is actually inspired by the TGD inspired model for the emergence of human language [L12, L13].

2.4 Model for how information is communicated to MB

Since MB represents a higher level in the self hierarchy, the above considerations suggest that the communication of information from BB to MB is analogous to speech or written language.

2.4.1 Could Josephson radiation patterms assignable to the myelinated portions of axon define "sentences"?

The intuitive feeling is that the decomposition of axon to myelineated portions and the Ranvier modes generating action potential should have some meaning from the point of view of communications from BB to MB. Since MB should provide a higher level cognitive representation of the sensory data, the natural idea is that Josephson radiation patterns assignable to the myelinated portions of axon define analogs of sentences and that the Ranvier nodes and the associated action potential defines an analog of punctuation mark. BB would be talking to MB and MB would be bresponding.

For generalized Josephson junctions also nerve pulse patterns are communicated to MB and an interesting question is whether they could be analogs of punctuation marks or of stopping codons for DNA and divide the signal to MB to what might be regarded as "sentences".

1. If one assumes generalized Nottale's hypothesis, the nerve pulse durations of about ms would be longer than the cyclotron frequency $f_c = 6 \times 10^5$ Hz of electron in B_{end} by a factor of order 10^3 and the propagation along myelinated portion would last about $T = 1$ μs, which is of the same order of magnitude as $T_c = 1/f_c(e)$ so that the interpretation is not plausible. Rather, slow modulation of generalized Josephson radiation for electrons looks a more plausible interpretation.

2. For ions, T is too short as compared with the cyclotron time scale T_c for B_{end}. Ions could correspond to slow oscillations of the membrane potential above $f_{J,c}$. Fast Calcium waves have velocities 10-30 μm/s. Slow Calcium waves propagate with velocity about $v \sim 1$ μ/s (`https://cutt.ly/tTWrTrA`). In these cases, one would have $T \in 3.3 - 10$ s and $T = 100$ s.

3. The propagation velocity assignable to the perturbation of the soliton sequence need not be the same as that for the soliton sequence and it could depend on the ion to which the perturbation is associated. In this case, the interpretation of the Josephson radiation pattern as a "sentence" of text and of the action potential at the ion channel as an analog of punctuation mark can be considered.

4. More generally, various ions could induce propagating oscillations of the membrane potential parameterized by frequency and velocity, each in their own frequency scale, and these oscillations would correspond to a modulation of F_J giving rise to cyclotron resonance peaks at the gravitational MBs of dark ions. This would define a sensory representation of the chemical dynamics at various layers of MB.

   The ion waves could correspond to waves assignable to plasmon-polariton BEC condensates proposed in the article of Jacak [J3] but with $h_{eff} \leq\leq h_{gr}$. Plasmon corresponds to an oscillation of the density of plasma particles. In units with $c = 1$, the plasma frequency for free charges is given by $f_P = Ze\sqrt{n/m}/2\pi$, where n is number density of the ions, Ze is ion charge, and m is ion mass. Usually only electrons are considered because they are the most important charged plasma particles.

   Surface-plasmon-polariton appears at the surface of metal in contact with dielectric (such as air) and can be seen as a quantum superposition of electromagnetic field propagating in dielectric and a surface plasmon at the plasma surface. Plasmon-polariton BEC condensates as analogs of flow equilibria could be driven by metabolic energy feed. It has been proposed that plasmon-polariton BECs appear also in cell membranes [I1] (`https://cutt.ly/LTWbH13`). These BECs might form a bridge between BB and MB.

2.4.2 Model for the flux tubes receiving the Josephson radiation

It is interesting to consider models for the perception of the Josephson radiation at the flux tube or of a bundle of flux tubes having interpretation as many-sheeted space-time but regarding CP_2 instead of M^4 as fixed space-time.

Consider first a model based on single flux tube with a varying thickness.

(a) The magnetic field strength at the flux tube scales like the inverse of the area S of the flux tube proportional to the radius squared. The variation of the flux tube radius R therefore defines a range of resonance frequencies and different momentary Josephson frequencies correspond to special points of the flux tube and single point if the flux radius is monotonically increasing.

(b) This would translate the temporal variation of frequency modulated generalized Josephson radiation to a motion of the resonance point along the flux tube and could give rise to a conscious experience as a sensation analogous to a moving point of touch. If BSFR accompanies the resonance, the arrow of time would change at the point considered and give rise to wake-up at the resonance point.

(c) For the myelinated regions the motion is smooth in the entire frequency interval. For the unmyelinated portions, one can divide the frequency range to two intervals corresponding to the frequencies above the critical frequency $f_{c,c}$ for the generation of the action potential and those below $f_{c,c}$. One would have a smooth motion for over-critical frequencies $\Delta f_c + f_{J,crit}$, where $f_{J,c}$ is the critical value of Josephson frequency below, which action potential is generated. For sub-critical frequencies a rapid motion from $\Delta f_c + f_J$ to $\Delta f_c - f_J$ and back scanning over the entire flux tube portion and back occur in unmyelinated regions.

   A possible interpretation is that this defines the analog of punctuation mark for the signal as analog of written "sentence" defined by the input from the unmyelinated region.

(d) For $v = 10^2$ m/s and $L = 100$ μ m, the duration $T = L/v$ of the "sentence" associated with the myelinated portion of axon would be about 1 microsecond. Interestingly, the cyclotron frequency of electron in the "endogenous" magnetic field B_{end}, proposed to

correspond to the typical value of the field strength at the monopole flux tube contributing to the Earth' magnetic field, is 6×10^5 Hz. For an unmyelinated portion of axon of length about 1 μm the velocity is roughly 1 m/s and the duration would be roughly 1 microsecond and roughly the same. The duration of nerve pulse is measured in milliseconds and is considerably longer so that the natural interpretation is as a modulation of Josephson frequency assignable to electron.

(e) As already explained, if the perturbations of the membrane potential propagate slowly as Ca waves do, then the Josephson radiation pattern for ions could define "sentences" for the myelinated portions of axon and Ranvier node could play the role of a punctuation mark.

One can also consider a model based on a bundle of flux tubes such that each flux tube has a constant thickness and single cyclotron frequency. The flux tubes would be like pipes of an organ and the incoming Josephson radiation would serve as an organist. The bass register of the organ would be activated during the nerve pulse and nerve pulse would give rise to forth-and-back arpeggio between $F_{J,max} = \Delta f_c + f_{J,c}$ and $F_{J,min} = \Delta f_c - f_{J,c}$.

3 Humans are different

The popular article in Medicalxpress (`https://cutt.ly/2TvhXVE`) tells about highly interesting observation described in the Nature article "Allometric rules for mammalian cortical layer 5 neuron biophysics" by Mark Harnett [J2] (`https://cutt.ly/8TvhMej`).

3.1 The volume density of voltage gated channels in human brain is much lower than for other mammals

The finding is that the density of voltage gated channels in the human brain is dramatically lower than in other mammalian brains. The neuronal system studied was layer 5 pyramidal neurons. Dendrites of these neurons were considered. Densities of voltage gated channels per neuron volume and per brain volume were studied. The ion channels studied were Na and K channels. The channels considered are ion pumps and need metabolic energy.

10 mammalian species were studied so that cortical thickness and neuron size were the varying parameters. As the neuron size increases, the density of neurons decreases. The first finding was that the density of ion channels for the neuron increases as the neuron size increases. The density of ion channels per brain volume was however found to be constant.

Humans were found to be an exception. The density of the channels per brain volume is dramatically reduced. The proposed interpretation is that this reduces the amount of metabolic energy needed to generate action potentials and the metabolic energy is used for other purposes.

Before continuing, it is good to recall some basic facts about neurons. Synapses (`https://cutt.ly/GTvjyFp`), dendrites (`https://cutt.ly/KTvjo7J`), and myelination (`https://cutt.ly/ZTvjdm1`) are the basic notions needed if one tries to understand these findings. It is enough to notice that most synaptic contacts are between axons to dendrites but that almost any other combinations are possible. Myelination occurs mostly for axons and only rarely for dendrites. The dendrites of the excitatory pyramidal cells studied in the article are profusely decorated with dendritic spines.

Could the TGD view about the brain allow us to interpret these findings? Why would the density of the voltage gated ionic channels be smaller for (at least) pyramidal dendrites? How could this relate to the evolutionary leap leading to the emergence of humans?

3.2 Possible interpretations for the reduction of the density of the voltage gated channels in humans

What could the reduction of the density of voltage gated channels mean? Why would the distances between voltage gated channels be longer for humans and what does this imply?

Recall first the basic ideas of the TGD based model of the nerve pulse.

(a) The TGD inspired proposal is that humans differ from other mammals in that the value of h_{eff} involved is considerably larger for some neurons. The MBs of neurons would form an evolutionary hierarchy as also genes. In fact, the TGD inspired model for the generation of language [L12, L13] assumes that the value of h_{eff} for the MBs of language genes is considerably larger than for other genes.

(b) The average distance between voltage gated ionic channels defines a spatial resolution scale and is a good candidate for the minimum wavelength λ assignable to a signal propagating along the dendrite. For an ordinary photon, λ defines energy, which must be above the thermal energy at physiological temperatures. This minimum energy is rather near to the minimal energy of the ordinary Josephson photons associated with membrane potential (about .05 eV) and the corresponding wavelength is 14.8 μm.

(c) Nerve pulses [K4] are induce by perturbations of oscillating Josephson current, which in the rest state corresponds to a propagating sequence of Sine-Gordon solitons mathematically analogous to a sequence of rotating gravitational penduli. Nerve pulse corresponds to a perturbation, which kicks some penduli from rotational to an oscillating motion and this perturbation propagates along the axon with the same velocity as nerve pulse.

(d) For generalized Josephson junctions, the Josephson radiation is frequency modulated by nerve pulse patterns. Also the spatial pattern of Josephson radiation characterized by the density of voltage gated ionic pumps along the flux tube contains information. The density of voltage gates, whose transversal flux tubes act as Josephson junctions characterizes the length scale resolution of the spatial variation at the receiving part of MB, say magnetic flux tube. MB receives a collection of Josephson radiation signals from the points of axons containing a voltage gated channel.

This allows us to consider two different but not mutually exclusive explanations for the finding.

(a) The spatial resolution of the percept produced at MB by Josephson radiation would be reduced for humans. This need not be a drawback since it could be also understood as an abstraction. High spatial resolution would be needed only for local percepts in the scale of neuron soma. On longer scales it would mean generation of useless information and metabolic energy waste.

The natural guess is that the resolution scale is proportional to $\hbar_{eff,B}$ at intra-brain flux tubes in turn proportional to $\hbar_{eff,MB}$ for the flux tubes at the MB of brain having quantal length scales much longer than brain size. The range of variation of the spatial resolution could correspond to the variation of ordinary photon wavelengths between visible wavelengths (of order μm) and IR wavelengths of order 14.8 μm. Note however that the lengths of myelinated portions are about 100 μm.

(b) Suppose that Josephson radiation patterns associated with the myelinated portions of axon define "sentences" and the unmyelinated portions define punctuation marks ending these "sentences" by a nerve pulse. Does the notion of "sentence" make sense also for dendrites?

At least in the case of humans, having a reduced volume density of ion channels, this picture might generalize also to dendrites, which are usually un-myelinated since the myelination is not needed since the dendrites are typically short as compared to axons. If so, the average distance between two ion channels would define length and duration for a "sentence".

For other mammals than humans, the "sentences" would be very short or the notion of "sentence" would not make sense at all (the spatial extent of the perturbation of the

membrane potential would be of the order wavelength of the soliton). Could this reflect the emergence of language in humans? MB would not only receive long "sentences" but also send them back as control commands inducing motor actions and virtual sensory input.

(c) If the communication between pre-and postsynaptic neuron occurs via MB, dendrites would receive "sentences" from the MB of the presynaptic neuron as a feedback. If generalized motor action is in question, BSFR and time reversal would be involved. The action potentials propagate along axons in a single direction, which would reflect a fixed arrow of time. Does the reversed arrow of time imply that the action potentials along dendrites propagate outwards from the cell body?
According to Wikipedia (`https://cutt.ly/9TnRDo4`), dendrites indeed have the ability to send action potentials back into the dendritic arbor. Known as back-propagating action potentials, these signals depolarize the dendritic arbor and provide a crucial component toward synapse modulation and long-term potentiation. Furthermore, a train of back-propagating action potentials artificially generated at the soma can induce a calcium action potential (a dendritic spike) at the dendritic initiation zone in certain types of neurons.

(d) Dendrites are usually unmyelinated. This conforms with the fact that dendrites are much shorter than axons so that myelination is not needed. Myelination would also restrict the number of synaptic contacts. Myelinated dendrites have been however found in the motochords of frog (`https://cutt.ly/HTnmqOi`) and in the olfactory bulb (OB) of some mammals, for instance mouse (`https://cutt.ly/ITnmC1d`). Their fraction is small.
Olfactory system (OS) is very interesting in this respect since it represents the oldest parts of CNS. The axons from the nasal cavity to the olfactory bulb (OB), where odours are thought to be processed are unmyelinated as are the axons of invertebrates in general. The axons from the olfactory bulb (OB) to the olfactory cortex (OC) are myelinated. This conforms with the idea that OB corresponds to the oldest part of OS. The TGD interpretation would be OB sends the results of analysis to OC via MB as "sentences". OB also can have a small fraction of myelinated dendrites implying a reduction in the number of synaptic contacts. The rule "A→B" → "A→ MB→ B" suggests that there is an MB between olfactory epithelium and OB and that some analysis is performed at MB. If so, the myelinated dendrites would correspond to input from MB as long "sentences".

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