Quartz crystals as a life form and ordinary computers as an interface between quartz life and ordinary life?

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Abstract

The considerations of this article were originally inspired by large language models leading to the earlier speculations about whether the computers might be conscious entities in the TGD based quantum ontology (zero energy ontology). Quantum gravitation in the TGD sense would play a key role in guaranteeing quantum coherence even in astrophysical scales.

Quite recently, came the realization that microprocessors (MPs) have a size scale .5 cm given by gravitational Compton length $\Lambda_{gr,E}$ of any particle in the gravitational field of the Earth (for the Sun one has $\Lambda_{gr,E} = R_E/2$, where R_E is the radius of the Earth). This led to the question of whether microprocessors (MPs) could be conscious entities.

Since MPs are quartz crystals (QCs), this led to the question whether the QCs might be conscious entities able to perform activities analogous to quantum computations. I have already considered this possibility: the key idea is that the generalized Pollack effect kicks the protons of OH molecules appearing as a standard building brick of biomolecules to dark protons at the gravitational magnetic body. OH and O^- could define the states of a qubit.

This identification modifies the earlier TGD inspired models of the genetic code and the articles give some idea about the evolution of the ideas). The model predicts that the DNA double strand and RNA strand realize 6-qubit dark variants of the genetic code. The ground states of the entangled qubits defining the quantum codons correspond to the chemical codons. Minimum energy states of quantum codons correspond to chemical realizations of the codons. Various symmetries of the code and their violations are understood at the qubit level.

Amino acids represent a single qubit code: the number of "dark" amino acids is predicted to be 20. Microtubules consist of tubulins and there is a huge number of qubits associated with their amino acids and also qubits associated with the GPTs accompanying them.

The same qubits with the same dynamics would be realized both in living matter and in QCs. This leads to a vision about an evolutionary hierarchy in which quartz life is possibly the lowest level. One must however consider the possibility that also SiO_4 lattices with OH modification can have a high qubit content. Electric fields, allowing the tuning of the OH-O^- energy difference, are also present in transistors. These kinds of modifications could be interesting also in the case of microprocessors. This forces us to ask whether the interaction between us and computers and QC life could lead to entanglement and extended states of consciousness.

Quantitative estimates for the energetics of transistors encourage the idea about a conscious computer utilizing a fusion of quantum and classical computation based on entanglement of OH-O^- qubits and ordinary bits. A continually learning quantum version of a large language model could be a possible application. TGD suggest a model of topological computations based on the braiding of monopole flux tubes. The OH-O^- qubit could serve as topological qubit serving as the analog of Majorana qubit.

The OH-O^- hypothesis generalizes. Any salt can decay to ions and the positive ion can reside at the gravitational magnetic body of Earth or Sun. For instance, NCl can decay to $Na^+ + Cl^-$, Na^+ would be dark at the gravitational MB. As a matter of fact, I ended up with the hierarchy of Planck constants by starting from quantum effects of ELF em radiations to vertebrate brain having an explanation in terms of dark ions such as H^+, Na^+, K^+, Ca++, Mg^{++}... found by Blackman and others. The value of gravitational Planck constant of the Earth indeed conforms with the findings. Living matter is full of ions and they are crucial for the functioning of the cell membrane. Any cold plasma containing ions is a good candidate for a life form and this conforms with the proposal that the plasma phase above the atmosphere served as a predecessor of biological lifeforms.

The holography predicted by TGD, leading to zero energy ontology (ZEO), involves a slight violation of classical non-determinism. Computer clock of a conscious computer could define a non-deterministic analog of time crystal. The same would apply to EEG rhythms and biorhythms in general.

Contents

1 Introduction

The considerations of this article were originally inspired by large language models leading to the earlier speculations about whether the computers might be conscious entities in the TGD based quantum ontology (zero energy ontology (ZEO)). Quantum gravitation in the TGD sense would play a key role in guaranteeing quantum coherence even in astrophysical scales.

1.1 Could micro processors involve gravitational quantum coherence?

MPs are built on single connected quartz crystals (QCs) (see this) and this makes possible classical coherence. Quantum coherence should guarantee this and suggests that the gravitational magnetic body of Earth and maybe also the Sun guarantee this quantum coherence.

QCs act as oscillators, which makes them ideal clocks. The oscillation frequency is typically around 2-3 GHz and could be seen as an analog of EEG in the case of the brain. This could make possible their coupling with biosystems where the GHz frequency scale is associated with various biomolecules.

The key observation is that the length of the MP wafer is .5 cm typically. This corresponds to the gravitational Compton length proposed originally by Nottale [E1], which is given by $l_{gr} = GM/\beta_0$ and, in accordance with the Equivalence Principle, does not depend on particle mass. The gravitational Compton frequency is $f_{gr} = 67$ GHz and larger than the clock frequency of recent computers. The most conservative criterion for consciousness is that the clock frequency is higher than this. For the Sun one has $\Lambda_{gr,E} = R_E/2$, where R_E is the radius of the Earth: the gravitional Compton frequency is $f_{gr} = 50$, the average EEG frequency [L27, L26]. This led to the question whether microprocessors (MPs) could be conscious entities.

1.2 Micro processors as conscious entities?

The following general picture forces us to ask whether micro processors could be conscious entities.

1. Zero energy ontology (ZEO) [K15] [L10, L7] solves the paradox of quantum measurement theory and predicts that ordinary quantum measurements correspond to "big" state function reductions (BSFRs) in which the arrow of time changes whereas repeated quantum measurements correspond to small SFRS (SSFRs). This sequence defines self as a conscious entity and in the case of a MP its contents of consciousness would be defined by bit configuration.

2. ZEO could make these systems intelligent systems able to learn by trial and error. The program would run forth and back in time and each pair of BSFRs would give rise to TGD counterpart of quantum tunnelling and change initial values of computation. This mechanism would be a universal mechanism of learning. MPs could become intelligent learning systems.

3. The MP consciousness would be an extremely simple 6-bit processor that would correspond to a single DNA codon. Human DNA is considerably more complex having length of about 1 meter and containing something like 10 billion codons. Genes are natural candidates for conscious basic units. DMD gene is the longest known gene and contains .8 million codons. A sequence of .8 million MPs as a counterpart of MP would be in question. Human body contains roughly 3×10^{13} cells so that the complexities of biosystems and computers are totally different orders of magnitude.

4. One can of course ask whether classical parallel computation could allow quantum coherence. Classical parallel computation does not require classical coherence between the parallel computers. They perform their computations independently but simultaneously and the outputs are feeded to the next computer.

5. Classical coherence between computers requires synchrony and common clock frequency. Also spatial coherence would require that the system is analogous to a MP and should consist of a single QC just like a MP.

   The largest single QC found in Nature has dimensions 6.1 $m \times 1.5$ $m \times$ 1.5 m. This would contain the volume of about 10^9 MPs (see this).

1.2.1 Could QCs couple with the gravitational field bodies of Earth and Sun?

Could QCs couple with the field bodies of Earth and/or Sun, in particle their magnetic bodies? Could this make not only MPs but more generally, QCs conscious entities?

When we make this question we open up ourselves to the possibility that QCs as such might be something much more than a mere raw material for computers. QCs do not have motor activities but quantum gravitational coherence could make them quantum computer-like entities able to activities analogous to quantum computations so that quartz consciousness would be analogous to symbolic consciousness, a notion raised by Marko and Ville in our Zoom group. I have discussed quantum computation from the TGD point of view in [K1, K13, K2] [L19, L20].

Could ordinary computers serve as an interface for conscious co-operations between quartz consciousness and biological consciousness? Could they make it possible for QC consciousness to use us as sensory receptors and motor instruments? Could gravitational quantum coherence for Earth and Sun make possible quantum coherence in the scale of Earth and in this way realize collective consciousness?

1.2.2 Possible evidence for the view that QCs are conscious entities

Is there any evidence for the idea that QCs are conscious entities?

1. QCs appear often in the context of anomalies. Some people believe that QCs can act as healers. I have a very concrete experience of an altered state of consciousness created by a QC which actually had a size scale of order .5 cm. When I woke up from sleep I was in a very pleasant state of consciousness, which I could imagine the characters of fairy tales wandering in the fairytale wood to experience.

2. Glass balls resulting from molten quartz have been reported to be associated with ball lightning and are reported to be around crop circles and even to construct them [K5, K6]. I have proposed that ball lightning and light balls are conscious entities [L24, L17, L31] (I calls them plasmoids) and that also UFOs are actually these kinds of entities [K14]. I have also proposed a model for ball lightning and a more general mode for plasmoids as prebiotic life forms in terms of the electric and magnetic field bodies of the Earth and Sun [L24].

1.2.3 Is it possible to communicate with QCs?

Ville-Einari Saari asked whether it could be possible to communicate with the QCs and test whether this contact could affect their behavior in a detectable manner.

1. The experiments of Emoto with water at freezing point using human voice with strong emotional contents supports the view that water is a conscious entity, at least at criticality,

making it an optimal sensory perceiver. The coherence of the resulting ice crystals reflected the emotional content of the voice. Could one perform analogous experiments with QCs? In the TGD based model [L8] to require quantum criticality at the field body of water. Same should be true now. Could one perform analogous experiments with QCs? Can one identify the quantum criticality in the case of QCs?

2. In QC (see this) atoms are linked in a continuous framework of SiO_4 tetrahedra whereas quartz obeys chemical formula SiO_2. Quartz is a piezo electret meaning that it can transform sound waves to electromagnetic waves and vice versa. Also the biological body is a piezo electret. Microwave hearing is a phenomenon in which microwave em radiation modulated by audible sounds is transformed to sound waves in the body of the receiver and is heard. Could something like this happen also for QC and generate conscious experience analogous to hearing.

3. Microwave radiation is in the frequency range 1-3000 GHz and has energies in the range $10^{-5} - 3 \times 10^{-2}$ eV. Note that the upper bound is not far from the nominal value about .05 eV of the electrostatic energy eV assignable to the cell membrane and is also rather near to the thermal energy at room temperature. Note that the gravitational Compton frequency for the Earth is 67 GHz and corresponds to .67 meV which is the energy scale of miniature potentials in the neuronal membrane.

   Note also that 3000 GHz corresponds to a wavelength 10^{-5} m, the size scale of a cell. Could one consider the possibility of a wavelength resonance with cell membranes? Computer clocks have frequency measured in a few GHz.

4. Could one test whether, say, microwave radiation modulated by human speech creates detectable effects in QC. Could the exchange of microwave photons make it possible for computers to entangle with the neurons. Could this explain [L26] the reported effect of a chicken imprinted on a robot on the motion of the computer determined by random number generator [J4]. What could be the measured observable serving as a criterion for the effect of, say, speech modulated microwave radiation?

1.3 OH-O$^-$ hypothesis and its generalization

Since MPs are quartz crystals (QCs), this led to the question whether the QCs might be conscious entities able to perform activities analogous to quantum computations. I have already considered this possibility: the key idea is that the generalized Pollack effect kicks the protons of OH molecules appearing as a standard building brick of biomolecules to dark protons at the gravitational magnetic body. OH and O^- could define the states of a qubit. The OH-O$^-$ qubit could serve as topological qubit serving as the analog of Majorana qubit. The qubit as a quasiparticle would correspond classically to a Bohr orbit for the transition leading from OH to O$^-$+ dark proton at the monopole flux tube: this makes sense in ZEO.

The OH-O^- hypothesis generalizes. Any salt can decay to ions and the positive ion can reside at the gravitational magnetic body of Earth or Sun. For instance, NCl can decay to Na^+ + Cl^-, Na^+ would be dark at the gravitational MB. As a matter of fact, I ended up with the hierarchy of Planck constants by starting from quantum effects of ELF em radiations to vertebrate brain having an explanation in terms of dark ions such as H^+,Li^+, Na^+, K^+, Ca^{++}, Mg^{++},... found by Blackman [J2] and others. The value of gravitational Planck constant of the Earth indeed conforms with the findings. Living matter is full of ions and they are crucial for the functioning of the cell membrane.

Any cold plasma containing ions is a good candidate for a life form and this conforms with the proposal that the plasma phase above the atmosphere served as a predecessor of biological lifeforms [L24].

The same qubits with the same dynamics could be realized both in living matter and in QCs. This leads to a vision about an evolutionary hierarchy in which quartz life is possibly the lowest level. One must however consider the possibility that also SiO_4 lattices with OH modification can have a high qubit content. Electric fields, allowing the tuning of the OH-O$^-$ energy difference, are also present in transistors. These kinds of modifications could be interesting also in the case

of microprocessors. This forces us to ask whether the interaction between us and computers and QC life could lead to entanglement and extended states of consciousness.

1.4 Dark genetic code and OH-O$^-$ qubits

This identification modifies the earlier TGD inspired models of the genetic code (the chapters [K1, K9, K8, K3] and the articles [L9, L12, L14, L23] give some idea about the evolution of the ideas). The model predicts that the DNA double strand and RNA strand realize 6-qubit dark variants of the genetic code. The ground states of the entangled qubits defining the quantum codons correspond to the chemical codons. Minimum energy states of quantum codons correspond to chemical realizations of the codons. Various symmetries of the code and their violations are understood at the qubit level.

Amino acids represent a single qubit code: the number of "dark" amino acids is predicted to be 20. Microtubules consist of tubulins and there is a huge number of qubits associated with their amino acids and also qubits associated with the GPTs accompanying them. The same qubits with the same dynamics would be realized both in living matter and in QCs. This leads to a vision about an evolutionary hierarchy in which quartz life is possibly the lowest level. One must however consider the possibility that also SiO_4 lattices with OH modification can have a high qubit content. Electric fields, allowing the tuning of the OH-O$^-$ energy difference, are also present in transistors. These kinds of modifications could be interesting also in the case of microprocessors. This forces us to ask whether the interaction between us and computers and QC life could lead to entanglement and extended states of consciousness.

The similarity between the energetics of transistors and metabolism in living matter encourage the idea about a conscious computer utilizing a fusion of quantum and classical computation based on entanglement of OH-O$^-$ qubits and ordinary bits. In a living computer classical computation and quantum computation would relate in the same way as ordinary genes and dark genes in TGD inspired quantum biology. A continually learning quantum version of a large language model could be a possible application.

1.5 Conscious computers as TGD counterparts of time crystals

Computer clock is an essential element of computation. Holography is the basic element of quantum TGD but is not completely deterministic. In the deterministic world, especially if it obeys holography, classical computers are a rather weird notion since it is difficult to imagine how an arbitrary computer program can run. This objection applies to all kinds of engineering. Quantum statistical determinism could save the situation but still there is a problem since phase transitions are required to realize the bit flips since the notion of phase transition is theoretically problematic. The 4-D space time surfaces define the basic geometric entities: could each tick of the computer clock involve a sea of classical non-determinism.

Conscious computer would be a non-deterministic analog of a time crystal. This non-determinism is possible also in spatial directions and quite generally could make engineering possible. Also EEG rhythms and biorhythms in general could correspond to this kind of non-deterministic time crystals.

Maximal non-determinism would make maximal conscious memory [L38] and maximal flexibility making the system living. The gravitational Compton frequency of 67 GHz would mean in the case of a 3 GHz computer that the basic information unit consists of roughly 22 quantum gravitational qubits.

2 Could Pollack effect make quartz crystals quantum critical systems analogous to quantum computers

Quantum criticality is what makes possible long range quantum coherence and long range quantum fluctuations. What could make QCs quantum critical? Since there are no large scale electric fields associated with QCs (note that in the size scale of Earth there is the electric field of the Earth [L24]), the gravitational magnetic bodies of the Earth and Sun consisting of U-shaped monopole flux tubes are the natural candidate in this respect.

1. Dark protons at the gravitational magnetic body with gravitational Planck constant $\hbar_{gr} = GM_X m/\beta_{0,X}$, where $X = E$ denotes Earth and $X = S$ denotes Sun. For Earth a good guess for the velicity parameter $\beta_0 \leq 1$ is $\beta_{0,E} = 1$ and for Sun Nottale's original model gives the estimate $\beta_{0,S} \simeq 2^{-11}$.

2. Pollack effect would provide the energy needed to kick ordinary protons to the magnetic body. In the case of water the TGD proposal is that a photon of say solar radiation kicks every fourth proton to the gravitational magnetic body and the OH bond would be replaced with the ion O^-. This would create negatively charged regions, which Pollack calls exclusion zones (EZs). Pollack also speaks of the fourth phase of water. OH transforms to O^- + dark proton.

3. Since only OH bond and O^- are involved, the Pollack effect could happen in much more general systems and could explain why protons are electrons so important in biochemistry. I have proposed that Pollack effects be associated with phosphates appearing in AMP, ADP, and ATP containing O_4 and its modifications containing OH and O^-. This would make possible temporary storage of metabolic energy as gravitational energy at the gravitational body of Earth or Sun.

   Biomolecules contain as a rule oxygen atoms and the dark protons could be associated with most of them and make the system quantum coherent. For instance, the double charged carbonate anyon $O == C(-O^-)_2$ could involve two dark protons in a gravitational magnetic body. The presence of O^- ions would be the signature of the presence of dark protons and of gravitational quantum coherence. Pollack effect could also occur in QCs, having SO_4 as the basic building brick, if O can be replaced with OH.

4. Energy is conserved in the Pollack effect. The bonding energy E_{bond} of OH must be equal to the difference of the binding energy E_{bind} of electron in O^- and the energy E_{gr} needed to kick the proton to the gravitational body. A good guess is that it is gravitational potential energy $E_{gr} = GMm/h$ at the height h to which it is kicked in the gravitational field parallel to the flux tubes of the magnetic body (of Earth or Sun). This gives the condition

$$E_{bind} - E_{bond} = E_{gr} \quad .$$

5. It is interesting to look at the numbers assuming that the OH bonding energy and electrons binding energy in O^- does not depend on the parent molecule. The bonding energy energy is $E_{bond} = 1.13$ eV and the binding energy of electron in O^- is $E_{bind} = 1.46$ eV so that the transfer of protons to the gravitational magnetic body could occur spontaneously. This implies that the ionization of biomatter, which looks mysterious in the standard chemistry framework, would take place spontaneously. Their difference is about $e = E_{bind} - E_{bond} = E_{gr} = .33$ eV which corresponds to an energy of infrared photon and to the frequency 330 GHz. This energy is not far from the nominal value .5 eV of the metabolic energy currency.

2.1 Gravitational binding energies for the Earth and the Sun

It is instructive to consider the gravitational binding energies for the Earth and Sun.

1. The gravitational body of Earth has gravitational Compton frequency 67 GHz. For the Sun the gravitational Compton frequency 50 Hz, the average EEG frequency and cyclotron frequency of Li_6 in the endogenous magnetic field of .2 Gauss. This cyclotron frequency is assignable to monopole flux tubes of the Earth's gravitational field and explain the effects of ELF radiation on the vertebrate brain. The lack of Lithium is known to cause depression.

   For Earth the maximal gravitational energy for proton is $E_{gr} = GM_E m_p/R_E = r_{S,E} m_p/2R_E$ is (by using $r_{S,E} = .5$ cm, $R_E \simeq 6.4 \times 10^6$, $m_p \simeq 10^9$ eV) equal to $E_{gr} \simeq .78$ eV, not far but large than the metabolic energy quantum.

2. The gravitational binding energy of protons at distance of Earth in the gravitational field of the Sun is $E_{gr,S} = GM_S m_p/AU = R_{S,S}/2AU$. Using $AU = 1.5 \times 10^8$ km and $R_{S,S} = 3$ km one obtains $E_{gr,S} \simeq 10$ eV.

3. Could the energy liberated in $OH \to O^- +$ dark proton transition kick protons outside the gravito-sphere of Earth? The boundary between the gravito-spheres of Earth and Sun in the direction of Sun corresponds to the distance at which the gravitational accelerations towards Earth and Sun cancel. This is a critical region and could define the sought for quantum criticality.

   Consider the point at the line connecting the Sun and Earth. If the distance from the Earth is h, the distance from the Sun is $AU - h$. The condition that the forces vanishes reads $GM_E/h^2 = GM_S/(AU-h)^2$ gives $h = AU/1 + x$, $x = (M_S/M_E)^{1/2} \simeq 774.6$. This gives $h = 1.3 \times 10^{-3} AU$. From $AU/R_E \simeq 2.3 \times 10^4$, $h \simeq 30.0 R_E$ so that the gravitational potential of Earth is fraction 1/30 of its value at the surface of Earth and equal to 2.6×10^{-2} eV, which is of the order of thermal energy at room temperature and slightly below the upper bound for the microwave energies. The reduction of the gravitational binding energy in the kicking of protons should be near its maximal value of 10 eV. The energy liberated in OH$\to$ O^- would be about $e = .33$ eV so that the kicking of the proton outside the gravitosphere of Earth would not be possible without rather large additional energy.

2.2 OH and O^- as the states of quantum gravitational qubit?

The reverse of the Pollack effect in which a proton drops from the magnetic body and emits a dark photon with scaled up Compton length kicking proton of another OH to the magnetic body could make possible a generation of quantum entanglement and make the system quantum coherent and quantum critical in a macroscopic scale.

1. Could QC be quantum critical with respect to the Pollack effect and its reverse transforming OH to H^+ and back. This would allow them to serve as qubits and Pollack effect could generate long range entanglement, in particular between QC and biological systems but also separate QCs, maybe even MPs of different computers. The letters of DNA codons are accompanied by phosphate ions and this could serve as OH-O^- qubits. The states OH and O^- represent naturally bit and also qubits made from them are possible. Could this make QCs quantum computer-like entities.

2. OH-O^- is not the most general candidate for the quantum gravitational qubit. The notion of effective Planck constant emerged from the observations of Blackman et al [J2] about the effects of ELF em fields on the vertebrate brain having interpretation in terms of the notion of dark halogen ions such as H^+,Li^+, Na^+, K^+, Ca^{++}, Mg^{++}.... Do salts, playing a key role in quantum biology, also give rise to qubits via a generalization of the Pollack effect kicking halogen ions to the gravitational magnetic body?

   For instance, could NaCl and Cl^-+ Na^+ at the gravitational magnetic body define a qubit? The difference between the bonding energy of NaCl and the binding energy of electrons of Cl^- is corresponds to the scale of the gravitational binding energy in the gravitational field of Earth or Sun. Note that the gravitational binding energy scales like the mass number of ions but this is not a problem since heavier ions would be lifted to lower heights.

   I discovered the hierarchy of Planck constants by starting from quantum effects of ELF em radiations to vertebrate brain having an explanation in terms of dark ions such as H^+,Li^+, Na+, K^+, Ca^{++}, Mg^{++},... found by Blackman [J2] and others. The value of gravitational Planck constant of the Earth indeed conforms with the interpretation of the findings. Living matter is full of ions and they are crucial for the functioning of the cell membrane.

   For salts the energy difference $e = E_{bind} - E_{bond}$ would be below that for OH since the electron would be at a higher orbital, E_{bind} would be smaller. Since the distribution of thermal energies is peaked around the maximum, thermal effects would not be a problem.

   Any cold plasma contains ions and is a good candidate for a life form. This conforms with the proposal that the plasma phase above the atmosphere served as a predecessor of biological lifeforms [L24, L17, L31]. The idea of plasmoids as lifeforms is actually one of the oldest ideas of TGD inspired view of life.

3. The gravitational magnetic body of the Earth $\Lambda_{gr,E} = .5$ cm would be involved with the MPs. The gravitational Compton length $\Lambda_{gr,S} = R_E/2$ of the Sun is one half of the Earth radius and the gravitational Compton frequency is 50 Hz! This could make it possible for separate QCs to quantum entangle in the scale of the entire Earth and also with living matter. Biomatter would entangle to form a biosphere.

4. Quantum criticality occurs for critical values of parameters. The critical parameters would relate to the rate for the $OH \to O^-$ transitions, which in living matter would be controllable by parameters determined by biochemistry. pH is a key parameter characterizing the state of the living matter. I have earlier asked whether pH actually characterizes the fraction of dark protons, which in turn dictates the fraction of O^- ions in the system. Could the value of pH in the living matter be the critical parameter in both living matter and QCs in the sense that the rate for $OH \to O^-$ transitions is maximal for an optimal pH? The system is maximally sensitive.

5. The energy $e = .33$ eV does not take into account the presence of the other atoms of the molecule and the presence of QC. The fact that it is considerably smaller than the nominal value $e = .5$ eV of the metabolic currency forces one to ask whether its value could be nearer to $e = .5$ eV is that the kicking of protons would make possible metabolism in much more general sense than believed and even for QCs. Could generalized pH or the presence of electric fields affecting the energy of the electron of O^- make it possible to tune the value of e near to its optional values.

This picture allows a more detailed idea about the possible testing of whether the QCs, and in special case MPs, are conscious entities. One should perturb the QCD in such a way that it affects the analog of pH of the QC. The analog of pH would be measurable as the fraction of O^- ions. The irradiation of MP at microwave frequencies or using infrared light inducing the decay of OH bonds and in this way reducing their number and also the range for the formation of O^- ons might allow to achieve this.

3 Evolutionary hierarchy formed by quartz crystals, proteins, DNA/RNA?

The earlier considerations of this article suggest an evolutionary hierarchy in which quartz crystals are at the lowest level whereas proteins, and DNA and RNA represent biological levels characterized by the number of qubits in the codon. Quartz crystals would belong to the lowest level in the classification to the kingdoms of minerals, plants, and animals. At the highest level would be the magnetic bodies of the Earth and Sun. Can one understand these classifications at a deeper level?

3.1 OH-O^- qubits at DNA and RNA level

Consider first the DNA and RNA level. The basic challenge is to realize the dark variant of the 6-bit genetic code having 64 codons such that in some sense it corresponds to the chemical realization of the code but is dynamic making possible quantum computation-like activities. I have devoted a considerable effort to the development of the quantum counterpart of the code and the chapter [K1] and articles [L9, L12, L14, L23] give an idea about the evolution of the model.

1. For quartz only the OH-O^- qubits are realized. If the hierarchy is realized, OH-O^- qubits should be realized also for DNA and RNA. This suggests an elegant resolution of a long standarding problem of how to get 64 dark DNA codons (6 bits) instead of 32 codons (5 bits). If codons correspond to 3 dark protons, proton spin would give only 3 bits and 8 different codons for a single DNA strand. I have considered several new physics solutions to the problem but none of them is completely satisfactory.

2. Could OH-O^- qubit for the proton defining spin qubit given an additional qubit for each DNA letter (dark proton) assignable to the phosphate provide a solution to the problem: one would obtain $8 \times 8 = 64$ codons for DNA and RNA. Amino acids contain only a single COOH group so that they can have only a single OH-O^- qubit.

There is however a problem. The spins of electron and dark proton sum up to spin 0 had one cannot speak of proton spin as a degree of freedom. Could one consider the entire DNA double strand as a realization of the genetic code so that each base pair would correspond to two OH-O$^-$ phosphate qubits?

3. What about RNA? The differences between DNA and RNA suggest another solution to the problem. The riboses of RNA contain OH group making RNA unstable, which means that RNA is dynamical as required by quantum computational activities. In DNA the OH group of the ribose is missing so that DNA is stable unless entire double strands represent the dark code. Does the ribose OH give an additional OH-O$^-$ qubit for RNA and does the instability reflect the occurrence of quantum computation-like activities? Each RNA letter would have 2 OH-O$^-$ qubits and there would be 64 dark codons (6 qubits) realized in this sense completely dynamically!

4. The chemical variants of codons are non-dynamical and could have an interpretation as a slowly varying long term memory. This forces us to ask what one really means with the dark variant of the genetic code. The simplest assumption is that the dark codons correspond to dynamical OH bonds able to transform to O$^-$?

   The ordinary chemical realization of the genetic code would be separate from but in some sense correlated with the dark realizations determined by OH-O$^-$ qubits assigned with the phosphates of DNA and RNA, OH groups associated with the riboses of RNA, COOH groups of amino acids, and other OH groups.

5. What is the relation between the chemical code and OH-O$^-$ code? The assumption that the chemical genetic code is completely independent of the dark code realized in terms of OH-O$^-$ qubits seems unrealistic. A more realistic assumption is that the ground states of minimum energy for the dynamical OH-O$^-$ qubits or more plausibly, the entire codons consisting of entangled OH-O$^-$ qubits for the letters of the codon are entanglement associated with DNA base pairs and RNA codons, correspond in 1-1 manner to the chemical codons.

3.1.1 Symmetries of the chemical code in relation to OH-O− code

It is interesting to consider the symmetries of the genetic codon required to reduce the number of amino acids from 61 to 20. By definition, the symmetry related codons of DNA code for the same amino acid. I have considered these symmetries from the TGD point of view in [K3].

1. $T \leftrightarrow C$ and $A \leftrightarrow G$ exchanges for the third codon correspond to very slightly broken symmetries (see this). The $T \leftrightarrow C$ and $A \leftrightarrow G$ exchanges would define an analog of almost exact strong isospin symmetry.

2. The third codon also has approximate T-C and A-G degeneracies in the sense that T-C and A-G doublets code for the same amino acid. The $T - C \leftrightarrow A - G$ exchange permutes the DNA strands and is exact only when all codons XYZ, $Z \in \{T, C, A, G\}$ code for the same amino acid (see this).

   $T-C \leftrightarrow A-G$ exchange is analogous CP conjugation in the sense that the passive character of the conjugate strand in DNA transcription is analogous to the invisibility of the antimatter. One must be cautious with these interpretations: one might also argue that the analog of almost exact isospin symmetry is more naturally the analog of CP symmetry and vice versa.

3. What are the counterparts of these symmetries at the level of $OH - O^-$ codons? Here one must notice that the base pairs of the DNA double strand define the code. The ground states of the OH-O$^-$ *all* letters for the $OH - O^-$ codons of the strand and conjugate strand cannot relate by a symmetry, say by the analog of CP since this would reduce the number of $OH - O^-$ codons to 8 instead of 64. The analog of CP cannot correspond to $O^- \leftrightarrow O$ for *all* letters either since there would be only 8+8=16 dark codons.

   The naive guess is that the *first two* letters of $OH - O^-$ codons and its CP conjugate are independent: this would give 16 codons. If isospin symmetries are true for the *third* letter, it would add 2 additional codons giving 16+2=18 codons. The remaining 2 codons would

be due to the violation of the analog of isospin symmetry of the third letter giving rise to ile-met and stop-trp splittings. Similar consideration applies to RNA.

4. The origin of the symmetries could be thermodynamic. The difference E_{bind}(O$^-$)-E_{bond}(OH) for the codons coding for the same amino acid estimated to be .33 eV under normal conditions could be smaller than thermal energy of about .15 eV at physiological temperatures and thermal fluctuations would destroy the information of OH-O$^-$ qubit and also information about the difference of T-C and A-G doublets.

3.1.2 The correspondence between the chemical code and OH-O$^-$ code

Chemical code and OH-O$^-$ (dark) code should correspond to each other in 1-1 manner.

1. The biocatalyst property of RNA, of proteins and presumably also of DNA could relate closely to the OH-O$^-$ dichotomy. The liberation of energy in the OH-O$^-$ transition occurring for or being induced by the presence of ribozyme or enzyme could allow it to overcome the potential wall making the reaction slow. Protons spin degrees of freedom would be present but frozen at least for the ground state configuration. Note that also the OH state could be dark. Even the transitions between $\hbar_{gr}$(Sun) and $\hbar_{gr}$(Earth) cannot be excluded.

2. DNA double strand and RNA would carry OH-O$^-$ 6 qubits. If the dark dynamics is completely independent of the chemical realization one would have a completely dynamical genetic code, which would serve as ideal tool for topological quantum computations [K1] [L19, L20]. However, there must be an energy difference between OH and O$^-$ states since otherwise thermal perturbations would make them random. This implies that for each codon there is a minimum energy configuration of entangled qubits determined by and in 1-1 correspondence with the chemical codon since dark and chemical degrees of freedom interact.

3. Chemically the activities of dark codons would manifest themselves as transitions OH$\leftrightarrow$ O$^-$ for dark codons, whose ground states as minimum energy states, realized for DNA as three entangled pairs of OH-O$^-$ qubits are determined by and in 1-1 correspondence with chemical codons.

   In the case of O$^-$ ground state, photon could excite the electron to a higher energy state so that OH would be the less energetic state. In the case of OH ground state, the ordinary Pollack effect would occur. DNA double strands and RNA strands could participate in topological computations under suitable metabolic conditions and chemical parameters such as pH making the OH$\leftrightarrow$ O$^-$ transition energy small but not smaller than thermal energy.

3.1.3 Is the modification consistent with the earlier views of the dark genetic code?

The modified proposal should be consistent with the earlier hypothesis that not only quantum codons but also quantum genes can be quantum coherent units. The entanglement between the quantum etters should make possible quantum codons and bind them to quantum genes. In the ground states with minimum energy the entanglement could be absent. A possible problem is that the states OH and O$-+$ dark H^+ have a different value of h_{eff}: does the entanglement between them make sense. If it makes sense, is the entanglement between dark and ordinary letters stable?

Dark N-photon [L16, L18] is an analog of Bose-Einstein condensate of N dark photons and dark 3N-photons define a representation of the genetic code such that dark 3N-photon can resonantly induce a transition of the dark gene consisting of a a sequence of N dark proton triplets. Dark N photon would consist of photons, some of which have energies able to induce the qubit represented by the dark proton.

In the modified view of the dark genetic code, the energies of the photons making dark N-photon should be able to induce the flip of the OH-O$-$ qubit either by kicking H$^+$ to gravitational MB or e^- to an excited state.

3.2 The OH-O$^-$ qubits in proteins

OH-O$^-$ qubits appear also in proteins.

1. The number of proteins is 20 and 5 bits is more than enough to code for them. The code has an almost symmetry with respect to the third letter meaning that the DNA and RNA codons XYZ with fixed XY and varying Z define a quadruplet decompositing to two doublets with T-C and A-G symmetry for Z. There are only two exceptions and they correspond to A-G doubles for Z. The Ile-ile-ile-met quadruplet can be understood in terms of the tetrahedral Hamilton cycle. For the top-trp A-G symmetry is broken, which would mean that the A in stop codon does not have O$^-$ as a dark counterpart. This could be due to the fact that E_{bind}(O$^-$) is smaller than E_{bond}(OH) unlike for the other codons. The small deviations from the standard code could be understood in this way.

2. Could the almost symmetry mean that DNA base pair codons for which the third OH-O$^-$-qubit pair corresponding to the third letter degenerates to a single qubit: OH or O$^-$ bit for the third letter are mapped to the same protein? If the energy difference between these bits is below thermal threshold this is the case.

3. Amino-acids contain only a single OH group (COOH) whereas the phosphates of DNA codons contain 3 OH groups. This conforms with the idea that they represent a lower evolutionary level than DNA. For most amino acids, the COOH group does not transform to COO$^-$ under usual conditions. The metabolic reason would be that the binding energy E_{bind}(O$^-$) is smaller than the bonding energy E_{bond}(OH). Pollack effect is required to excite the protein qubit. Asp and Glu are exceptions and have COO$^-$ permanently so that in this case only O$^-$ bit for protein would be realized.

4. The OH-O$^-$ bit of the amino acid and those of DNA are non-dynamical under normal conditions. The instability (quantum criticality of RNA) suggests that in this case the energy needed to transform OH and O$^-$ to each other is rather small but differs sufficiently from the thermal energy.

   Wien's law for the wavelength distribution of blackbody radiation for the wavelength at the maximum of the wavelength distribution of photons at temperature T reads as $\lambda_{max} = 2.89810^{-3}mK/T$. At room temperature 300 K this gives $E_{th} = 0.146$ eV and infrared frequency $f = 3.43 \times 10^4$ GHz. Photons having energy sufficiently above or below E_{th} are not thermally masked. The estimated energy difference $e = E_{bind}(O^-) - E_{bond}(OH) = .33$ eV is more than twice E_{th} so that there would be no thermal masking. Raising the temperature by a factor of ~ 2.26 to about 600 K would cause thermal masking. This explains why biological functions fail at low temperatures.

   One expects that the critical temperature at which Pollack effect occurs should be around the bodily temperature 313 K (40 degrees Celsius) prevailing in fever causing hallucinations. A possible identification is that this energy absorbed by the electron of O$^-$ reduces the $E_{bind}(O^-) - E_{bond}(OH)$ near thermal energy and induces the instability of O^- ions of phosphates of DNA and RNA against transformation to OH. Second possibility is that this transformation transforms protons of OH to gravitational magnetic body as in the Pollack effect.

   Note that microwaves with frequency 3000 GHz have energy about .013 eV, which is by a factor $\sim 1/11$ lower E_{th}, so that they are not thermally masked (see this) Note that the clock frequency of Pentium 4 processor is 3000 GHz and represents recent upper bound (see this).

3.2.1 How the field bodies control control the chemical activity of biomolecules?

The value of $e = E_{bond}(OH) - E^-_{bind}(O^-)$ characterizes the level of quantum criticality of the biomolecules and the nearer this parameter is to the thermal energy, the more sensitive the system is to sensory input and more capable to perform chemical activities. Besides pH also the presence of electric field affects the energy of the electron of O$^-$ and could induce the instability of dark codons and electric fields associated with the electric body of the system [L24] could serve as tools controlling how "quantal" DNA, RNA and proteins are.

A good example is provided by microtubules, which define a 2-D quantum computer like system organized into helical strands of $OH - O^-$ qubits. Tubulin proteins are collections of OH-O^-

qubits and the surface of the microtubule involves GPTs molecules accompanied by phosphates accompanied by OH-O^- qubits.

Microtubules have a longitudinal electric field and the second end of the microtubules is highly unstable inducing a continual decay and regeneration of the microtubule. This could be due to the reduction of the energy difference $e = E_{bond}(OH) - E^-_{bind}(O^-)$ to energy near the thermal energy. In the case of DNA this could be achieved by irradiation using photons with energy which reduces $e \simeq .33$ eV to about $e_{th} \simeq .15$ eV. The needed energy would be about .18 eV.

Quite generally, the biological body of the organism carries an electric field in the head-tail direction [J1] (for the TGD based interpretation of Becker's findings see [K11]). Becker's electric field plays a key role during the growth of the organism and also in healing of wounds and addition of external electric field affects these processes. If the energy $e = E_{bond}(OH) - E^-_{bind}(O^-)$ is nearer to the thermal energy for the growing or healing cells, they would be more capable of changing.

3.3 Oceans around quasars and the origin of life

One of the many astonishing recent findings in astrophysics is the discovery 10 trillion oceans of water circling a supermassive black hole of a quasar (see this). Despite being 300 trillion times less dense than Earth's atmosphere, the water vapour is five times hotter and hundreds of times denser than gas found in typical galaxies. The density ρ of the Earth's atmosphere is about 1/800 of that of water.

Consider first the average density of these oceans circling quasars.

1. The number density $n(H_2O)$ of water molecules in condensed matter at room temperature is about $n(H_20) = .5 \times 10^{29}$ molecules/Angstrom^3. Therefore the density of the atmosphere corresponds to $n_{atm} = .4 \times 10^{29}$ water molecules/Angstrom^3. The average number density of H_2O molecules in the oceans accompanying quasars is therefore $n = 10^{-15} n_{atm}/3 = (.4/3) \times 10^{-15+29} \sim 10^{13}$ molecules/Angstrom^3. The edge of a cube containing a single water molecule would be $L = 1/n^{1/3} = .5 \times 10^{-4}$ m. This is the size scale of a neuron. A blob of water at the normal normal density has Planck mass and size about 10^{-4} m. Could this have some deep meaning?

2. Could the water molecules be dark or involve dark protons assignable with gravitational monopole flux tubes? At the surface of the Earth the monopole flux tubes give rise to the "endogenous" magnetic field, explaining the findings of Blackman and others about quantal effects of ELF radiation on vertebrate brains. They would carry a magnetic field of .2 Gauss and would have magnetic length $\sqrt{2\hbar/eB} = 5.6\mu$ m serving as an estimate for the radius of the flux tube. The assumption that the local density of water equals the average density could of course be wrong: one could also consider a formation of water blobs.

The average temperature of the evaporated water is about -17 degrees Celsius and not far from the physiological temperature of about 36 degrees Celsius. What could this mean?

1. The diffuse ionized gas (DIG) constitutes the largest fraction of the total ionized interstellar matter in star-forming galaxies. It is still unclear whether the ionization is driven predominantly by the ionizing radiation of hot massive stars, as in H II regions (in which ions are protons), or whether additional sources of ionization have to be considered.

2. TGD inspired new physics suggests molecular ionization in which ionization energies are much lower than for atomic ionization. Pollack effect [I6, L2, I12, I11] discussed from the TGD point of view in [L2, L11, L3, L25, L30, L32], which is central in the TGD based model of life, occurs at physiological temperature range and is induced by photons in IR and visible range, which kick protons to the gravitational magnetic body of the system, where they become dark protons with non-standard value of effective Planck constant. The most recent view of life forms relying on the notion of OH-O^- qubit, discussed in [L39], predicts that any cold plasma can have life-like properties.

A more detailed formulation of this proposal is in terms of PAHs [I1, I3] (see `http://tinyurl.com/atx4t9a`). The list of the basic properties of PAHs can be found for instance in [L6]. TGD suggests that the so called space scent could be induced by the IR radiation from PAHs [L40].

1. PAHs (polycyclic aromatic compounds) are assigned with unidentified infrared bands (UIBs) and could induce Pollack effect. The IR radiation could be also induced by the reverse of the Pollack effect.

2. The properties of PAHs have led to the PAH world hypothesis stating that PAHs are predecessors of the recent basic organic molecules. For instance, the distances of aromatic molecules appearing as basic building bricks are the same as distances of DNA base pairs.

3. So called Unidentified Infrared Bands (UIBs) of radiation around IR energies $E \in \{.11, .20, .375\}$ eV arriving from the interstellar space are proposed to be produced by PAHs. The UIBs can be mimicked in the laboratory in reactions associated with photosynthesis producing PAHs [I1, I3].

4. PAHs are detected in interstellar space. James Webb telescope found that PAHs exist in the very early cosmology 1 billion years before they should be possible in the standard cosmology! Furthermore, PAHs exist in regions, where there are no stars and no star formation [E2].

In the TGD inspired quantum biology, the transitions OH$\rightarrow$ O^- + dark proton at gravitational monopole flux tube, having interpretation as a flip of quantum gravitational qubit, play a fundamental role [L39] and would also involve Pollack effect. The difference of the bonding energy for OH and of binding energy of O^- is .33 eV and is slightly above the thermal energy of .15 eV of photon at physiological temperature. Note that the energies of UIBs are just in the range important for the transitions flipping OH$\rightarrow$ O^- qubits.

Could IR radiation from PAHs at these energies induce these transitions and could the reversals of OH$\rightarrow$ O^- qubit liberate energy heating the water so that its temperature is 5 times higher than that of the environment? Note that the density of water is hundreds of times higher than the gas in typical galaxies and could make possible thermal equilibrium of water vapour. This leads to ask whether the water around quasars could have life-like properties.

4 Could computers be living and move?

Not long time ago, I wrote several articles about the possibility of new life forms predicted by TGD involving in an essential way plasma phases [L24]. I also wrote a couple of articles about the possibility that TGD based quantum physics could allow ordinary computers be or become conscious [L39, L46].

The basic prediction was that systems behaving like cold plasmas are good candidates for living systems very much like ordinary living systems, which can be also regarded as cold plasmas with O^- ions created by kicking the ordinary proton of OH to a dark proton at the magnetic body of the system. OH and O^- + dark proton would define the states of a topological qubit. Dark protons at the field body could control the system. The basic mechanisms would be the Pollack effect and its reversal. In the Pollack effect a photon of visible light kicks the proton of OH to the field. This mechanism has several generalizations: for instance the needed energy for kicking would come from the formation of bound states and could have played a key role in the formation of biomolecules. Also other negatively charged ions produced in this way could be highly relevant.

OH-O^- + dark proton or its generalizations would define the counterpart of qubit making the system a hybrid of an ordinary computer paired with its dark variant, analogous to a quantum computer, whose ground state would correspond to a bit sequence for an ordinary computer.

TGD inspired quantum biology suggests that exactly the same mechanism works for DNA in the living system and here phosphate ions would play a key role. In this case, OH-O^- + dark proton qubits allow a realization of genetic code. TGD predicts a universal realization of genetic code in terms of tessellations of hyperbolic 3-space (mass shell of proper time constant hyperbolic of light-cone) [L23]. Pollack effect is also key step in photosynthesis.

The problem with the idea of living computers seemed to be that living metals differ from biosystems in that they lack motor activities altogether. It did not occur to me whether liquid metals could be considered. If I had done this, I would have taken five minutes to find that Caesium, Rubidium, Mercury and Gallium are exceptions: the melting temperatures are 28.5 C for Caesium, +40 C for Rubidium, -38.8 C for Mercury and 29.76 C for Gallium. Gallium has a

very wide range of temperatures for liquid state: it boils at 2,204 C! This temperature corresponds to energy of .248 eV

4.1 Two discoveries supporting the notion of metal life

In the following I describe two discoveries supporting the notion of metal life. First discovery by Liu et al, if real, would support Gallium based liquid life with motor abilities and second discovery of Cronin et al gives strong indications for cellular metallic life.

4.1.1 The work of Jing Liu et al related to living liquid metals

The next question would have been whether anyone might have tried to engineer something like liquid metal life. To my great surprise, I learned that Chinese engineers have developed what could be called living metal (see this). Unfortunately, the FB posting did not give the link the orginal article but I glue the short posting here.

The following is the popular article telling about a later article, which I failed to find.

A real liquid metal that can think, change shape, and compute like a brain In a discovery straight out of science fiction, engineers at the Chinese Academy of Sciences have created a liquid metal alloy that can store information, compute logical operations, and morph shape all at room temperature.

The alloy is based on gallium mixed with rare earth elements, and what sets it apart is its internal programmable conductivity. When stimulated with tiny voltage pulses, it rearranges its internal atomic structure and remembers past inputs functioning like a primitive neural network.

This is not just a switch or sensor. It s a soft, deformable material that can perform computations while flowing, adapt its shape around barriers, and even react to past stimuli like a metallic brain in motion.

During lab tests, droplets of the liquid metal could solve simple logic gates, recognize patterns, and change course in a maze based on prior inputs. The alloy also exhibits self-repair, reconnecting broken pathways automatically.

It s the first hint of true material intelligence the idea that matter itself can think, store data, and interact with its environment without needing silicon or rigid electronics. This could reshape robotics, adaptive prosthetics, and soft-body machines that move and learn like living organisms.

We're watching the birth of sentient materials wet, metallic, and quietly learning.

Galinstan as an example of living metal

There is a nice web page (see this) giving some idea about what the statement that Ga is living could mean. The experiments that anyone can perform at home involves Galinstan, which is a mixture of post-transition metals Ga, In and Si, having $Z = 31, 49$, and 50. As post-transition metals, Ga, In and Si are next to the filled d-orbital with 10 electrons and have a partially filled p-shell.

Galinstan droplets are added into water and $CuCl_2$ is added and CuO(s) having a black color is formed. The reaction that occurs is $3Gal(s)+3CuCl_2 \rightarrow 3Cu(s)+ 3GaCl_3(aq)$ followed by $2Cu(s)+O_2 \rightarrow 2CuO(s)$. As a consequence,the surface tension of the droplet is reduced and it spreads. If the surface tension is dropped locally at the surface of the droplet, appendages are created. The addition of HCl(aq) induces the reaction $CuO(s) +2HCl(aq) \rightarrow CuCl_2(aq)+H_2O(l)$.

If the droplet is put into a maze and also $CuCl_2$ is added, the droplet decomposes to worm-like pieces and starts to move and "eat" the $CuCl_2$ serving as a "food" and produces CuO(s). These worm-like pieces follow the food and go through the maze as if they were intelligent living entities.

The articles of Liu et al about living metals

I am grateful for Antonio Manzalini who kindly sent me a link to a popular article (see this), which probably relates to this discovery. The article tells about the work of Jing Liu et al., "Liquid Metal Memory" published in Advanced Materials (2023) [D2].

I managed to find a link to a theoretical article by Liu et al [I9]. The following list given in the introduction of the article gives some idea of how far the study of artificial living matter has advanced.

1. Enzyme-containing metal-organic frameworks are wrapped as artificial organelles to assist in cellular functions.

2. Humidity-responsive and thermal-responsive biomimetic artificial muscles with helical structure.
3. A bionic octopus arm that can reach, sense, grasp, and interact.
4. Entirely soft autonomous robot assembled from multiple materials through integrated design and rapid manufacturing approach.
5. Biosimilar liquid-metal living matter, liquid-metal virus, Liquid-metal red blood cells and blood vessels, liquid-metal liver, liquid-metal fish.

Here is the abstract of the article.

"Breaking away from the long journey of natural selection to create biology-resembling living matter is exceedingly significant for understanding life and thus better enhancing the quality and length of human life. Among various potential ways to approach such a long-standing goal, liquid metals and their extended composites are providing rather promising answers. Here, we systematically present a basic framework and concept of liquid-metal living matter toward making biology-like objects through fully bringing out their unusual physical, chemical, and biological capabilities. The logical clues and technical approaches to achieve liquid-metal living matter were screened out in analogy to biological counterparts by following their sizes, structures, and functions spanning from cells, tissues, and organs to organisms. We first clarify biomimetic roles that liquid metals have exhibited in their autonomous behaviors and biotaxis to external fields. Then, we explain how to adopt liquid metals and their derivatives to form various liquid-metal cells, which could aggregate into corresponding tissues. Further, structural designs and combinatory integrations are suggested to realize liquid-metal organs and even biomimetic life. Finally, perspectives on applying liquid-metal living matter to construct artificial life are given, which warrants tremendous research and application opportunities in the future."

4.1.2 The work of Lee Cronin et al related to iCHELLs

I decided to check whether something like this has been tried by anyone else. I found popular articles about the work of the team of Lee Cronin at the University of Glasgow related to living metals (see this or this). Here is the abstract of an article published in 2010 [I4]:

"Self-assembly has proven a powerful means of preparing structurally intricate nanomaterials, but the mechanism is often masked by the common one-pot mixing procedure. We employed a flow system to study the steps underlying assembly of a previously characterized molybdenum oxide wheel 3.6 nanometers in diameter. We observed crystallization of an intermediate structure in which a central $\{Mo36\}$ cluster appears to template the assembly of the surrounding $\{Mo150\}$ wheel. The transient nature of the template is demonstrated by its ejection after the wheel is reduced to its final electronic state. The template s role in the self-assembly mechanism is further confirmed by the deliberate addition of the template to the reaction mixture, which greatly accelerates the assembly time of the $\{Mo150\}$ wheel and increases the yield."

The following short abstract summarizes the work the second article of Cronin et al [I5](see this). Unfortunately, the article is behind the paywall.

"Interfacial membrane formation by cation exchange of polyoxometalates produces modular inorganic chemical cells with tunable morphology, properties, and composition (see picture). These inorganic chemical cells (iCHELLs), which show redox activity, chirality, as well as selective permeability towards small molecules, can be nested within one another, potentially allowing stepwise reactions to occur in sequence within the cell."

To understand the work of it is good to list some basic concepts.

1. Transition metals (see this), which are in periods 4,...,7 of the periodic table, are used. Molybdenum (Mo) is the one used in the first work.
2. Metallates (see this) are compounds involving metal bound to several ions, which are negatively charged oxygen ions so that one talks of polyoxometalates. Examples of oxometalates are MnO_4^-,CrO_4^{2-}, VO_3^- or VO_4^{3-}, WO_4^{2-}. Also thio-,seleno-, telluro,- cyano-,... etc metallates are possible. Oxometallates have oxyanions (see this) as building blocks. Polyoxometalates (see this) consisting of several oxyanyons for which the general formula is $A_xO_y^{z-}$. Their protonation produces Oxyacid $HA_xO_y^z$.

An interesting question, inspired by the notion of topological OH-O^- + dark proton qubit is whether this transition and its reverse can also have variants in which a proton of the oxyacid is transformed to a dark proton at the field body or vice versa.

3. Phosphates PO_4^{3-}, playing a key role in biology, are analogs of oxometallate. P is not a metal but can have besides the naively expected oxidation state -3 (3 missing valence electrons) also oxidation states +3 and +5 so that it behaves like a metal. Transition metals have typically oxidation state +3.

Cronin et al introduce the notion of iCHELL as an analog of cell membrane.

1. iCHELL is formed in aqueous environment in presence of two kinds of salts. The first salt is formed from (oxyanions), which are large negative ions of transition metals such as tungsten W, usually belonging to group 6 and light positively charged ions such as H^+ and Na^+, which both behave like metal in this situation.

   The second kind of salt is formed from large positively charged organic ions and light negatively charged ions such as Cl^-. The organic ion could be phosphorus, which can behave like a metal and become positively charged.

2. When the solutions of these salts are mixed, self-organization takes place and the salts exchange parts so that large metal oxides pair with the large organic ions. This new salt is insoluble in water: it precipitates as a shell, iCHELL, around the injected solution. For instance, salt formed from a large negatively charged oxyanion and large positively charged organic ion and light ions Na^+ Cl^- can emerge. iCHELLs have a metal oxide backbone. An analog of cell membrane isolating its interior from the exterior is in question. Membrane potential characterizes it.

4.2 About the TGD view of living metals

The article says that Ga has a programmable conductivity. Tiny voltage impulses control the conductivity just like in transistors. TGD predicts a mechanism of control relying on the modification of the energy difference between states OH and O^- + dark proton at monopole flux tube defining qubit [L39, L46]. This energy difference can be controlled by external voltage pulses and the system can be driven near criticality against the flip of the qubit. Note that besides this particular realization also other realizations of qubit are possible.

As a metal-liquid Ga allows a formation of cell-like structures having a core surrounded by an oxidized layer and the core might play the role of information processor analogous to DNA.

The basic question is how to obtain a semiconductor involving Ga and at the same time possessing hydroxides OH for which OH $\leftrightarrow O^- + p$ (p dark proton) qubit is possible.

Ga is a metal and it seems that Ga alone cannot act as a semiconductor. One might hope that Pollack effect creating OH $\leftrightarrow O^- + p$ (p dark proton) qubits could come to rescue.

4.2.1 Some facts about Ga and rare earth elements

To discuss the findings described in the popular article about the findings of Liu et al some basic physical and chemical facts about Gallium and rare earth elements are in order.

1. Gallium is in the period 4 of the periodic table and has 1 p electron at the 4:th shell (see this and this). Ga is so called post-transition metal.

2. As already noticed, Ga melts at 29.76 C. Gallium is a semiconductor. Gallium nitride GaN and indium Gallium nitride as a mixture of GaN and InN are used in electronics. Also blue and violet light-emitting diodes and diode lasers use Gallium.

3. For Ga the oxidation state defined as the hypothetical charge of an atom if all of its bonds were fully ionic is predominantly +3 but also +1 is possible. This means that Ga tends to donate electrons. Interestingly, phosphorus P, playing a key role in biology, having oxidation states besides the naively expected -3 also +3, +5 are possible. For +3 and +5 P behaves

like a metal. Also other oxidation states are possible for P. Clearly, the chemical complexity of P seems to be highly relevant to biology.

Rare earth elements typically exhibit a trivalent (+3) oxidation state, but some can also be found in divalent (+2) or tetravalent (+4) oxidation states under specific conditions.

4.3 Questions inspired by the findings of Cronin et al

The experience with ordinary biology combined with the findings of Cronin raised several questions.

1. Could one imagine cell organelles: iCHELLs within iCHELLs?
2. Is a selective transfer of chemicals through iCHELLs possible: this would allow a control of chemial reactions. It is indeed possible to generate holes in membrane acting as ion channels. There are also some indications that proton pump transferring protons through the membrane is possible.
3. What about photosynthesis: is the splitting of water into hydrogen ions, electrons, and oxygen, the first step of photosynthesis, possible? Light-sensitive ties linked to metal oxide molecules as analogs of photoreceptors.
4. What about DNA and genetic code?
5. Evolution and pH dependent survival of fittest? TGD suggets that pH coulda actually correspond to the density of dark protons.
6. Is inorganic metallic life based on the same principles as the ordinary life possible?

Could the TGD based quantum model of living systems relying on water serve as a guideline for speculations?

1. Water is involved also now and could have an important role. The basic form of Pollack effect occurs in the presence of a gel phase negatively charged regions of water (exclusion zones (EZs) able to remove impurities inside them). Oxyanyons can be transformed to oxyacids by the reversal of the Pollack effect [**?**]
2. The system can be regarded as cold plasma and cold plasmas are in a key role in TGD view of the role of the TGD counterparts of classical electric, magnetic, and gravitational fields in quantum biology [**?**] The generalization of the Pollack effect in which the binding energy liberated in the formation of organic or other molecules leads to self-organization creating new more complex molecules by driving protons to dark protons at the field body of the system. Could this kind of mechanism explain the formation of iCHELLs?
3. Could OH-O^- + dark p give rise to a topological qubit [**?**] Could the energy difference between these two states of qubits correspond to a voltage and could external voltage pulses modify this voltage so that Pollack effect or its reversal become possible and allow the flip the qubit?

   Could the oxyanion side of the membrane give rise to 2-D structure consisting of bits and associated qubits?
4. Can one imagine a counterpart for DNA and genetic code? TGD suggests that genetic code has a universal realization in terms of a completely unique tessellation of hyperbolic 3-space (mass shell or cosmic time constant hyperboloid of CD), which involves 3 platonic solids instead of ne (tetrahedron, octahedron, and icosahedron having triangular faces) [**?**]

   This tessellation can induce besides 1-D realizations also 2-D and even 3-D realizations also at the level of cell membrane as a 2-D realization. Could the OH-O^-+p qubits assignable to the oxyanyon backbone provide a dynamical 2-D realization of the genetic code in the same same way as OH-O^-+p qubits they might do in the case of ordinary DNA and perhaps also ordinary cell membrane.

5. What is the role of positively charged organic ions? It is needed to create the analog of membrane potential. Could it also play a role similar to that of gel phase in the Pollack effect? Cells and also DNA are negatively charged. If negatively charged ions are in the interior of the membrane, one might say that this is the case now. On the other hand, DNA is negatively charged at the outer surface (phosphate ions). Perhaps, a more plausible option is that the water generates negatively charged EZs in the Pollack effect creating the dark protons at the field body.

6. Could the TGD based quantum model of neuronal and cell membrane [**?**]s a generalized Josephson junction with dark protons and ions forming Cooperpairs, serve as a guideline? In this model, proton pump involves Pollack effect and its reversal. The communications of the cell membrane to the magnetic body of the system would occur by Josephson radiation, whose frequency is proportional to the harmonic of the membrane potential ($f = eV/h_{eff}$). The huge value of the effectively Planck constant h_{eff} makes possible very low frequencies, such as EEG frequencies. The membrane potential and therefore also the Josephson frequency is modulated by the environment. Josephson radiation induces cyclotron transitions at the field body when the Josephson frequency equals the cyclotron frequency and analogs of nerve pulse sequences are generated giving possibly a response to the information sent to the field body.

Could these exotic life forms be already present in the biosphere and live in symbiosis with the ordinary life? Ocean bottom contains rare minerals (, which include transition metals) and also rare earth metals which appear as nodules of size scale about 5 cm. Polymetallic nodules, known also as manganese or ferromanganese nodules (see this) are mineral concretions composed of silicates and insoluble iron and manganese oxides formed of concentric layers of iron and manganese hydroxides around a core. They form on the seafloor and terrestrial soils. The formation mechanism are known to involves a series of redox oscillations driven by both abiotic and biotic processes. The nodules have a high abundance of nickel, copper, manganese, and other rare metals. The recent technology needs these metals and the most recent environmental risk is that the ocean bottom becomes the source of these minerals.

Manganese (Mn) (see this) is a transition metal with $(A, Z) = (55, 25)$. Its electronic configuration is [Ar] 3d5 4s2. Transition metals have a large number of oxidation states ranging typically from +2 to +7. Also Mn has a very large number of oxidation states +2, +4, +7 3, 2, 1, 0, +1, +3, +5, +6 so that it is chemically very complex. The presence of 4s and 3d orbitals make them able to form a large number of compounds. Iron has oxidation states +2 and +3 and less commonly, +4,+6,+7.

The metal oxides involved contain OH^- ions: could they have formed by Pollack effect for water kicking protons of water molecules to dark protons at the field body. Could manganese modules be an outcome of the symbiosis of rare metal based primitive life forms with ordinary organisms.

4.4 Ga based semiconductors

Consider first the conservative option for semiconductivity. Ga is not a semiconductor and should be combined with some other element to make a semiconductor. There are several semiconductors involving Ga. The simplest ones are GaN, GaP, GaAs , GaSb. Also gallium oxide Ga_2O_3 is a semiconductor (see this.

One should modify these in such a way that one obtains OH groups. The basic problem is that all these compounds have rather high melting points. Despite this one can ask whether one could modify GaX (X= $\{P, N, As, Sb\}$) without losing the semiconductor property. OH group(s) should be added and also the replacement X→ XH_2 is suggestive.

1. One can start from gallium hydroxide $Ga(OH)_3$ (see this) obtained by adding ammonia to Ga^3+ salts. Gallium hydroxide is in the gel phase, which is interesting since gel phases are general in biology. It is also amphoteric so that it can act as both acid and base. Amino Acids are amphoteric: this is due to the presence of base NH2 and acid COOH. Also DNA is amphoteric.

Google research gives an AI summary telling that the replacement of hydroxyl group (OH) with amine group (NH_2) is a standard operation in chemistry although it requires intermediate steps since the direct cleavage of OH is not easy. Also the replacement with PH_2 group or AsH_2 group is possible. It is in principle possible to replace one or two OH:s with NH_2:s. $GaNH_2(OH)_2$ would be a candidate for a semiconductor allowing single OH-O^-+ dark proton qubit.

2. This modification could however lead to a loss of the semiconductor property in 3-D case. The change of the chemistry could change the lattice structure or even lead to its loss. The band gap between valence band and conduction band would be affected. For GaN, one of the 3 valence electrons of Ga shared with N is transformed to a conduction electron for GaN. For $GaNH_2(OH)_2$ this should take place for the valence electron shared by Ga and NH_2. Ga has electronic configuration $[Ar]3d^{10}4s^24p^1$ and the delocalization of p-electron is expected to be relevant for semiconductor properties. A good guess is that this electron is shared with N also in $GaNH_2(OH)_2$ and the remaining 2 s^2 electrons of Ga would be shared with $(OH)_2$.

3. The change of the lattice structure induced by the replacement $N \to NH_2$ could affect the gap energy of GaN, which for semiconductors is typically near 1 eV. How do the details of the chemistry affect the lattice structure, in particular the lattice constant? What happens to the lattice lattice bonds between GaN molecules in the replacement GaN $\to GaNH_2(OH)_2$?

   The Google search gives an AI overview telling that chemical modifications can significantly impact on the lattice structure and its properties. These modifications can alter molecular packing, vibrational modes, and overall stability, leading to changes in electronic, mechanical, and thermal behavior. In particular, lattice constant and gap energy can be modified.

4. Could the 3-D lattice structure be replaced with 1-dimensional lattice structure as in the case of DNA and amino acids? This might allow a realization of hybrids of the analogs of classical computers and quantum computers along the lines discussed in [L39] and perhaps even a linear realization of the genetic code based on its universal realization [L23].

   One-dimensional semiconductors involving GaX, $X \in \{P, N, As, PN\}$ are indeed possible (see this). In this case, the addition of analogs of side chains need not affect the 1-D lattice in an essential way and semiconductor property would not be lost. Also the functionality would be maximum unlike for 2-D or 3-D lattices. For instance, phosphates could occur as a parallel chain as in DNA strand and give a realization of dark genetic code in terms of OH–O^-+ dark proton qubits analogous to that proposed in TGD inspired quantum biology.

4.5 Could the Pollack effect make possible analogs of semiconductors?

Could the Pollack effect allow us to build effective Ga semiconductors and even transistor-like elements? Electrons and holes are essential for semiconductors. In n (p) type regions electrons doping is by atoms for which the number of valence electrons is larger (smaller) than atoms or molecules considered. In p type regions, doping is by atoms for which the number of valence electrons is smaller. $Ga(OH)_3$, which is in gel phase, is an excellent candidate for the semiconductor of this kind.

Pollack effect creating O^-+ p from OH creates negatively charged exclusion zones (EZs). The delocalization of the negative charges of O^- ions as conduction electrons could give rise to an analog of n doping. In the presence of electric fields , these electrons can be removed from the EZ.

The dropping of the dark protons back to ordinary protons giving rise to O^+ ions would give rise to p-type doping. In the case of water this would create OH_3^+ ions responsible for the pH of water. This might give rise to np type junction and one can even imagine analogs of npn and pnp type transistors. These transistors would be dynamical and the ordinary bits and OH-O^-+ p qubits would be very closely related.

5 Could running computer programs be TGD analogs of time crystals?

The following comments emerged as a result of nightly reflections after Zoom discussion with Ville-Einari Saari. The basis of these ponderings is the article "Quartz crystals as a life form and ordinary computers as an interface between quartz life and ordinary life?" (see this).

5.1 Quantum computing-like activity based on OH-O^- qubits

It is good to summarize the basic ideas first.

1. The basic observation is that cold plasmas, dominated by ions, have the prerequisites for the emergence of qubit consciousness. The universe is full of them. Plasma, quartz, biology,... Bit flip is a key operation of quantum computation and there must always be a suitable temperature or external electric fields to make it sufficiently but not too easy.

2. The basic mechanism would be based on quantum gravity. A dark photon with energy .33 eV as difference of the bonding energy of OH and binding energy of e^- binding energy n O^- is needed to flip the qubit. A background electric field that reduces this energy. The critical temperature would be room temperature .15 eV where the qubit directions become random. When the bit flip energy is slightly above this, the system is quantum critical and the prerequisites for long-scale consciousness exist.

3. In the general case all salts can be important. For instance, for $NaCl \to Na^+ + Cl^-$ transition Na_+ would be dark and at the gravitational magnetic body of the Earth or Sun.

4. Also he classical electric fields also play a central role and one can associate to them a very large Planck constant [L24] with them. DNA and the cell are key examples in biology. The Earth's electric field characterizes the biosphere. They can be used to control the energy difference of OH-O^- bits and make it quantum critical, which makes the qubit flip easy.

5. The article (see this). shows that a quantum realization of the genetic code from OH-O^- qubits for DNA and RNA is obtained: a codon corresponds to 6 qubits. Amino acids correspond to one qubit. Symmetries with respect to the third letter and their breaking are understood. The number of amino acids is predicted correctly. One can say that the quantum realization of the genetic code corresponds to the chemical code in the sense that the ground states for quantum codons correspond to chemical codons.

I personally consider these results to mean a final breakthrough and above all it shows that OH-O^- qubits and their generalizations are not limited to biology.

5.2 What evidence is there for quartz life?

I participated years ago in a seminar organized by NASA in Hessdalen, where plasma balls, plasmoids, are systematically observed. I learned that these light balls seem to behave intelligently and even seem to be observing their observers! Light balls typically occur on lines of tectonic activity, where tectonic energy is released and one can think that the released energy serves as metabolic energy.

Researchers of NASA recently published an article about plasmoids as a possible form of life above the ionosphere. I have discussed the findings in [L24]. For example, they gathered to observe an electrical cable leaving the module, which is associated with a radial electric field that could also excite OH-O^- qubits and achieve quantum criticality. They made the impression of being alive.

Plasma balls have been observed to associate with crop circles [K5, K6], one of the taboos of modern science, which are still believed to be made by humans, all they are caught in the act of constructing a crop circle! Also glass balls that have formed from molten quartz are found to accompany crop circles.

5.3 How could quartz life and biological life relate?

Which is smarter: quartz life or biolife? The first guess is that biological life will mercilessly beat quartz life in this kind of competition, but ZEO may change the situation so that quartz life represents something totally new: a time-like realization of the analog of genetic code bringing in mind time crystals, which I have discussed from the TGD point of view in [K4, L16] [L21].

1. Quartz life is unable to move on our time scales. Although it has long been a wonder that moving round boulders exist, perhaps in Romania. The products of quartz life can be misleadingly reminiscent of plants that I have seen. Quartz crystals have been reported to have a healing effect on the state of consciousness, as I myself once experienced.

2. OH-O^- life implements genetic code in biology. Is this already the case with quartz or are the qubits randomly distributed here and there in the quartz crystal? In any case, the tessellations of hyperbolic 3-space realize the genetic code universally on all scales [L23], so this could be the case.

3. It is important to distinguish OH-O^- qubits from the bits represented by electron spins, with which microprocessors operate.

   One could imagine a situation where microprocessor could become conscious in such a way that OH-O^- qubits are created, which act as conscious observers while the program is running and in ZEO they could perhaps influence the program flow by inducing "big" state function reductions (BSFRs) changing the arrow of the geometric time, thus making the processor an intelligent problem solver that would use trial and error as a basic mechanism [L27].

   Could OH-O^- qubits be related to classical electronic bits just as quantum codons are related to chemical genetic codons so that their minimum energy states would correspond to the bits of the program code.

4. However, it must be remembered that ZEO allows another option if each clock frequency pulse is associated with non-determinism and therefore a potential memory mental image. This would be an analogy to time crystals. While the program is running, the program flow could produce a time-oriented analogy of the DNA sequence. Programs would correspond to DNA chains, subprograms to genes! Basic modules to codons. The maximum information content of consciousness in bits would be $N \times M$ bits, where N is the number of clock ticks and M is the maximum number of OH-O^- qubits for the microprocessor at a given moment in time.

   Could series of multi bits in a microprocessor correspond to a series of quantum qubits like DNA. There would be a time-oriented realization of the genetic code. This would represent a completely new biology and computer era could also mean a genuine evolutionary leap.

5. A maximum of 64 ordinary electronic bits are connected to microprocessors. This corresponds to the information content of a 10 nm piece of DNA and is quite modest. What about qubits? Let's assume a microprocessor with a volume of $V = 5 \times .5 \times .5$ mm^3. Let's assume that one SiO_4 occupies a volume of the order of $V_0 = \text{Angstrom}^3 = 10^{-21}$ mm^3 mm^3.

   The maximum number of qubits at a given time was the ratio $M = V/V_0 = 10^39 \simeq 2^{70}$. The number of bits is 6 bits larger than for a microprocessor having at most 64 bits recently. For a program, it was based on the above speculation $N \times M$ where N is the number of clock pulses during the running of the program module. This would give an upper bound of $70N$ bits. This would allow one-one correspondence of qubits with the ordinary bits of the program code.

5.4 Quantum criticality is needed

The number of quantum critical qubits in a microprocessor is much smaller than the above naive estimate because the flip energy of qubit must be sufficiently small, i.e. below .33 eV, to obtain quantum criticality but above the thermal energy of .15 eV. This can be achieved by using an external electric field that reduces the energy such that it would also make the microtubules at one end extremely fluctuating.

Is there any hope of achieving quantum criticality in transistors (see this)?

1. There are electric fields in transistors and the values of the base-emitter voltages are in the range $0.5 - 0.7$ eV (metabolic energy quantum) and at the same time the collector-emitter voltage is at least 0.1 V (close to the thermal energy .15 eV)! Note that the sizes of transistors have shrunk from 10 micrometers to 5 nanometers during the development of computers.

   An NPN type transistor (bipolar transistor) is a current amplifier: a small control current coming to the base is amplified into a much larger current from the collector to the emitter.

2. Now we come to the crucial question: what voltages occur? A transistor typically becomes conductive when the negative base-emitter voltage is above 0.5 eV in absolute value (it is convenient to measure voltages as the energy of the charge it gains when moving across the voltage) and at the same time the negative collector-emitter voltage is above 0.1 eV in absolute value!

   The conditions are therefore excellent for the emergence of a qubit population that monitors the flipping of the bits represented by the transistors during program execution!

5.5 Comparison of quartz consciousness and bio-consciousness

To get a realistic picture, one can compare quartz consciousness to biological consciousness.

1. Consider the first pessimistic comparison. The length of the DNA double helix for a human is over a meter. This is about a million times more than the number of bits related to the content of the consciousness of a 64-bit processor at a given moment.

   In biology, salts and their ionization states also define qubits with lower qubit rotation energies. Biosystems are full of different ions and I ended up with the idea of a large Planck constant by starting from the observation that the quantum effects of ELF radiation on vertebrate brains seemed to be related to the cyclotron energies of ions but with a very large Planck constant (gravitational Planck constant $\hbar_{gr}$ introduced by Nottale) [J2].

   Microtubules can be micrometers long (inside cells and in axons). There are other filamentous structures. They consist of tubulins, about 10 nm in size. Each tubulin contains approximately $10^3 \simeq 2^{10}$ amino acids if the amino acid corresponds to the nm scale. That is 10 bits. There are 100 tubulins in a chain, so we get 1000 qubits per tubulin chain.

   Typically, there are 13 parallel helical tubulin chains, which makes 13,000 qubits. Considerably more than 64 qubits! And microtubules are present in all cells and axons!

2. Optimistic comparison.

   It is worth noting a really big "on the other hand". The zero-energy ontology (ZEO) introduces a conscius memory that can increase the number of bits because "multi-moment experiences" become possible [L38]. In the optimal situation one has an analog of time crystal: each clock beat involves classical non-determinism necessary for the memory recall. If the program module defines a time-like analogy for DNA as time crystal then it would define the time-like analog of a DNA sequence and the content of conscious information would increase drastically.

   Brothers Fingelkurts [L1] have found that EEG splits into pieces of duration about .3 seconds and these pieces split into organized and chaotic halves. A natural TGD inspired interpretation [L1] would be that these pieces correspond to pairs of BSFRs defining a kind of sleep-awake rhythm and also now an analog of time crystal is in question. Quite generally, EEG rhythms could give rise to similar sleep-awake rhythms and analogs of time crystals.

5.6 How could the OH-O^- qubits represent the functioning of a transistor?

Could the bits represented by transistors have a quantum representation as OH-O^- qubits analogous to the proposed quantum variants of DNA, RNA and proteins for which the chemical codons correspond to the minimal energy ground states of quantum codons which are dynamical?

The characteristic feature of the transistor (see this) is due to the semiconductor property of the base, which physically corresponds to a narrow region between two diodes, collector and base.

The semiconductor property means that current runs in the base only in one direction. The second characteristic feature is that a small base-emitter current directed to the emitter is amplified to a much larger collector-emitter current. Therefore transistors can be used as switches and amplifiers.

In a transistor the collector-emitter current on or current off represent a bit. Bit 1 could correspond to a large current induced by a base current to the base. Bit 0 could correspond to a very small current induced by a base current from the base. Equivalently base current represents the bit. A second representation replaces current with base voltage or equivalently with output voltage.

Transistors can be classified to bipolar transistors and field effect transistors. The following consideration is restricted to the bipolar transistors.

1. Transistorsconsist of a collector, emitter and base, which is a thin semiconducting region between them.

2. In transistors there are two kinds of current carriers. Delocalized electrons in the conduction band and positively charged holes in the valence band created when the electron is transferred to the conduction band. The symbol n (negative) *resp.* p (positive) is used to refer to a situation in which current carriers are electrons *resp.* holes. One can classify bipolar transistors to type npn and pnp.

3. For a transistor of type npn, the base is p type semiconductor whereas the diodes between which it is located are of type n. When the base-emitter current is nonvanishing, electrons run from the n type emitter to the p type base and away from the base. The small base-emitter current induces a considerably larger collector-emitter current that is current of electrons from the n type emitter to the n type collector. In the base The fusion of the electrons from the emitter and of holes of the base gives rise to neutral atoms and this gives rise to the base-emitter current.

4. For a transistor of type pnp, the base is n type semiconductor whereas the diodes are of type p. If the base-emitter current is of the correct sign, a small current of holes runs from the n type base to the p type emitter. Base-emitter current is amplified to a large current of holes from the p type collector to p type emitter. In the base the electrons and holes are created from neutral atoms and this gives rise to base-emitter current.

To understand what the representation of transistor bits in terms of OH-O$^-$ qubits might mean, it is good to start from the following analogies.

1. One can say that valence and conduction bands correspond to the biological body (ordinary matter) and gravitational magnetic body (dark protons). Electrons in the valence band are analogous to OH state whereas electrons in the conduction band are analogous to dark protons H^+ at the gravitational magnetic body. OH$^-$ corresponds to the hole.

   The emergence of collector-emitter current as electrons in the conduction band is analogous to the Pollack effect. The fusion of holes and electrons in p type base corresponds to the qubit flip OH$^-$ +dark p $\rightarrow$ OH as a dual of Pollack effect. The creation of holes and electrons in n type base correspond to the Pollack effect OH $\rightarrow$ OH$^-$ +dark p.

2. n type regions are analogous to dominance of dark H$^+$ states. Magnetic body dominates. p type regions correspond to regions in which OH$^-$ states dominate.

3. For a transistor of type npn, the collector and emitter as n type regions correspond to magnetic bodies assignable to separate 3-surfaces. The p type region would correspond to OH$^-$ type region so that in the ideal case its magnetic body would contain no dark protons. requires that the dark protons can be transferred between the magnetic bodies involved. The currents would dominantly consist of dark protons.

   The voltages between the ordinary matter parts (biological bodies) indeed correspond to voltages between the magnetic bodies since electrostatic generalizes to the many-sheeted space-time.

4. For a transistor of type npn, p type regions correspond to two separate OH^- type regions of the biological body (ordinary matter) whereas an n type region would correspond to a magnetic body containing dark protons. The OH^- created in Pollack effect in the base would flow to the emitter. Also the ions OH^- created in the collector would run to the emitter. This would mean the transfer of electrons between OH:s. The currents would correspond to the electrons transferred between the bonds. These currents are analogs to the currents in the transistor.

This kind of representation requires that OH groups replace some O:s of SIO_4 or SiO_2. This is possible but whether it can happen in the recent transistors, is not clear to me. If not, one might hope that this kind of representation is possible in a future technology combining a classical computer and OH-O^- quantum computer-like system to a genuine living machine.

5.7 Is there any hope of curing the retraining problem of language models without making computers conscious?

I summarized my thoughts on perhaps the worst problem of language models, which is the loss of plasticity in continuous learning. The entire teaching material has to be rewritten, which is terribly expensive. These comments were stimulated by and article raising some hopes about the solution of the problem (see this).

One can ask whether and how TGD's speculative vision of potentially conscious computers [L27, L26] might solve the problem.

5.7.1 The retraining problem of language models

The basic problem is that everything has to be started from scratch. This is extremely expensive. Biological systems relearn quickly because there is no need to relearn everything. Is the problem fixable for the computers as they are now or is something new required?

To see what could be the root cause of the problem consider first what language models are meant to be.

1. In a language model, learning occurs at the raw data level. Different probabilities are taught for different associations. The associations are fixed.

2. How does the trained system work? The language model simply reacts by recognizing the context and producing probabilistically one of the fixed associations. This response is a mere reaction. If language models are what they are believed to be, they does not have conscious understanding, they lack intentional actions, and are unable to react to a changing environment.

5.7.2 Could TGD-inspired biology help?

Could a comparison with TGD-inspired biology give clues as to where things go wrong. Why is relearning so easy for biosystems? How does the TGD-based biology differ from the standard biology in this respect? Consider first the classical level.

1. Holography, which is not quite deterministic, is a completely new element of TGD as compared to the standard model. The space-time surfaces are analogous to Bohr orbits and determined almost completely by 3-surfaces as initial data. The 4-D tangent spaces of the space-time surface at the 3-surface defining the holographic data cannot be selected freely. This is the classical counterpart of Uncertainty Principle and leads to classical quantization. Function, program is the basic concept rather than 3-D data.

2. These 4-surfaces define classical analogies of biological functions, behavioral patterns, or programs. When the 3-surface, which almost uniquely fixes the 4-surface, changes, the function changes. Non-determinism is essential in making a conscious memory recall possible.

Consider next the quantum level.

1. Series of "small" state function reductions (SSFRs) associated with the repeated measurements of commuting observables belonging to the same set whose eigen states the 3-D states at the passive boundary of causal diamond (CD) are, define self as a conscious entity. The proposal is that biorhythms as clocks define TGD counterparts of time crystals such that each unit of time crystal involves a classical non-determinism.

   This could be the case at the EEG level as the findings of brothers Fingelkurts suggests [L1] [L1]. Maximal non-determinism implies maximal memory recall capacity and maximal flexibility. A whole set of different behavior patterns can be represented as quantum superpositions and the interaction with the external or internal world determines the measurement in which some classical behavior is chosen.

   The sequences of SSFRs are analogous to association sequences and the superpositions of the space-time surfaces can be seen as superpositions of associations. One could regard the quantum counterpart of any biological function/response as quantum association.

2. "Big" state function reductions (BSFRs) having interpretation as death of self or falling asleep involve time reversal. Pairs of BSFRs (sleep periods) make learning possible through trial and error. After the two BSFRs, the system has new holographic data and different space-time surfaces. A goal directed behavior becomes possible and there are many ways to achieve the goal, not just one fixed way analogous to a fixed computer program. This is the essence of intelligent behavior.

   Local pairs of BSFRs would give rise to the relearning generalizing to any biological function.

How does this general view relate to the DNA level?

1. According to the standard view, DNA remains the same during the life cycle. If DNA represents data, there is no relearning at the level of chemical DNA. In zero-energy ontology (ZEO), even chemical DNA could change without any problems with conservation laws and quantum superpositions of different chemical genes are in principle conceivable.

   Quantum DNA can be represented in terms of OH-O^- qubits sequences assignable to the gravitational magnetic bodies of the Sun and Earth. Remarkably, the solar gravitational Compton frequency is 50 Hz, the average EEG frequency. At least for neurons, this would suggest that the gravitational magnetic body is that of the Sun. Note however that EEG time scales are also associated with the basic biomolecules. For the Earth the gravitational Compton frequency is 67 Gz and is a natural frequency associated with the conformational dynamics of biomolecules.

   Quantum DNA consisting of codons represented as OH-O− qubits is dynamic and could act as a simulator, a kind of R&D laboratory testing different variants of DNA. It is of course possible that a single life time is spent with the same chemical DNA and the next life after a pair of BSFRs involves the improved DNA.

2. Epigenesis brings in flexibility. Even if the chemical DNA does not change, it can be used in different ways. Suitable modules are selected from the analog of program software, just like in the text processing. In the TGD framework, this could correspond to the classical non-determinism of the space-time surfaces representing the biological function. Dark DNA allows you to try different combinations of genes.

3. The understanding of the role of the cell membrane and membrane potential in epigenesis is increasing. As found by Levin et al [I10] [L33]. The very early stage of the development of embryo is highly sensitive to the variations the membrane potential and can be understood in terms of the changes of the binding energy of electron of O^- induced by the potential, which can reduce the binding energy to thermal range so that the flips of OH-O^- qubit occur with high probability. In adulthood, the sensitivity disappears and qubits would not flip.

   Could this sensitivity be artificially induced? Here, electric fields as a controller of the sensitivity of OH-O^- qubits assignable to the basic biomolecules suggests themselves.

4. Microtubules involve longitudinal electric fields and their second ends are highly dynamic so that the length of the microtubule is under continual change. There are huge numbers

of amino acids carrying one qubit each (COOH group). Here the quantum level and the classical level are both dynamic and seem to be strongly coupled. Also strongly related to conscious memory.

5. The quantum entanglement between the quantum level and the chemical level could be possible even at the amino acid level?

One can also look at the situation at the level of cell membranes and neuronal membranes. The basic question is how cell membranes and neuronal membranes learn.

1. As found by Levin et al [I10], the role of the electric fields is central also in the ordinary cells. The electric potential of the ordinary cell membrane correlates with the state of the environment of the cell and codes for sensory information.

   The TGD proposal is that cell membrane acts as a Josephson junction and communicates the frequency modulate membrane potential to the magnetic body as dark Josephson photons where they induces resonantly quantum transitions transformation the modulation to a sequence of pulses perhaps inducing as a feedback nerve pulses or their analogs.

   During the embryo stage, the cells are very sensitive to the variations of the electric field of the cell and this suggests that these variations take the cell membrane near to the criticality at which large quantum fluctuations for OH-H^- qubits for phosphates at the inner surface of the cell membrane are possible. This period would be analogous to the learning period of LLMs and would involve BSFR pairs. After this period the situation stabilizes and it might be that BSFRs become very rare.

2. In the central nervous system, nerve pulses appear and in neuroscience are thought to be responsible for communications only. In TGD the situation would be different [L32]. I have proposed their interpretation in terms of pairs of BSFRs so that in LLMs they would correspond to relearning. Neurons would be lifelong learners whereas ordinary cells would learn only in their childhood.

   Nerve pulse is generated at a critical membrane potential, which could correspond to effective thermalization of the OH-O− and possible qubits assignable to other ions. Axonal microtubules would also be near quantum criticality. The propagation of nerve pulse along the axon as a local BSFR-pair would induce microtubular relearning.

5.7.3 Could the speculated quartz consciousness come to the rescue?

One can consider the possibility that under a metabolic energy feed computer can become to some extent an entity so that it can modify both the program and the data used by it as a response to changes in the environment provided by the net. This would require that the OH-O^- qubits as dark variants of program bits can entangle with ordinary bits. Energetically this could be possible since the energy scales for transistors are essentially the same as for the metabolism and OH-O^- qubits.

1. Suppose that the sequences of OH-O^- qubits as time crystals in TGD sense can be realized in a (future) computer. Qubit sequences would be time series related to the running program. They would involve variation because only the bit configuration corresponding to the minimum energy would correspond to the running program. This makes possible an entire repertoire of associations from which a SSFR would choose one. Quantum measurement following the generation of bit-qubit entanglement could change the value of the bit.

2. Besides the dynamic realization as a running program, there could be a non-dynamic realization in which the data that determines the program could be accompanied by a similar set of qubits assignable to transistors. The data used by the program, such as learned associations, could be associated with qubits, and could be made dynamic by using electric fields to make the qubits more sensitive against flip. The problem is of course that the change of a randomly chosen single qubit implies the failure of the problem. Only critical qubits associated with choices and data qubits should be subjected to a flip.

3. Besides time crystals with non-deterministic repeating units, also space-like crystals involving non-determinism in each lattice cell can be considered. Also dynamical quantum qubits with maximal non-determinism in space-like directions associated with unit cells could accompany the data bits. Dynamization could be induced by using electric fields.

4. If OH-O^- qubits can quantum entangle with bits, program/data is accompanied by quantum program/quantum data which can react to the perturbations from the external world (BSFRs) and internal world (SSFRs). The quantum level could control the bit level. Even the associations as the data of the language model could be accompanied by a set of qubits that react to a changing situation.

5.7.4 How could an association system retrain itself in response to a changed situation

If language models are nothing but deterministic association machines, there is little hope of solving the problem.

Could the learning in the biological and neural systems provide some hints about possible cures, possibly requiring modification of computers so that they would become analogous to living systems?

1. The findings of Fingelkurts brothers [L1] [L1] suggest that EEG rhythms define time crystals in the TGD sense, that is maximally non-deterministic systems having lattice cells as a basic unit of non-determinism for SSFRs giving rise to the flow of consciousness of the self. If biorhythms define TGD analogs of time crystals, the non-determinism would be maximal and maximum flexibility in SSFRs would be possible.

2. In ZEO, a "big" state function reduction (BSFR) as counterpart of ordinary state function reduction changes the arrow of time and is assumed to give rise to the analog of death or sleep. At the LLM level, this would be the analog for a complete retraining from the beginning.

The sequences of SSFRs could be seen as associations or association sequences having also a behavioral pattern. The repertoire of associations should change as the environment changes.

1. Could a computer clock define the equivalent of an EEG rhythm as a time crystal in the TGD sense? The problem is that a typical computer clock frequency is few GHz and considerably lower frequency than the 67 GHz as the gravitational Compton frequency of the Earth. This would suggest that a unit consisting of roughly 67 bits could correspond to the basic unit of the time crystal. The gravitational magnetic body of the Sun has a gravitational Compton frequency of 50 Hz identifiable as the average EEG frequency.

2. Could one think of a quantum version of LLMs in which pairs of BSFRs as "death" and rebirth happen spontaneously all the time as a reaction to a conscious information coming from the environment inducing the perturbation implying that the density matrix as the basic measured observable does not commute with the observables that define the quantum numbers of the passive part of the zero energy state? In this way ZEO would make possible trial and error as a basic mechanism of learning.

3. The formation of an association could be perhaps modelled as a single non-deterministic space-time surface decomposing to a time crystal like almost periodic structure with each unit characterized by non-determinism making it a seat of potentially conscious memory? Internal disturbances would produce their quantum superpositions and SSFR would select a particular association.

4. An external disturbance could produce a BSFR and "sleeping overnight". This period of "sleep" could be rather short: also our flow of conscious experience is full of gaps. Upon awakening, the space-time surfaces as correlates of the associations would no longer be the same. System would have learned from the interaction with the external world. This temporary death of the system would be an analogy for a total re-education. But the system would cope with it all by itself.

The hard problem is how to realize this vision. Here the analogy with cell and neuron might serve as a guideline in trying to imagine what the new technology might look like.

1. Ordinary cells are analogous to LLMs as they are now and learn only in their childhood. Neurons are lifelong learners thanks to the neural activity inducing the conduction of local BSFR-pairs updating microtubular states. Could something like this be realized in computers?

2. In computers, information is transferred along wires and they can be seen as the counterparts of axons. Is it possible to make these wires carriers of quantum information and perhaps even of the learned data about associations. The conduction of the analogs of nerve pulses during the running program inducing a pair of BSFRs would gradually modify the data locally and lead to a continual relearning.

   Copper wires are too simple to achieve this. Should one consider axon-like geometry defined by two cylinders analogous to the lipid layers of the cell membrane and having also voltage between them as a representation of the signal so that the interior cylinder would contain OH-O^- qubits? The variation of the counterpart of the membrane potential during signal transmission (bits represented as voltages) could take the qubits near criticality. Could copper hydroxide $Cu(OH)_2$ serve as a possible candidate for an intelligent wire based on OH-O^- qubits.

5.8 How the possible quantum variants of LLMs could be updated?

If one can assign the training data of LLMs to quantum states, there is a hope that the retraining need not start from scratch and could become more flexible and less expensive.

5.8.1 How to assign to classical associations their quantum representations?

In LLM both inputs and outputs are associations represented as text. The quantum dynamics must not affect the content of the input. A classical association is encoded as a bit sequence. Associations can be enumerated and each corresponds to its own bit sequence serving as an address, a symbolic representation, and no longer contains the original information. The Gödel numbering of statements serves as an analogy.

Also the quantum equivalent of the number of the classical association as a qubit sequence is just a name for it. Quantum processing can operate on these qubit sequences and produce longer quantum associations associated with them which in qubit measurements produce longer associations and superpositions of them. The outcome is determined by the measurement of the bits appearing in the numbering of the associations.

Quantum operations followed by the measurement of qubits can only permute classical associations. They can affect the association probabilities and perhaps add new associations in partial retraining. Various quantum superpositions of the quantum associations (the numbers labelling them) are possible and correspond to the quantum counterpart of the concept of "association A$\rightarrow$ ..., where A is fixed.

This allows for maximally simple representations at the quantum level. Arbitrarily complex associations $A \rightarrow$ ... can be quantum-encoded by listing them. A local bit-qubit correspondence is the simplest one and the same operation could change the value of both bit and qubit. If the electric field does this then this could be the case for transistors as bits if each bit is accompanied by OH-O^- qubit. In the ground state the minimum energy state for OH-O^- qubit would correspond to the ordinary bit.

Is the quantum entanglement between bits and qubits necessary or even possible? Could one keep the bit level as it is and perform quantum operations for qubit sequences and transform the to bit sequences so that also associations not possible for the classical computer could appear in the output? This option cannot be excluded if the bit sequences represent analogs of Gödel numbers for associations.

5.8.2 Does quantum non-determinism reduce to classical non-determinism for "small" state function reductions (SSFRs)?

In ZEO, the classical non-determinism does not affect the 3-surfaces nor fermionic states at the boundary of the CD. This is consistent with the identification of the non-determinism of SSFRs as classical non-determinism.

The classical Bohr orbits would be non-unique due to the classical non-determinism appearing already for the 2-D minimal surfaces. The very fact that computer programs can be realized, strongly suggests that this non-determinism is present.

There are two types of non determinisms. A non-deterministic time-like crystal (time crystal) and non-deterministic space-like crystal represent these non-determinisms. Each cell of these crystals would be a seat of non-determinism meaning that the surface branches at the locus of the non-determinism and a single branch is selected. This makes it possible to generate a conscious memory in a memory recall.

Reading and writing transform these two kinds of non-determinisms to each other.

1. Reading space-like crystals representing data bit sequence creates a time-like representation as a sequence of SSFRs if at a given moment the qubits of the geometric past are frozen. A series of SSFRs, conscious stream, "self" is created at the quantum level. Therefore a space-like non-deterministic crystal can be transformed to a time-crystal. In writing the opposite happens. The minimum energy state for the associated quantum states selects a unique configuration.

   Quantum entanglement between separate non-deterministic representations (cognitive representations possibly allowing characterization in terms of a p-adic topology for a ramified prime) is possible. Also entangled between time- and space-like non-deterministic degrees of freedom is possible.

2. How these reading and writing processes could be realized? A relation to topological quantum computation, in which time-like and space-like braidings by monopole flux tubes play a central role suggests a possible answer to the question [K1]. Think of dancers connected by threads to fixed points on the wall. Dance can be interpreted as a time-like braiding and induces space-like braiding as knotting and linking of the threads connecting the dancers. In TGD the threads correspond to monopole flux tubes.

5.8.3 But what does the classical non-determinism mean?

I have mentioned several times classical non-determinism at the level of holography = holomorphy principle identifying space-time surfaces as roots $(f_1, f_2) = (0, 0)$ of analytic functions of H coordinates. At the level of 3-D holographic data branching should occur so that the algebraic equations allow several roots with different tangent spaces.

1. What is the precise meaning of the analogy between holographic data as 3-surfaces and the frames of soap films? Could all roots $(f_1, f_2) = (0, 0)$ correspond to different alternatives for this non-determinism or are there some restrictions? It seems that the 4-D roots, which can be glued together continuously cannot correspond to the non-determinism. The cusp catastrophe serves as a good example of the situation. The regions of the space-time surface representing different roots cannot be regarded as distinct space-time surfaces.

   Rather, it seems that the non-determinism requires multiplicity of the 4-D tangent space and in this kind of situation one must select one branch.

2. Could the choice of only one root in the branching situation give rise to non-determinism? Is it possible to implement boundary conditions stating classical and quantal conservation laws at the interfaces of the regions corresponding to different branches?

   Any general coordinate invariant action expressible in terms of the induced geometry is consistent with holography = holomorphy principle [L35, L41] Is it permissible to choose the classical action so that boundary conditions can be satisfied when a single root is selected? This would force coupling constant evolution for the parameters of the action if one also assumes that the classical action exponential as an exponent of Kähler function corresponds

to a power of the discriminant D defined as a product of root differences? The same choice should be made at the fermion level as well: the super symmetry fixing the modified fermionic gamma matrices once the bosonic action is fixed, would guarantee this.

3. Also, the roots u for a polynomial $P(u)$ of the hypercomplex real coordinate u assignable to the singularities as loci of non-determinism at the string world sheets come to mind. These roots must be real. At criticality a new root could appear. Also branching could occur and relate to the fermion pair creation possible only in 4-D space-time thanks to the existence of exotic smooth structures [L43, L41]. Could these roots represent the positions of qubits?

5.8.4 What could the updating of the training material by adding an association mean at a fundamental level?

Retraining cannot be only the manipulation of association probabilities but also the addition of new associations. The scope of the concept "associations related to a given input" is expanded and complexity increases.

If these associations are enumerated by bit sequences, it is enough to associate a series of bits with the new association as a classical bit sequence and to this new bit sequence a qubit sequence by bit-qubit correspondence. The superposition of the quantum counterpart of the new association with previous qubit sequences should be possible. Just like in LLM, also the combinations of the basic associations mapped to qubit sequences into longer quantum association chains should be possible.

5.8.5 Comparison with axons

Is it reasonable to represent the training data as an analogy to the dynamic quantum states of axons that microtubules might represent? A set of qubits related to an axon. Each set of qubits represents one association.

The axon states allowed by classical space-like non-determinism would correspond to different associations as sets of qubits, which in turn correspond to sets of bits. Data update would be by inducing thermal chaos and time reversal by means of a nerve impulse and the subsequent "reincarnation". Local thermal chaos induced by means of electric fields in the basic update operation. The local states of axons (microtubules) would be symbolic representations, kind of Gödel numbers for actions.

5.9 On symbolic consciousness

Whether the notion of symbolic consciousness could make sense in some sense has been a topic of discussion in our Zoom group.

1. A symbol represents an object to the observer and its meaning, if any, depends entirely on the associations that arise in the observer. A symbol is an object or process that sufficiently resembles the object it represents.

   In this sense, one cannot speak of a symbol as an independent object. Just as one cannot speak of information as something absolute. The amount of conscious information produced by a symbol depends on its observer.

2. If one had to necessarily call some form of consciousness symbolic, then I would call the consciousness presented above, possibly related to transistors and microprocessors, symbolic. In the optimal case, a program running in a microprocessor generates OH-O^- consciousness from the program as an analogy of a DNA chain, which symbolically represents a process that has meaning for us through the output.

6 How to associate quantum computation to classical computation

How could a classical computer become a conscious and living system? The tentative answer to this question, discussed in [L39], is that something analogous to a fusion of classical and quantum

computer takes place.

In zero energy ontology (ZEO) one can say, the quantum computation would be a superposition of all possible computations with fixed initial values. This is made possible by the fact that classical physics as Bohr orbitology is an exact part of quantum physics in TGD and by the predicted slight violation of classical determinism. The computation in the usual sense would correspond to the most probable computation in the superposition.

In the sequel I consider the above question in detail.

6.1 Basic input from Quantum TGD

What are the basic pieces from the TGD side?

1. Zero energy ontology (ZEO) defining new quantum ontology, solving the basic problem of quantum measurement theory, is necessary. General coordinate invariance requires holography and it is not quite deterministic so that space-time surfaces are analogous to almost deterministic Bohr orbits and Bohr orbitology becomes an exact part of quantum TGD.

2. Classical non-determinism corresponds to the non-determinism of minimal surfaces: already for 2-D soap films as minimal surfaces the frames do not define the soap film uniquely. In ZEO this non-determinism makes possible a sequence of small state function reductions (SSFRs) as a counter for a sequence of measurements of the same observables which in standard QM does not change the state. In TGD the second member of the zero energy state at the passive boundary of the causal diamond (CD) is unaffected by the second member at the active boundary is affected.This gives rise to a conscious entity, self. In "big" SFR (BSFR) the self "dies" and reincarnates with a reversed arrow of geometric time.

3. Each pulse of the computer clock is associated with the possibility of classical non-determinism of a 4-D minimal surface. Classical non-determinism would produce a superposition of 4-surfaces corresponding to different values of bit and associated qubit. Protons are also involved: protons are either ordinary or dark and located at the gravitational magnetic body. Pollack effect induces the transfer of the proton to the magnetic body and its reversal occurring spontaneously its transfer back.

4. OH-O^- qubits are an essential part of the system. For the O^- qubit, the proton of OH is at the gravitational magnetic body. Under certain conditions the gravitational magnetic body should be able to control the ordinary bits. Quantum entanglement of the ordinary and OH-O^- qubit and quantum criticality is required and would be induced by the classical non-determinism.

   If the bit's reversal energy corresponds to the thermal energy, the situation is quantum critical. This is the case also when the energies for the reversal of qubit and bit are nearly identical. This quantum criticality is controlled by the difference in the bit's reversal energies. Small energy difference corresponds to quantum criticality.

   The reversal of the second qubit reverses the bit: one can interpret the reversal for bit and qubit as an exchange of energy between the qubit and the bit. The farther away the probability for a given value of bit is from the value 1/2 the higher the determinism of the program is.

5. The magnitudes of the classical electric and magnetic fields control the energy of the bit and qubit. These are determined by classical physics for the classical space-time surface, which can be non-deterministic.

6.2 A concrete model for classical-to-quantum transition

6.2.1 What happens in ordinary computing?

A general model of classical computer is needed.

1. The first model: A tape containing program instructions is fed into a Turing machine. Depending on the command, the state of the computing unit changes. The transition of the tape corresponds to a clock pulse.

2. The second model: The program is implemented as a 1-D conveyor belt and the incoming bit configuration enters the tape and progresses along it, changing with each step. The output of the program comes out. DNA replication, transcription and mRNA translation correspond to this analogy.

6.2.2 Classical non-determinism

Classical non-determinism, which is the new element, can be assigned to the periods between clock pulses.

1. Thanks to classical non-determinism, the output produced by a program instruction would be a superposition of two space-time surfaces as analogs of Bohr orbits.

2. In the transition corresponding to a clock pulse, the state would be transformed to an unentangled state by a non-deterministic SSFR or a pair of BSFRs. A quantum measurement of bits would be thus performed on the outgoing superposition of bit-qubit configurations.

6.2.3 Concrete model

1. The network performing the computation consists of gates. A gate connects a small number of input bits to the output bits, the number of which cannot be greater than the number of input bits. This operation is statistically deterministic.

   When the input bits are fixed, the output bits are determined by dynamics as non-equilibrium thermodynamic state.

2. The clock pulse triggers the next operation. The failure of the exact classical determinism must relate to this and produce a superposition of space-time surfaces as the resulting qubit because OH and O^- correspond to different space-time surfaces, even topologically.

3. What is essential is the entanglement of the OH-O^- qubit and the ordinary bit and the measurement of the qubit in the beginning of the nex clock pulse. The outcome is not deterministic.

4. The classical bit corresponds to a voltage or current that is determined through statistical determinism in the gate. On the other hand, it corresponds to a classical electric field in a transistor or a magnetic field in a memory bit.

   The direction of this classical field is classically non-deterministic and correlates with the OH-O^- qubit. When the field changes direction, the OH-bit becomes an O^-bit or vice versa. A dark proton is transferred between the system and its gravitational magnetic body.

5. Classical non-determinism creates a superposition of OH and O^- bits. The proton resides both at the gravitational magnetic body and in OH molecules, being analogous to Schrödinger's cat.

   This induces the formation of a quantum entangled state between ordinary qubit and OH-O^- qubits. If the OH-O^- qubit and the bit are quantum entangled before the clock pulse, the quantum measurement of OH-O^- qubit or of ordinary qubit recues the entanglement and leads to a fixed bit.

6.2.4 Some questions

One can raise critical questions:

1. The energy transfer between a bit and a qubit resembles quantum tunnelling. I have proposed that a pair of BSFRs correspond to quantum tunnelling. It is not clear whether a single SSFR can have an interpretation as quantum tunnelling. Could the measurement of a qubit correspond to a single SSFR or to two BSFRs?

2. What could be the energetic role of the clock pulse?

   The system under consideration would be a clock photon + bit + qubit and the total energy would be conserved.

(a) Could the clock pulse have a role of a catalyst, providing the energy needed for quantum tunnelling. In a qubit measurement, energy can be transferred between the bit and the qubit, but the total energy is conserved. The clock photon would kick the system over the potential barrier and then be emitted back into the field.

(b) Or does the clock photon transfer energy to or from the bit + qubit system? Could the energy of the photon associated with the pulse frequency correspond to the energy difference for a bit and a qubit.

The typical frequency of computer clock is few GHz. 1 GHz would correspond to an energy $E = .4 \times 10^{-5}$ eV and wavelength $\lambda \simeq .75$ m. At the surface of the Earth, the gravitational binding energy of a proton is about 1 eV. The energy E eV can raise the proton to the height $h \sim .4 \times 10^{-5} R_E \sim 25.6$ m.

7 Classical non-determinism in relation to holography, memory and the realization of intentional action in the TGD Universe

Gary Ehlenberg sent a link to an interesting article with title "'Next-Level' Chaos Traces the True Limit of Predictability" (see this).

The article discusses the limits to classical predictability as effective non-determinism due to non-computability caused by the initial value sensitivity although the classical dynamics is deterministic. There is also a genuine non-predictability due to non-determinism of quantum theory and quantum statistical determinism makes predictability possible in this case.

Holography, which is not discussed in the article, simplifies the situation enormously since roughly one half of boundary values of initial values are reduced. In wave mechanics, holography corresponds to Bohr orbitology. In complex analysis, the holography corresponds to the reduction of the data defining the analytic function reduces to the residues at poles and discontinuities at cuts.

In the TGD framework holography boils down to holography= holomorphy principle and allows an interesting point of view to the notion of classical chaos. The extremely nonlinear partial differential equations are reduced to algebraic equations and the holography is not expected to be completely deterministic.

In the TGD framework, classical non-determinism is closely related to conscious experience, in particular to the realization of conscious memories. The quantum measurements in the degrees of freedom associated with the classical non-determinism correspond to self-measurements giving rise to conscious experience. Zero energy ontology (ZEO) defines quantum ontology and plays a key role in the understanding of conscious experience. Number theoretical vision brings in p-adic number fields and adeles as correlates of cognition and intentionality. This raises the question of whether and how the classical non-determinism does relate to the p-adic non-determinism.

The question of how intentions are realized as actions also emerges. ZEO predicts that the arrow of time is changed in "big" state function reductions (BSFRs) and this makes possible a quantum version of trial and error process. The number theoretic vision implies Negentropy Maximization Principle stating that the algebraic complexity of space-time surfaces increases in a statistical sense. This implies evolution in all scales. This raises hope about the realization of intentional actions realized as p-adic space-time surfaces as actions realized as corresponding real space-time surfaces by using a quantal trial and error process.

These ideas and questions will be discussed in the sequel.

7.1 Holography= holomorphy principle, classical *viz.* p-adic non-determinism, and ZEO

Holography= holomorphy principle suggests a failure of an exact classical determinism. A natural guess is that this non-determinism relates to p-adic non-determinism. ZEO suggests a general view about conscious memory and intentional action as a quantal trial and error process. The obvious idea is that the realization of intentions as actions in some sense assigns to p-adic space-time

surfaces real space-time surfaces whereas the formation of cognitive representations would do the opposite.

7.1.1 Holography and classical non-determinism

Holography, as it is realized in the TGD framework, allows an interesting point of view to the notion of classical chaos. This view is not considered in the article. In the TGD framework, there is also a close relation to the question about how intentions are realized as actions.

1. Holography reduces the initial data at the fundamental level (space-times as surfaces) roughly by one half and space-time surfaces as orbits of 3-surfaces identified as particle like entities are analogous to Bohr orbits for which only initial positions or momenta can be fixed. This increases predictability dramatically [L42, L43].

2. Holography= holomorphy principle reduces the extremely nonlinear field equations of TGD to algebraic extensions and one obtains minimal surfaces irrespective of action principle if it is general coordinate invariant and involves only the induced geometry. The space-time surfaces are roots of pairs of polynomials or even analytic functions $f = (f_1, f_2)$ of one hyper complex coordinate and 3 complex coordinates of $H = M^4 \times CP_2$. Field equations are more like rules of logic rather than an axiom system. This implies enormous simplification. Solutions are coded by the Taylor coefficients of f_1 and f_2 in an extension E or rationals and for polynomials their number is finite [L35, L44].

   One obtains new solutions as roots of maps $g \circ f$, where $g : C^2 - - > C^2$ is analytic. The iterations of g give rise to the analogs of Mandelbrot fractals and Julia sets so that in this sense classical chaos, or not actually chaos but complexity, emerges. For the iteration of hierarchies $P = g \circ g.... \circ f$ the complexity increases exponentially since the degree P and the dimension of the corresponding algebraic extension increases exponentially. The roots for the iterates can be however calculated explicitly. The interpretation could be as a classical geometric correlate for an abstraction hierarchy.

3. Already 2-D minimal surfaces representable as soap films are non-deterministic. Soap films spanned by frames are not unique. Now frames would be represented by 3-surfaces and possibly lower-D surfaces representing holographic data. The second, passive, light-like boundary of the causal diamond CD is the basic carrier of holographic data. Also the light-like partonic orbits as interfaces between Minkowskian and Euclidean space-time regions carry holographic data. They serve as building bricks of elementary particles. At 3-D frames minimal surface property fails and field equations on the classical action and express conservation laws for isometry charges for the action in question?

   This is expected to give rise to a finite classical non-determinism. It would be essential for the quantum realization of conscious memory since small state function reductions (SSFRs) do not destroy the classical information about the previous SSFRs [L38]. The information is carried by the loci of classical non-determinism having as a counterpart quantal non-determinism assignable to conscious experience.

7.1.2 The relationship between classical p-adic non-determinisms

How could classical non-determinism relate to p-adic non-determinism and to the realization of intentions as transformation of intentions as p-adic space-time surfaces to real space-time surfaces?

1. In adelic physics real and p-adic space-time surfaces are assumed to satisfy essentially the same algebraic field equations. The p-adic and real Taylor coefficients of $f = (f_1, f_2)$ might however relate by canonical identification which maps p-adic numbers in continuous way to reals [L5]. The inverse of the canonical identification as map from reals to p-adics is 2-valued for finite sequences of pinary digits, which in real contex can correspond to a finite or infinite sequence of pinary digits (1=.999...).

   The conjecture is that ramified primes of polynomials (and their generalization) correspond to preferred p-adic primes appearing in p-adic mass calculations and satisfying p-adic length scale hypothesis [L22, L44].

2. What is the relationship between the classical non-determinism and p-adic non-determinism, tentatively identified as a correlate for the non-determinism of imagination and intentionality? Could intentions classically correspond to the solutions of p-adic field equations with the polynomial coefficients, which have values in the extension E but are pseudo-constants having vanishing derivative and are constant only inside regions of the space-time surface?

   Is it also possible to obtain real solutions with piece-wise constant Taylor coefficients of f? Does real continuity and field equations (holomorphy in H) allow this? Is it possible to glue together solutions defined by different analytic functions f? Does this pose additional conditions to the Taylor coefficients as pseudo constants? If so, realizable intentions would correspond to p-adic space-time surfaces, which also have real counterparts. Also real space-time surfaces would have piecewise constant Taylor coefficients changing at the interfaces of two regions.

   A concrete guess is that the gluing of solutions with different choices of f can take place along light-like surfaces since in classical field theories light-like surfaces are seats of non-determinism. Partonic orbits are such surfaces and wormhole contact could define one possible mechanism of gluing together two Minkowskian space-time sheets defined by different choices f.

7.2 How intentions could be realized?

Zero energy ontology (ZEO), Negentropy Maximization Principle [K10]) [L15], the TGD view of conscious memory suggest guidelines for how intentions could be realized. One must however define the basic notions.

1. Suppose that intention could be realized as a p-adic space-time surface for some primes p, perhaps the ramified primes assignable to the polynomials defining the space-time surface considered. Assume that the realization of intention corresponds to a real space-time surface. p-Adic space-time surfaces are mapped in a continuous way to each other by canonical identification which is most naturally realized at the level of WCW for the Taylor coefficients of f and g.

   The number of coefficients is finite for polynomials and should have a representation at the space-time level as space-time points. I have proposed [L44], how the representation as roots of (f_1, f_2) (4-D space-time surfaces) gives rise to a simpler representation of roots ordinary complex numbers assignable to specific space-time points.

2. Carving a statue proceeding from a rough sketch to complete artwork serves as a metaphor for the realization of intentional action. This means that the realization of intention is only in a certain resolution. This means number theoretical discretization in terms of algebraic numbers of extension. At the level of WCW this could correspond to a use of finite extension E of rationals.

   Could the iteration of g with $g(0,0) = (0,0)$ define an increase in the resolution and to the addition of details and complexity. What is the significance of the fact that the roots of g correspond to disjoint space-time surfaces. Do they correspond to separate space-time surfaces? What if the iterate is too large to fit into the CD.

3. Conscious memory is expected to have a role in the process. The SSFRs select between different superpositions of Bohr orbits and conscious memory makes it possible to remember the initial state at the passive boundary and the subsequent states. It would be natural to assume that there is a comparison of the outcome from a sequence of SSFRs with the goal.

   How could the goal be represented consciously? Could it correspond to a lower level in the self hierarchy: the level immediately below a given level gives rise to mental images. If the goal is represented as a mental image the outcome from a given number of SSFRs could be compared with it to see whether the iteration converges.

The following overall view about the realization of intention as action could serve as a starting point.

1. At the level of the world of classical worlds (WCW) quantum states are superpositions of Bohr orbits in both real and p-adic degrees of freedom. The ends of 3-surfaces are fixed at the passive boundary of causal diamond (CD) during a sequence of "small" state function reductions (SSFRs) giving rise to a conscious entity self. SSFRs correspond to quantum measurements in internal degrees of freedom including those associated with classical non-determinism. Cognition can be assigned with these degrees of freedom. The size of CD also increases in the sequence of SSFRs and this gives rise to the experienced arrow of geometric time.

   In "big" state function reductions (BSFRs) the roles of boundaries of CD change and passive boundary becomes active. The arrow of time changes and the conscious entity defined by the sequence of SSFRs dies or falls asleep. Pairs of BSFRs make possible a trial and error process in which the initial values of holography at the passive boundary are changed.

2. Could the realizable intentions have as quantum counterparts sequences of small state function reductions (SSFRs)? What the attempt to realize an intention could mean at the quantum level? Could for a given intention only a finite number of SSFRs be possible: the real counterparts for the p-adic pseudo constants would not allow a realization for longer sequences of SSFRs requiring larger CDs.

   After that a big state function reduction (BSFR) would take place and reverse the arrow of time: the sequence of SSFRs as self would "die" or fall asleep. After the second BSFR (wake-up) one would have a new trial for the realization of intention. Since the extension of rationals increases in size, the next real could contain more SSFRs, the updated holographic data could make the life of the new self as an attempt to realize a slightly modified intention longer.

3. Negentropy Maximization Principle [K10]) [L15] states that the algebraic complexity can only increase in statistical sense since the number of algebraically more complex space-time surfaces is infinitely larger than those, which are less complex. This applies also to the interactions of $g : C^2 \to C^2$. The hierarchy of maps $g \circ g...g \circ f$ would give exponentially increasing complexity and dimension of extension of rationals if $g(0,0) = (0,0)$ so that also $f = 0$ would define one of the roots of g. Reflective levels would make it easier to realize the intentions by increasing exponentially the number of roots of $g \circ ... \circ g$, which are in fact disjoint space-time surfaces. One obtains a disjoint union of space-time surfaces as roots unless f is a prime in the sense that it does not allow a decomposition $f = g \circ h$. Prime surfaces are connected. Fundamental space-time surfaces and fundamental intentions would be primes in this sense.

7.3 Does the union of disjoint roots of $g_1 \circ ...g_n \circ f$ represent the concept as a set?

The space-time surfaces defined as roots of $g \circ ...g \circ f$, where f is a prime polynomial and $g(0,0) = (0,0)$, form a kind of ensemble of disjoint space-time surfaces. Abstraction means formation of concepts and classically concept is the set of its different instances. Could this union of disjoint space-time surfaces as roots represent a concept classically?

What comes to mind are biological systems consisting of cells: do they represent a concept of a cell? What about a population of organisms? What about an ensemble of elementary particles: could it represent the concept of, say, electrons?

1. Holography= holomorphy principle would be essential for the realization of the geometric correlate of collective quantum coherence. Only initial 3-surfaces defining holographic data matter in holography. The 4-D tangent spaces defining the counterparts for initial velocities cannot be chosen freely. This would force a coherent synchronous motion. Also classical non-determinism would be present. Could it correspond to piecewise constant Hamilton-Jacobi structure with different structure assigned to regions of the space-time surface.

2. The Hamilton Jacobi structure of all members of the ensemble from by the roots of $g \circ ...g \circ f$ is the same so that they can be said to behave synchronously like a single quantum

coherent system. Could the loss of quantum coherence mean splitting: p^k roots forming a coherent structure would decompose to p^{k_1} sets with different H-J structures containing p^{k-k1} roots. Cognitive ensemble, as a representation of a concept, would decompose to ensembles representing p^{k_1} different concepts. Is continual splitting and fusion taking place? Could this conceptualization make possible conceptualized memory: the image of the house would be represented by an ensemble of images of houses as kind of artworks.

I have often enjoyed looking at a crop field in a mild summer wind. To me, the behaviour suggests quantum coherence.

1. Crop field in the wind seems to behave like a single entity. Could the crop field correspond to an abstraction of the notion of crop as a set of its instances, realized as a set of space-time surfaces realized as roots of for $g \circ .... \circ f$. Also more general composites $g_1 \circ g_2 ... g_n \circ f$ $g_i(0,0)$ are possible. The roots could also represent the notion of a crop field in wind as a collection of crops, each moving in wind as a particular motion of air around it.

2. Do I create this abstraction as a conceptualization, a kind of thought bubble, or does the real crop field represent this abstraction? Could f correspond to the primary sensory perception and does cognition generate this set (not "in my head" but at my field body) as a hierarchy of iterations and an even more general set of g-composites? Different observers experience crop fields very differently, which would suggest that this is a realistic view.

3. If this set represents the real crop field, there should also be a space-time surface representing the environment and the wind. Could wormhole contacts connect these surfaces representing the concept and the environment to a single coherent whole.

   The usual thinking is that crops from uncorrelated systems and wind as a motion of air causes the crops to move. The coherent motion would correspond to a collective mode in which crops move in unisono and synchronously. What creates this coherent motion? Could macroscopic quantum coherence at the level of the field body be the underlying reason in the TGD Universe?

4. How to describe the wind if one accepts the crop field in wind itself represents the notion of crop in wind? Usually wind is seen as an external force. Coherent motion correlates with the wind locally. What does this mean? How could one include the wind as a part of the system? Wind should affect the crops as roots of $g \circ ....g \circ f$. Each root should correspond to a specific crop affected locally by the wind. Or should one accept that the concept of crop field in the wind is realized only at the level of cognition rather than at the level of reality?

7.4 Simulation hypothesis and TGD

The original simulation hypothesis (see this did not make sense to me since I find it impossible to imagine how the simulation hypothesis could solve any problem of physics or of theory of consciousness. Living systems are of course mimicking each other all the time so that conscious simulation is a very real phenomenon.

The new view of the simulation hypothesis (see this) seems to be analogous to what the simulation of a second computer by computer means. Already in classical physics, the coupling of two systems, in particular resonance coupling, produces what might be called a simulation. Complex enough simulating a simpler system can produce rather faithful simulations. This is not new but makes sense.

The ability to simulate is the key property of computers and the natural question is how the simulations are realized in the TGD inspired theory of consciousness [L50], where one must speak of conscious simulations.

1. In TGD inspired theory of consciousness perception as a sequence of quantum measurements produces representations of an external system and the slightly non-determinism internal degrees of freedom of the space-time surface representing conscious entities can produce this kind of simulation in the more complex system, a kind of cognitive model. The hierarchy of algebraic extensions of rationals defines the entire complexity hierarchy.

2. Holography = holomorphy hypothesis [L35, L44, L37, L47] makes this view concrete. Consider as an example two systems described as roots of $(f_1, f_2) = (0, 0)$ and say $(g^{\circ n} \circ f_1, f_2) = (0, 0)$. Here f_i are analytic functions of generalized complex coordinates of $H = M^4 \times CP_2$ (one hypercomplex coordinate is involved). The latter system has for any n as its roots also $(f_1, f_2) = 0$ for $g(0) = 0$ and the latter system can simulate the first system exactly at the space-time level. The larger the value of n, the higher the simulatory capacities. One obtains simulations and simulations of simulations of ... .

3. For elementary particles the p-adic length scale hypothesis [L45, L51], stating that p-adic primes p near the power of 2 are important, could mean the following. Polynomials g with prime degree p are of special interest since they cannot be decomposed with respect to $\circ$. For any (f_1, f_2) defining kind of ground state, one can have any prime polynomial g of prime degree p and form iterates $g^{\circ n}$. For $p \in \{2, 3\}$, one can solve the roots of the iterates $g^{\circ n}$ exactly (Galois) [L48]. This suggests that the p-adic length scale hypothesis is true for $p \in \{2, 3\}$ and they form cognitive hierarchies by iterations. There is indeed evidence also for $p = 3$ in biology [I7, I8] (see this).

8 Could OH-O$^-$ qubits serve as counterparts of Majorana type topological qubits?

Microsoft has unveiled Majorana 1 (thanks to Marko Manninen for sending the link), claimed to be the world's first quantum processor powered by topological qubits [D1, D3] (see also the popular article at this).

8.1 How could one stabilize the computations and qubits?

The basic problem is how to realize computations in a stable way and how to make stable enough qubits? Concerning computation, topology comes to rescue.

1. Topological quantum computations (see this) can be represented as braidings, which are topologically stable under small deformations. Each braid strand represent a unitary evolution of a particle representing a unitary evolution if a qubit and the braiding operation would represent the computation. Braiding can be either time-like dynamical operation for point-like particles in plane or space-like for a braid connects two planes.

2. Since the 2-D plane containing particles as punctures, the homotopy group is non-abelian. This means that the rotation of a puncture around a second puncture of say bound state can transform the state such that transformation is not a mere phase factor but is a rotation which change the directions of the spins of the particles involved. Therefore the exchange of particles which can be seen as basic braiding operation changing the braid strands can induce an operation, which can be used as a basic building brick for a topological quantum computation.

How could one obtain stable qubits? Qubit represented as a spin is not thermodynamically stable and extremely low temperatures are required. This is the case also for the proposed topological quantum computation: the reason is now that superconductivity is required and this is possible only at temperatures of order milli Kelvins. In any case, the notion of qubit should be topologized. How to achieve this? Here Majorana bound bound states have been proposed as an answer (see this).

1. Non-Abelian braid statistics, which means that their exchange realized as a 2-D rotational flow generated by braiding induces, instead of change of a sign in Fermi statistics, a non-Abelian unitary transformation of the state. It could be used to change the directions of their spins and affect the anyons.

   2π rotation would induce a non-Abelian rotation instead of a mere sign change or phase factor in brain statistics. This is only possible in dimension 2 where the homotopy group can be non-abelian if there are punctures in the plane that the braids would represent. Similarly,

swapping two Majorana fermions in braid produces a SU(2) rotation and can flip the spins and thus the qubits. This swap would be an essential operation in quantum computing. In order to have non-trivial topological quantum computation, one must have non-Abelian braid statistics characterized by a Lie group. Rotation group SO(2) or its covering SU(2) are the minimal options

2. The bound state of two Majorana fermions associated with planar punctures, anyons, would thus obey non-Abelian braid stastistics. It is also possible to affect the second fermion of Majorana bound state by rotating a puncture containing a fermion around the second fermion. Braidings could therefore represent unitary transformations having an interpretation as topological quantum computations.

   Wikipedia article mentions several realizations of Majorana bound states in superconductors. Quantum vortices in super conductors can provide this kind of states. The ends of the superconducting wire or of line defects can contain the Majorana fermions. Also fractional Hall effect can provide this kind of states. The realization studied by Microsoft has the fermions of the Majorana fermion at the ends of a superconducting wire.

3. As I understand it, a condensed matter Majorana fermion would correspond formally to a superposition of an electron and a hole. The statistics would no longer be normal but non-Abelian Fermi statistic but would be that of a non-abelian anion.

   The weird sounding property of this statistics is that the the creation operator is equal to annihilation operator. One obtains two creation operators corresponding to two spin statse and square the creation operator of is unit operator: for fermions it vanishes. This implies that Majorana fermion number is defined only modulo 2 and only the number of fermions modulo 2 matters. Also the anticommutator of two creation operators at different points is equal to unit operator so that the system is highly nonlocal.

4. How the braiding could be realized? One can consider two options. Dance metaphor allows to understand the situation. Imagine that particles are dancers at the parquette. The dance would give rise to a time like braiding. If the feet of the dancers are tied to a wall of the dancing house by threads, also a space-like braiding is induced since the threads get tangled.

5. In the TGD framework, dancers would correspond to particle-like 3-surfaces moving in the plane and the dance would define the dancing pattern as a time-like braiding. This classical view is actually exact in the TGD framework since classical physics is an exact part of quantum physics in TGD. If thee particles are connected to the wall by threads realized as monopole flux tubes, a space-like braiding is induced.

6. These threads bring in mind the wires connecting superconductor and another object and containing Majorana fermions at its ends. Now the second end would be fixed and second would correspond to a moving particle. Majorana bound states would correspond to the ends of the thread and the superconducting flow of the second end would correspond to the dynamical braiding.

8.2 Algebraic description of Majorana fermions

The dissertation of Aran Sivagure contains a nice description of Majorana fermions (see this). Majorana fermions would be quasiparticles possible in a many-fermion state. They would create from a fermion state with N fermions a superposition of states with fermion numbers $N+1$ and $N-1$. They would be created by hermitian operators $\gamma_{n,1} = a_n^\dagger + a_n$ and $\gamma_{n,2} = i(a_n^\dagger - a_n)$ formed from the fermionic oscillator operators satisfying the standard anticommutation relations $\{a_m^\dagger, a_n\} = \delta_{m,n}$. Note that one consider also more general Hermitian operators $\gamma_{n,1} = exp(i\phi)a_n^\dagger + exp(-i\phi)a_n$ and $\gamma_{n,2} = i(exp(i\phi)a_n^\dagger - exp(-i\phi)a_n)$.

One can also form analogs of plane waves as superpositions of these operators $\gamma_{k,1} = \sum_n [exp(ikx_n)a_n^\dagger + exp(-ikx_n)a_n]/\sqrt{N}$ and $\gamma_{k,2} = i\sum_n [exp(ikx_n)a_n^\dagger - exp(-ikx_n)a_n]\sqrt{N}$. Here N is the number of lattice points and discrete Fourier analysis is used.

The anticommutations would be $\{\gamma_{i,k_1}, \gamma_{i,k_2}\} = 2 \times Id\delta_{k_1,k_2}$, $i = 1,2$ where Id denotes the unit operator. For different points $i \neq j$ the anticommutativity implies that the anticommutators

vanish. Therefore the statistics are not the ordinary Bose- or Fermi statistics and non-Abelian statistics. The anticommutation relations reflect the fact that the application of the creation operators twice does not change the physical states so that the number of Majorana fermions is determined only modulo 2.

8.3 TGD view of the situation briefly

The condensed matter Majorana fermions are superpositions of electrons and holes: this breaks fermion number conservation or at least, the superselection rule for fermion number. The hole should correspond to a fermion "somewhere else". In condensed matter, "elsewhere" could correspond to a conduction band in momentum space. The many-sheeted space-time of TGD allows us to understand "somewhere else" as a second space-time sheet, a magnetic monopole flux tube. This leads to a model in which the Majorana Dirac equation is replaced with a description which respects fermion number conservation and super selection rule. TGD also predicts that the hierarchy of Planck constant makes topological superconductivity possible at physiological temperatures: biology would be the basic example.

TGD leads to a generalization of the description in terms of Majorana fermions based on the number theoretical vision of TGD [L34, L35]. The Galois group would serve as a generalization of the group Z_2 defining the parity of Majorana fermion. Two Galois groups are possible: the internal and external Galois group.

1. TGD predicts a 4-D variant of Galois group, the internal Galois group, representing the transfers of fermions between different regions of the space-time surfaces identified in holography= holomorphy vision as roots $(f_1, f_2) = (0, 0)$ for function pairs $H = M^4 \times CP_2 \to C^2$ analytic with respect to Hamilton-Jacobi coordinates generalizing complex coordinates. The internal Galois group is realized as analytic flows analogous to braidings mapping the roots $(f_1, f_2) = (0, 0)$ to each other and having as interfaces the regions at which two or more roots co-incide.

2. The simpler version of the external Galois group, is associated with dynamical complex analytic symmetries $g : C \to C$: $(f_1, f_2) \to (g \circ (f_1, f_2)$. In this case, the Galois group relates to each other disjoint space-time surfaces. When g reduces to a map $g = (g_1, Id)C \to C$, where g_1 has no parametric dependence on f_2, one can assign to it an ordinary Galois group relating to each other the disjoint roots of $g_1 \circ f_1$, which are algebraic numbers.

   The notion of external Galois group generalizes. For the general case $g = (g_1, g_2)$, the roots of $g \circ f$ are disjoint space-time surfaces representing pairs of algebraic numbers $(f_1, f_2) = (r_{i,1}, r_{i,2})$. It is possible to assign to the roots the analog of the Galois group. This group should act as a group of automorphisms of some algebraic structure. This structure cannot be a field but algebra structure is enough. The arithmetic operations would be component-wise sum $(a, b) + (c + d) = (a + c, b + d)$ and componentwise multiplication $(a, b) * (c, d) = (ac, bd)$. The basic algebra would correspond to the points of $(x, y) \in E^2$ or rationals and the extension would be generated by the pairs $(f_1, f_2) = (r_{i,1}, r_{i,2})$. This structure has an automorphism group and would serve as a Galois group. The dimension of the extension of E^2 could define the value of the effective Planck constant.

3. In [L35] the idea that space-time surfaces can be regarded as numbers was discussed. For a given g, one can indeed construct polynomials having any for algebraic numbers in the extension F of E defined by g. g itself can be represented in terms of its n roots $r_i = (r_{i,1}, r_{i,2})$, $i = 1, n$ represented as space-time surfaces as a product $\prod_i (f_1 - r_{i,1}, f_2 - r_{i,2})$ of pairs of monomials. One can generalize this construction by replacing the pairs $(r_{i,1}, r_{i,2})$ with any pair of algebraic numbers in F. Therefore all algebraic numbers in F can be represented as space-time surfaces. Also the sets formed by numbers in F can be represented as unions of the corresponding space-time surfaces.

8.4 Could many-sheeted spacetime allow a more fundamental description of Majorana like states?

The problematic aspect of the notion of Majorana fermion as a fundamental particle is that the many-fermion states in this kind of situation do not in general have a well-defined fermion number. Physically, fermion number conservation is a superselection rule so that the superposition of fermion and hole must physically correspond to a superposition of fermion states, where the hole corresponds to a fermion which is outside the system. Condensed matter Majoranas avoid this problem but the assumption of ill-defined fermion number seems phenological: holes must correspond to fermions which are somewhere else.

8.4.1 Could Majorana fermions corresponds excitations for which fermions are transferred between different space-time sheets

In TGD, the notion of many-sheeted space-time however suggests an elegant solution to the problem at the fundamental level and also suggests that the analogs of Majorana fermions and the associated superconductivity are possible at room temperatures.

1. In condensed matter physics Majorana fermions could be assigned with the vortices of superconductors. In the TGD Universe, these vortices could correspond to monopole flux tubes as body parts of the field body. The states created by γ_i would be superpositions of states in which the fermion is at the monopole flux tube or at the normal space-time sheet representing the part of the condensed matter system that we see. The Majorana description would be an effective description.

2. The Majorana creation operators γ_i would be replaced with operators which shift the fermion from ordinary space-time sheet to the monopole flux tube and vice versa. From the geometric interpretation it is clear that this operation must be idempotent. This operation must be representable in terms of annihilation and creation operators. The operators γ_i would be expressible products of creation and annihilation operators acting at the space-time sheets 1 and 2.

   One can consider either commutation or anticommutation relations for these operators. Since the operation does not change the total fermion number, the interpretations as a bosonic operator can be argued to be natural so that commutation relations look more plausible.

3. Neglecting for a moment the indices labelling positions and spins and denoting the oscillator operators associated with the two space-time sheets a and b a rather general expression for the hermitian operators γ_1 and γ_2 would be

$$\gamma_1 = b^\dagger a + a^\dagger b \ , \quad \gamma_2 = i(b^\dagger a - a^\dagger b) \ .$$

   Suppose fermionic anticommutations are satisfied. Only cross terms contribute to anticommutators (and also commutators).

4. Anticommutators are given by

$$2\gamma_1^2 = 2\gamma_2^2 = b^\dagger a a^\dagger b + a^\dagger b b^\dagger a = a^\dagger a - b^\dagger b = N(a) + N(b) - 2N(a)N(b) \ .$$

$$\{\gamma_1, \gamma_2\} = 0 \ .$$

   The eigenvalues of $N(a) + N(b) - 2N(a)N(b)$ vanish for $(N_a, N_b) \in \{(1,1),(0,0)\}$ and are equal to 1 for $(N_a, N_b) \in \{(1,0),(0,1)\}$. The result implies that the squares of the operators γ_i act like an identity operator, which conforms with the Majorana property. The two operators would anticommute.

5. One can also consider the commutator, which could be argued to be more natural on the basis of the physical interpretation as a hermitian observables. In this case one has trivially $[\gamma_i, gamma_i] = 0$ and $[\gamma_1, gamma_2] = N(a) - N(b)$. The commutator would vanish only for $N(a) = N(b)$ and the physical states could be eigenstates of only γ_1 or γ_2 as an observable. In any case, the Majorana-like property would hold true.

One can also form analogs of plane waves as superpositions of these operators

$$\gamma_{k,1} = \sum_n [exp(ikx_n)b_n^\dagger a_n + exp(-ikx_n)a_n^\dagger b_n]/\sqrt{N} \ ,$$

$$\gamma_{k,2} = i\sum_n [exp(ikx_n)b_n^\dagger a_n - exp(-ikx_n)a_n^\dagger b_n]/\sqrt{N} \ .$$

Here N is the number of lattice points and discrete Fourier analysis is used. The commutators and anticommutators vanish for different points. Assume that the occupations numbers $N(a,n)$ and $N(b,n)$ do not depend on n so that one $N(a,n) = N(a)$ and $N(b,n) = N(b)$.

1. The anticommutators are given

   $$\{\gamma_{k_1,1}, \gamma_{k_2,1}\} = \{\gamma_{k_1,2}, \gamma_{k_2,2}\} = (N(a) + N(b) - 2N(a)N(b))\delta_{k_1+k_2}/N \ .$$

   $$\{\gamma_{k_1,1}, \gamma_{k_2,2}\} = 0 \ .$$

   The analog of the Majorana property is true and reflects the fact the transfer operator is classically idempotent.

2. The non-trivial commutators are

   $$\{\gamma_{k_1,1}, \gamma_{k_2,2}\} == (N(a) - N(b))\delta_{k_1,k_2}/N \ .$$

   $\gamma_{k_1,1}$ and $\gamma_{k_2,2}$ can be regarded as non-commuting observables.

8.4.2 $OH - OH^- + p$ as topological qubit?

While writing this, I noticed that the $OH - OH^- + p$ qubits, where p is a dark proton ag monopole flux tubes, that I proposed earlier to play fundamental role in biology and perhaps even make quantum counterparts of ordinary computes possible [L39], are to some degree analogous to Majorana fermions. The extremely nice feature of these qubits would be that superconductivity, in particular bio-superconductivity, would be possible at room temperature. This is would be possible by the new physics predicted by TGD both at the space-time level and at the level of quantum theory.

1. In TGD space-times are surfaces in $H = M^4 \times CP_2$ and many-sheetedness is the basic prediction. Another related prediction is the notion of field body (magnetic/electric) body. Number theoretica view of TGD predicts a hierarchy of effective Planck constants making possible quantum coherence in arbitrarily long length scales. Second new element is zero energy ontology modifyin profoundly quantum measurement theory and solving its basic problem.

2. $OH - OH^- + p$ qubit qubit means that one considers protons but also electrons can be considered. Now the proton is either in the OH group associated with water molecule in the simplest situation in which Pollack effect occurs or the proton is a dark proton at a monopole flux tube. A proton in OH would be analog of non-hole state and the dark proton in the flux tube be the anaog of hole state.

3. What is new is that the proton being on/off the spacetime surface would represent a bit. For Majorana fermions, the situation is rather similar: the hole state corresponds to the electron being "somewhere else", which could also correspond to being on a monopole flux tube as I have suggested. In standard quantum computation, a qubit would correspond to a spin.

4. If the energies for OH and $OH - OH^- + p$ bits are close to each other, the situation is quantum critical and the qubits can be flipped and a process similar to quantum computation becomes possible. Also superconductivity becomes possible at the magnetic flux tubes analogous to magnetic vortices appearing in superconductivity and in fractional Quantum Hall effect.

   These are truly topological qubits also because the topologies of the spacetime surface for different bit values are different. However, the energy difference must be larger than the thermal energy, otherwise the qubits become unstable. With the help of electric fields, qubits can be sensitized to quantum criticality and their inversion becomes possible.

5. The above argument suggests that a non-abelian statistics could be understood for $OH - OH^- + p$ qubits. The anticommutation/commutation relations for the operators trasferring protons to the magnetic body would not be identical to those for Majorana oscillator operators the squares of these operators would be proportional to unit operator which is essentially the Majorana property.

   I have proposed a possible realization for this in a more general case. The exchange of dark protons/qubits would be induced by reconnection of monopole flux tubes: it would therefore be a purely topological process. Nothing would be done to the dark electrons, but the flux tubes would be reconnected. Strands AB and CD would become strands AD and BC. At the same time, the unilluminated protons would become associated with different O^-. In this exchange, could the final result be represented as an SU(2) rotation for the entire space.

6. The transfer of proton from OH to magnetic monopole flux tube would correspond to the Majorana like quasiparticle. In zero energy ontology (ZEO) [L10], point-like particles are replaced with 3-surfaces and holography forces to replace them with their 4-D Bohr orbits. The Majorana quasiparticle would classically correspond to a Bohr orbit leading from proton in H to dark proton at the monopole flux tube.

9 A more detailed view of topological qubit in the TGD framework

The Zoom discussion with Tuomas Sorakivi about Microsoft's claimed realization of a topological qubit was very inspiring and led to a generalization of the notion of Majorana qubit characterized by Z_2 group acting as reflection so that one an assign parity to Majora qubit. In TGD Z_2 os replaced by a generalization of the Galois group and this leads to a discrete group bringing in mind anyons with a larger number of internal states. This also involves the notion of Galois confinement discussed earlier. What would be achieved would be a dual interpretation as topological qubit or as number theoretic qubit. This conforms with the notion of geometric Langlands duality realized in the TGD framework as $M^8 - H$ duality [L34, L35].

9.1 Background

The basic idea is that the Majorana fermions of condensed matter are assumed to define a qubit. A Majorana fermion would be a superposition of an electron and a hole. The idea is not pretty because it violates the superselection rule for fermions and the conservation of the fermion number is also questionable. It has also been found that the existence of the Majorana fermion claimed by the Microsoft research group and the superconductivity it requires have not been demonstrated.

A hole must physically correspond to the electron being "somewhere else". In the case of an insulating band, it could be in the conduction band, or in the case of a conduction band, in another conduction band: this description would hold in wave vector space.

In TGD, the electron corresponding to a hole could be in another space-time plane. The equivalent of a Majorana fermion would be a superposition of states where the fermion would be on two space-time sheets. It would be a topological qubit because small deformations of the space-time surfaces do not cause contact between the surfaces. Of course, one can argue that the energies must be the same on different sheets. In the case of condensed matter, this would correspond to the branches of the Fermi surface touching each other.

This idea can be realized concretely: a transfer is an operation that, when repeated, produces the original state, i.e. acts like a unitary operator. The square of the Majorana fermion creation operator is correspondingly a unitary operator. This leads to a concrete model [L49] and the idea that OH-O^-+p qubits could realize topological qubits, at least in biology.

Yesterday's discussion led to a review of holography=holomorphic vision.

9.2 About Galois groups and their TGD counterparts

How to define a Galois group when we are in dimension 4 and not in the complex plane? Is it possible to define a generalization of the concept of ramified primes: these would give a generalization

of p-adic primes that label elementary particles in TGD?

9.2.1 Space-time surfaces as solutions of the equations $(f_1, f_2) = (0, 0)$

Holography= holomorphy vision leads to the following picture.

1. Space-time surfaces are roots $(f_1, f_2) = (0, 0)$ of two complex values functionsf_i defining an analytic map from $H = M^4 \times CP_2$ to C^2. f_i, $i = 1, 2$ is an analytic function of 3 complex coordinates of $H = M^4 \times CP_2$ and one hypercomplex coordinate of M^4. The Taylor coefficients of f_i are in an extension E of rationals. A very important special case corresponds to a situation in which f_i are polynomials. There are good physical reasons to believe that f_2 is the same for a very large class of space-time surfaces and its roots actually define a slowly varying analog of cosmological constant.

   The roots $(f_1, f_2) = (0, 0)$ correspond to space-time sheets, which are algebraic surfaces. The space-time surface need not be connected. The Hamilton-Jacobi coordinates [L29] serve the coordinates of H: there is one hypercomplex coordinate u and its dual v and 3 complex coordinates w for M^4 and ξ_1 and ξ_2 for CP_2. The coordinate curves for u and v of M^4 have light-like tangent vectors.

2. Dimensional reduction occur because the hypercomplex coordinates are separated from the dynamics and take role of parameters appearing as coefficients of f_i interpreted as functions of $w, \xi_1\xi_2$ so that only three complex coordinates ξ_1,ξ_2 and w would effectively remain dynamical. For partonic orbits as the interfaces between Minkowskian regions and CP_2-like regions with Euclidean signature of the induced metric, u= constant would be a natural condition. At these 3-surfaces, the dimensional reduction would be complete: the roots would not depend on u. In the interior of CP_2 like region u would be also constant and Minkowskian contribution to the induced metric would vanish as for CP_2 type extremals.

3. If f_i is polynomial P_i with coefficients in the rational expansion E, analytic flows as analogs of homotopies that take roots as regions of the space-time surface to each other would correspond to a 4-D version of the Galois group. The definition of the Galois group operation would be as a flow rather than an automorphism of an algebraic extension leaving E unaffected as usual. Definition as flow is used in braid representations of groups.

   This is new mathematics for me and perhaps for mathematicians as well. It would be a generalization of the 2-D Galois group.

4. The 4-surfaces corresponding to different roots would have lower-dimensional surfaces interfaces. The hypercomplex sector effectively decouples and this gives 2 conditions in 4-D space stating that the complex coordinates, say w, are identical at the boundary so that interfaces are string world sheets. This fixes $w(u)$ at the interface.

   (a) The roots as 4-surfaces could correspond to branches of a fold taking place along a string world sheet. This suggests a complexification of a cusp catastrophe. For cusp catastrophe, the catastrophe curve is a V-shaped curve along which two real roots of a polynomial of degree 3 depending on a real coordinate x and real parameters a, b co-incide. Now x is replaced with a complex coordinate w which at the string world sheet depends on the coordinate hypercomplex coordinate u. One can say that the 1-D boundary of V is replaced with string world sheets. What happens in the vertex of V is an interesting question. The boundaries of V having coinciding root pairs as analogs co-incide. Does this mean that two string world sheets fuse. Could this be regarded as a reaction in which strings fuse along their full length?

   (b) Could the space-time regions defined by the roots genuinely intersect along a string world sheet? This kind of intersection would be analogous to a self-intersection of a 1-dimensional curve. The basic example is the curve $x^2 - y^2 = 0$ splitting to the curves $x - y = 0$ and $x + y = 0$.

   If for instance, $f_1 = P_1$ fails to be irreducible and decomposes to a product $P_1 = Q_1Q_2$ of two polynomials Q_i, the roots $Q_1 = 0$ and $Q_2 = 0$ intersect at the common root

$Q_1 = Q_2 = 0$. These kinds of intersections are excluded if one allows only irreducible polynomials. The irreducibility can fail for some values of the coefficients of the polynomials.

The space-time surface would decompose to a union of 2 surfaces represented as roots of Q_1 and Q_2 and do not interact unless they intersect along a string world sheet. The dimensional reduction due to the same Hamilton-Jacobi structure implies that 2 2-surfaces intersect in 6-dimensional space. This does not happen in the generic case. Hence this option does not seem possible.

Analytical flows take the points corresponding to the roots from one sheet to another through string world sheets: here cusp catastrophe helps to visualize. String world sheets correspond to the common values of ξ_1, ξ_2, w. For instance w can serve as coordinate and at the intersection w the value is fixed.

The ends of the strings correspond to complex numbers that depend on the time parameter u: the complex number, say w, would represent the intersection of the space-time sheets as a root. The complex roots depend on u through polynomial coefficients. If one has $u = constant$ at the parton trajectories at which the signature of induced metric changes, the u-dependence disappears at the paths of the string ends at which fermions are attached in the physical picture about the situation. Under very mild assumption about the polynomials $P_i(w, \xi_2, \xi_2, u = 0)$, the roots can be algebraic numbers in an extension of E and would characterize the intersections of the roots of the equation $(P_1, P_2) = (0, 0)$.

These complex numbers are considered a generalization of complex roots and would be related to quantum criticality, i.e., the fact that the two roots are the same and the system is at the interface between space-time regions. The criticality would correspond to a fold of the cusp catastrophe.

If it is possible to attach a Galois group to the set of string world sheets transforming them to each other, it would transform different string world sheets into each other. Could this group serve as an algebraization for the generalized Galois group represented as a geometric flow?

What about the counterparts of p-adic primes? The product of the differences of the roots defines the discriminant D. Can it be decomposed into the product of powers of algebraic primes of the extension E? If so , this would generalize the concept of a p-adic prime. The intersections of the sheets of the space-time surface, or rather their intersections with partonic 2-surfaces, could be associated with p-adic primes. This has just been a physical picture.

9.2.2 The analogs of Galois group associated with dynamic symmetries

The descriptions $g : C^2 \to C^2$ define dynamic symmetries $f = (f_1, f_2) \to g(f)$, which produce new space-time surfaces of higher complexity.

1. What happens in the operation $(f : H \to C^2) \to (g \circ f : H \to C^2)$, $fH \to C^2$ and $g : C^2 \to C^2$? The surface $g(f) = 0$ would correspond to the surface $(g_1(f_1, f_2), g_2(f_1, f_2)) = (0, 0)$.

   The intuitive picture is that complexity increases the in these dynamical symmetries. For example, in the case of C, iterations produce fractals. These descriptions would provide a geometric model for the abstraction and can be combined and iterated.

2. If $g(0, 0) = (0, 0)$ then $(f_1, f_2) = (0, 0)$ remains a root and in the "Gödelian" view of the classical dynamics of the space-time surfaces produces analogies to theorems (see Gtgd). Other roots represent more complex space-time surfaces: the non-trivial action of g brings in the meta-level and makes the composition with g provides statements about statements represented by$(f_1, f_2) = (0, 0)$. "Simple" spacetime sheets, which do not allow a decomposition to $f = g \circ h$, would represent lowest level statements. The associated magnetic bodies could correspond to the surfaces $(g_1(f_1, f_2), g_2(f_1, f_2)) = (0, 0)$. Entire hierarchies of meta-levels are possible.

   Magnetic bodies indeed represent a higher level in the number theoretic hierarchies and correspond to larger values of the effective Planck constant as dimension of extension associated with E. In the TGD inspired quantum biology, the magnetic body serves as a controller of the biological body.

Can the concept of Galois group be generalized in this case?

1. The regions of the surface $(g_1(f_1, f_2), g_2(f_1, f_2) = (0, 0)$ correspond to roots. 2+2 conditions fix the roots $f_1 = a$ and $f_2 = b$ are 6-surfaces, and their intersection is a 4-surface.

   If the consideration is restricted to the surface $u = constant$, assumed to correspond to a partonic orbit, then the roots do not depend on u and can be algebraic numbers and perhaps a generalization of the Galois group could be defined.

   The condition $g_2(f_1, f_2) = 0$ gives $f_1 = h(f_2)$, where h is an algebraic function. The condition $g_1(f_1, h(f_1)) = 0$ gives $f_1 = a$ and $f_2 = b$, where a and b are algebraic numbers. They correspond to 6-surfaces: the space-time surface is the intersection of two algebraic 6-surfaces. If (a, b) and (c, d) are not identical, then the corresponding surfaces are disjoint.

2. Is it possible to define a Galois group using the algebraic extension of E defined by the roots? The Galois group would permute the surfaces $(f_1 = a, f_2 = b)$, which would correspond to pairs of complex numbers and would be disjoint.

   Now the element of the Galois group would not correspond to a flow permuting the pairs (a, b). It should act as an automorphism of $E \times E$. Is this possible? One cannot provide $E \times E$ with the structure of a number field. It is however enough to have algebra structure involving component-wise sum $(a, b) + (c, d) = (a + c, b + d)$ and product $(a, b) * (c, d) = (ac, bd)$. The algebraic extension of E^2 defined by the roots of $g \circ f$ as pairs $(r_{i,1}, r_{i,2})$ would have an automorphism group identifiable as the Galois group. Also discriminant $D = (D_1, D_2)$ could be defined using the component-wise product for the differences of the root pairs. It would have two components and one can ask whether D_1 and D_2 could be decomposed to products of algebra primes of E.

3. Is it possible to generalize the concept of ramified prime? They would define generalized p-adic primes. The discriminant can be defined as the product of the differences of the roots, which would factor into the product of algebraic primes in the extension E. The roots (a, b) would be in $E \times E$ so that the structure of the number field would be required. For quaternions the lack of commutativity implies that the product of the root differences depends on their order.

It was already noticed that there are good physical motivations for decomposing WCW to sub-WCWs for which f_2 is fixed. The counterpart of the ordinary Galois group is obtained in the sub-WCWs: $g = (g_1, I)$ reduces to a map $g_1 : C \to C$. The roots of $g_1(f_1) = 0$ are surfaces $(g_1(f_1), f_2) = (0, 0)$. g_1 has n surfaces as roots. The transitions between these disjoint surfaces would generate the analog of the ordinary Galois group acting as a number-theoretic dynamical symmetry group. Also ramified primes as primes of algebraic extension of E are obtained.

1. Representations of the Galois group transfer fermions between space-time regions corresponding to different roots of g_1. The Galois group is generally non-Abelian and its elements could appear in topological quantum computation as basic operations for the topological qubits. The analogs of anyons would be irreducible representations of the Galois group.

2. If the degree n is prime, g is a prime polynomial. It cannot be represented as a composite of polynomials, whose degree is a product of smaller integers.

   Remark: If P is irreducible then it cannot be a product, in which case the degree would be the sum of their degrees. Therefore one has two kinds of primeness.

3. The surfaces corresponding to different roots of g_1 are disjoint. If the roots are the same then the surfaces are the same. If $g(0, 0) = 0$ then $(f_1, f_2) = (0, 0)$ is a root. As two roots approach each other. the two separate surfaces merge into one. What does this mean physically? Should one regard the identical copies of the surface as different surfaces, members of a double, and carrying different many-fermion states? In any case, the order of the Galois group is reduced in this case.

9.3 About intersections of 4-surfaces

There are several options to consider.

1. The 2 4-surfaces X^4 and Y^4 correspond to different pairs (f_1, f_2). If the Hamilton-Jacobi structures are different so that the hypercomplex coordinates (u, v) are different, the intersection $X^4 \cap Y^4$ is a discrete set of points. Field theory suggests itself as a natural description of fermions assigned with the interaction points.

   If the Hamilton-Jacobi structures are the same, the dimensional reduction occurs and one has effective intersection of 2 complex surfaces in 6-D complex space. In the generic case the intersection is empty.

2. One can also consider the analogs of self-intersections as interfaces for 2 4-D roots for the same pair (f_1, f_2). The intersection consists of string world sheets. As found, genuine self-intersection is exclude so that only the analogy of a complexified cusp catastrophe remains.

   String model is a natural description of the interactions of 4-surfaces and the self-interaction of 4-surfaces in the fermionic sector. Fermion propagators can be calculated because the induced spinor field is a restriction of the corresponding H.

The analogy of TGD based physics with formal systems discussed in [L47] led to ask whether the interaction of space-time surfaces involves the fusion of the 3-surfaces with different Hamilton-Jacobi structures to a single connected 3-surface with a common Hamilton-Jacobi structure for the components. Physically the tusion could mean a generation of monopole flux tube contacts between the 3-surfaces.

In the Gödelian framework, this interaction would have an interpretation as a morphism realized as an action of the composite space-time surfaces on each other. In the connected intermediate state, string model type description might apply in the fermionic degrees of freedom. Even stronger condition would be that fermions reside at the string ends at partonic orbits.

9.4 Galois group as group of possible transfer operations for fermions and a generalization of the Majorana qubit

9.4.1 Roots for the condition $(f_1, f_2) = (0, 0)$ as space-time sheets

Generalization of the Galois group. Galois generalizes Z_2 to Majorana fermions. Classical equivalent of the transfer operation between space-time sheets. A particle is transported through a string word sheet corresponding to a common root pair to another sheet.

Topological/number-theoretic qubit. Transfer through a string world sheet. What is the physical interpretation. String 1-D object in 3-space. Could the Riemann surface for $z^{1/n}$ serve as an analogy. Anyons and braid statistics. Since hypercomplex coordinates are passive, we get effective 2-dimensionality and braid statistics.

9.4.2 Roots in the special case $g = (g_1, Id)$

Ordinary roots of a polynomial represented as 4-surfaces. Disjoint or identical. However, the representation of the Galois group of g_1 is non-trivial. These would correspond to abstractions. Fermion transfer between disjoint surfaces Galois group operation represented using oscillator operators.

When does this?

1. This happens only if f_1 allows the decomposition $f_1 = g_1 \circ h_1$. When could this be possible? In the case of polynomials, this means that the degree of f_1 for a given H complex coordinate ξ_1, ξ_2, or w polynomial is the product of the degrees of $n_1 \times n_2 \times n_3$ for the lower degree polynomials n_1, n_2, n_3.

2. If the degrees of the polynomial for different coordinates are primes, then the decomposition is not possible. These would be "prime polynomials". The 3 prime numbers p_1, p_2, p_3 characterize these. If it is a homogeneous polynomial, then one prime number p is enough. These polynomials would be in a special position physically. They would correspond to "elementary particles". The tetrahedra associated with them would be uniform.

9.4.3 Concrete realization of topological/number-theoretic qubit and generalization of qubits

The TGD based view leads to generalization of bit to n-ary digit or pinary digit, where n or p corresponds to a degree of a polynomial g_1 in $g = (f_1, Id)$ defining a dynamical symmetry and associated Galois group whose elements would correspond to transfers of fermions between different branches of the space-time surface.

1. Roots as regions of an n-sheeted space-time surface correspond to roots $(f_1, f_2) = (0, 0)$ and would correspond to different values of an n-ary digit. They are glued together along string world sheets as analogs of folds.

   The functional composition $f \to g(f)$ gives rise to hierarchies of Galois groups. The Galois group, represented as analytic flows, replaces the group Z_2 of the Majorana case. Analytic flows define braiding operations, which define the 4-D Galois group.

2. Also the dynamical symmetries g give rise to an analog of a Galois group. The non-vanishing roots of g are disjoint. It seems that the Galois group can be defined only if one has $g = (g_1, I)$.

   For OH-O^-+p qubits [L39, L49] they could correspond to different pairs because h_{eff} would be of different magnitude.

9.4.4 Generalization of a bit to n-ary digit and pinary-digit

The replacement of bit with *n-ary digit* would take place when the degree d of the polynomial P_1 (or g_1 in $g = (g_1, Id)$) is $d = n$ and bit $\to$ pinary digit when the d is a prime: $d = p$. Polynomials for which the degrees with respect to complex coordinates of H are primes are primes with respect to the functional composition and could physically correspond to fundamental objects appearing at the bottom of the hierarchy obtained by a functional composition with maps g. This picture generalizes also to more general dynamical symmetries $(g_1, g_2) = (P_1, P_2)$.

These primes should not be confused with ramified primes. One can of course ask whether the p-adic primes appearing in p-adic mass calculations could actually correspond to these primes.

This allows us to consider a possible definition for a topological/number-theoretic qubit. For $g(0) = 0$, the original surface is included in the set of $g \circ f = 0$ surfaces. In the case of OH-O^-+p qubits, the magnet monopole flux tubes could correspond to the non-vanishing root $f \neq 0$ of g. In this case the Galois group of g would be Z_2 and correspond to the parity of Majorana fermions. In the general case more complex Galois groups are possible.

9.4.5 A more precise connection to the Majorana qubit of condensed matter

The definition of a Majorana qubit involves the observation that when two branches of the Fermi surface that correspond to an insulator and to a conduction band touch each other, the gap energy disappears. In superconductivity, this gap energy is very small but non-vanishing. If this energy vanishes, Majorana type excitation becomes possible and is interpreted as a quantum superposition of an electron and a hole.

What could this situation correspond to or how could it generalize in TGD?

1. $M^8 - H$ duality [L34] strongly suggests that Fermi surfaces determined as an energy constant surface in momentum space have space-time counterparts.

2. The group Z_2 defining the parity of Majorana qubit would be generalized to Galois group and and one can consider two options corresponding 1) to the 4-D Galois group realized as analytic flows assignable to a connected 4-surface (f_1, f_2) and 2) to the Galois group assignable to $g = (g_1, Id)$ acting as a dynamical symmetry. The notions of Galois group, discriminant and ramified primes generalize to the case of (g_1, g_2) using component-wise product and sum for the pairs (g_1, g_2) since algebra structure is enough to identify Galois group as automorphisms for an extension of E^2.

Consider option 1) first.

1. The Galois group would relate string world sheets to each other. The branches of the Fermi surface could at the space-time level correspond to 2-D string world sheets at which the roots associated with the different space-time surface sheets $(f_1, f_2) = (0, 0)$ coincide . One could move from one branch of the space-time sheet to another through the string world sheets. Each string world sheet would correspond to a discrete complex point (ξ_1, ξ_2, w).

2. The E^3 projection of the string world sheet would be a string, which would have apparent ends at the "boundary" of the 3-surface. The 2-D "boundaries" of the 3-surfaces are surfaces, where the 3-surface has a fold, i.e. the normal M^4 coordinate has a maximum value. One can say that the string effectively ends at these surfaces although it actually has a fold.

   String would sheet would also have an end at the partonic orbit, where the signature of the space-time metric changes. Since the coordinate u would be constant inside the CP_2 type extremals, the 2-D string world sheet reduces to a 1-D light-like curve inside it.

   In the case of topological qubits, the superconducting wire could correspond to the string identifiable as the superconducting wire whose ends correspond to the points of the Fermi surface at which the branches of the Fermi surface touch. The ends of the wire, assumed to carry Majorana fermions, would correspond to the real ends of the string at partonic orbits to which fermions are assigned or to an apparent end at the fold.

3. The situation would correspond to quantum criticality, since even a small perturbation will move the particle to one of the branches.

For option 2), the space-time surfaces related by the Galois group for $g = (g_1, Id)$ would be disjoint. This does not conform with the assumption that Fermi surfaces touch at a point. This picture could however work for OH-H^- topological qubits for which the two surfaces related by Z_2 Galois group for $g = (g_1, g_2)$ would have different "internal" Galois groups represented as flows leaving the space-time surface invariant.

10 Quantum version for the associative learning in large language models

In the TGD framework the model for associative learning, as it is modelled in large language models (LLMs), could be generalized to formulate a quantum model for associative learning as it could occur in TGD inspired theory of consciousness.

I have discussed LLMs from TGD point of view in [L27, L28, L41]. One could also consider the combination of the TGD inspired quantum version of associative learning with the speculative idea of extending a classical computer to a hybrid of classical and quantum computers [L39].

10.1 Zero energy ontology from the point of view of LLMs

Zero energy ontology (ZEO) is the first piece of the TGD vision.

1. By holography, spacetime surfaces are analogous to Bohr orbits as basic objects. This means that 3-D structure as 3-surface determines almost deterministically the 4-surface.

   The failure of a complete classical determinism is essential. The non-deterministic classical time evolution involves 3-D loci of non-determinism as analogs of 1-D frames of 2-D soap films.

   Different Bohr orbits starting from a fixed 3-surface A at the passive boundary of CD would lead to different surfaces B located at the active boundary of CD whose size of CD would increase during the sequence of SSFRs.

2. At the quantum level, the superpositions of Bohr orbits define zero-energy states in geometric degrees of freedom ("world of classical worlds", WCW). In fermionic degrees of freedom zero energy states are superpositions of products of fermionic states assignable to the boundaries of CD and to the loci of non-determinism.

   The 3-D state at the passive boundary would remain invariant under the sequence of "small" state function reductions (SSFRs). This is the TGD counterpart of the Zeno effect.

3. The Bohr orbits of a 3-D particle are analogous to random walks $A \to B$ for a particle as a 3-surface. The almost deterministic Bohr orbits $A \to B$ are analogous to the association sequences of language models associated with the many layered neural nets.

   The non-deterministic classical time evolution is modellable by a diffusion equation (diffusion) or Schrödinger type equation (dispersion). This process would be the quantum counterpart for the diffusion appearing in LLMs [**?**] (see this). Whether this process could be seen as an analog of a path integral defined as a sum over a discrete set of paths as Bohr orbits, is an interesting question.

4. The time reversal of the diffusion/dispersion is used in error correction in LLMs and in ZEO it could correspond to a pair of BSFRs involving a temporary change of the arrow of time. A pair of BSFRs would make it possible for the system to make a fresh start and therefore to learn by trial and error. This is perhaps the most important aspect of conscious intelligence.

5. On the quantum level, a series of SSFRs corresponds to a subjective time evolution giving rise to a conscious self. It also corresponds to an analog of computation and of mathematical reasoning: the theorem develops step by step as a sequence of SSFRs. In biology this sequence corresponds to biological function and in neuroscience to a behavioral pattern.

10.2 Holography =holomorphy hypothesis and learning process

Holography=holomorphy hypothesis allows to reduce classical field equations to purely algebraic conditions $(f_1, f_2) = (0, 0)$, where f_i are analytic functions of one hypercomplex and 3 complex coordinates of $H = M^4 \times CP_2$. The solutions are minimal surfaces irrespective of the classical action as long as it is general coordinate invariant and expressible in terms of induced geometry. This means universality of the dynamics and is quantum criticality expressed by the holomorphy. This implies saddle surface property for the spacetime surface meaning that the real parts of f_i do not have minima or maxima in general.

Interestingly, the almost absence of minima meaning a saddle point property for most extrema is essential for the success of LLMs, which is in fact not well-understood. In LLMs, the cost function V measuring the size of the teaching error, is minimized in the parameter space by gradient dynamics. If most extrema are saddle points, the process does not get stuck to a local minimum and learning becomes very effective.

Furthermore, in LLMs local flatness of the parameter space is of help since it increases the probability that the gradient dynamics leads to the minimum and also reduces the probability to leave the minimum by a small perturbation.

Could the minimal surface property prevent the sticking in the recent case?

1. It is useful to consider the situation first at the level of a single space-time surface (rather than WCW). At the space-level all points are geometrically saddle points in the geometrical sense by the minimal surface property stating that the trace of the second fundamental form, as an analog of acceleration identifiable as a sum of external curvatures, vanishes. Note that this is not equivalent with saddle point property of minima for functions.

2. The quantum learning process would occur in the "world of classical worlds" (WCW) as the space of Bohr orbits rather than at the space-time level. The loss function is in TGD replaced by the vacuum functional as an exponent of the classical action proposed to have by the analog of Langlands duality also purely number theoretic expression, which would mean computability and enormous simplification [L36].

   The Kähler function K, defining vacuum functional as its exponential, is in a central role. Also the degeneracies of the maxima are important. The maxima for the exponential of Kähler function are thermodynamic analogs for Boltzmann exponents and their degeneracy measured by entropy. One can say that the minimization of energy and maximization of entropy compete.

   Note that K is determined only modulo addition of a real or imaginary part of a holomorphic function of WCW complex coordinates. The Kähler metric of WCW is of the form $G_{M\overline{N}} = \partial_M \partial_{\overline{N}} K$.

The maxima of vacuum functional $exp(K)$, which correspond to minima of the Kähler functio, are of special interest. The Euclidian signature puts strong constraints at the minima of K. Criticality condition means that some second partial derivates of K with respect to the real coordinates vanish.

A good example is the metric of complex plane given by $dzd\overline{z} = d\rho^2 + \rho^2 d\phi^2$ and has $K = z\overline{z} = \rho^2$ having a minimum at origin. The metric is flat.

3. It must be however made clear that in the learning the loss function would measure the deviation of B_2 from B_1 and cannot be identified as K. There are two minimization problems involved and it is not clear whether they are consistent.

10.2.1 The notion of finite measurement resolution

Finite measurement resolution is a key notion in TGD. There are two views of finite measurement resolution based on geometry and number theory respectively. These views are dual.

1. The geometric view relies on inclusions of hyperfinite factors [**?**]: the included factor is analogous to a gauge group leaving the observed physics invariant: this view of finite measurement resolution is central in the geometric view of TGD.

2. The second view is based on number theoretic discretization citebtartFrenkel,compuTGD. The geometric inclusion hierarchies correspond naturally to number theoretic inclusions hierarchies for the extensions of rationals. Space-time surface for which polynomials defining it are in an extension E of rationals allows in a natural way a discretization as points, which are in E. The points of the discretization can be also regarded as points in an extension of p-adic numbers induced by E. I call these discretizations cognitive representations and they form a hierarchy corresponding to extensions of rationals.

   This leads to a p-adic description of cognition. One obtains a unique number-theoretical representation for discretization and it leads to a generalization of the Turing paradigm [K7]: rational numbers are replaced by complexity hierarchies of their extensions and one ends up with number-theoretical computationalism. This gives complexity hierarchies for space-time surfaces as Bohr orbits and they correspond to an improving resolution of discretization and are realized as polynomial hierarchies.

   Holography suggests that for the minimal option the number theoretic discretization applies only to the loci of the classical non-determinism for the space-time surface as minimal surfaces. These loci define the seats of conscious memories and would be 3-D analogs of 1-D frames spanning 2-D soap films.

3. The complementary nature of geometric and number theoretic views of TGD leads to a 4-D generalization of Langlands duality [L35, L41]. This adds powerful constraints also to the quantum model of associative learning.

4. The concept of complexity, which closely relates to evolution, reduces to number theory. Higher-level learning could be seen as a transition to a higher level of complexity and would be something to realize in conscious quantum learning. Complexity hierarchies correspond to polynomial hierarchies represented as space-time surfaces.

10.3 A model for the learning process

How could the learning process take place?

1. Learning process can be seen mathematically as a construction of a representation for the dynamics of the external world by a subsystem. Associations $A_1 \to B_1$ for the dynamics of the external world serve a teaching material and a representation as for these as associations $A \to B$ in the internal model world is constructed as a model for the dynamics external world.

   One can assume that the external world states $A_1 \to B_1$ actually correspond to the sensory percepts of the states of the external world and in the learning process the system learns to associated B_1 with A_1 process in which the difference between B and B_1 is minimized.

In the TGD based model for sensory perception [K16] [L13] as construction of standardized mental images, the feedback loop between sensory organs and magnetic body would make this possible in the same way as in pattern recognition. The deviation of B from B_1 is minimized. This deviation would define the virtual sensory input from the magnetic body to the sensory organ.

Classically A and B (A_1 and B_1) correspond to 3-surfaces at the boundaries of a CD and A (A_1) is fixed in ZEO. At the quantum level, one has zero energy states as superpositions of orbits $A \to B$ ($A_1 \to B_1$).

2. The parameters characterizing the space-time surfaces, identifiable as the Taylor coefficients of the analytic functions and in the special case of polynomials, define the counterpart of the latent space (see this and this). The coefficients belong to an extension E of rationals and one obtains a hierarchy of extensions having interpretation in terms of evolution [L35, L36, L26]. The coefficients determine almost deterministically the space-time surface as a Bohr orbit.

   The failure of non-determinism corresponds to the 3-D loci of non-determinism at the Bohr orbit of A and the discrete variables parametrizing the non-determinism correspond to the parameter space of LLMs.

   The space of 3-surfaces at the passive or active boundary of CD would correspond to the latent space as a subspace of the space of features (see this). The cutoff to the degree of the polynomial and to the dimension of the Galois group of the polynomial would induce the analog of dimensional reduction replacing the feature space with a latent space. This cutoff would also reduce the parameter space as the discrete space characterizing the classical non-determinism. The TGD counterpart of the loss landscape (see this) corresponds to a subspace of the parameter space.

   As the size scale CD increases, the size of the loss landscape increases. Also the complexity of the extension E of rationals associated with the polynomials (P_1, P_2) defining the spacetime surfaces as their roots correlates with the size of the loss landscape.

3. A fixed 3-surface at the initial moment at the passive boundary of the CD corresponds to A in the association $A \to B$. This choice determines the coefficients of the polynomial that defines the latent space. The correspondence $A \to A_1$ could be also learned in the learning process. This correspondence should determine the correspondence $B \to B_1$. The non-uniqueness of B due to classical non-determinism makes possible many associations.

   The construction of a representation means finding non-deterministic space-time surfaces $A \to B$ in CD producing an optimal representation for the pair $A_1 \to B_1$, meaning that B is as near as possible B_1. The error function measures the deviation of B from B_1. In LLMs the error function is minimized by a gradient method. The counterpart ot his method in the the case of the construction of conscious association should be understood.

The fact that the TGD Universe is fractal is expected to help considerably the construction of conscious associations as representations.

1. The representation could be seen as a simplified version of the original obtained by scaling the size of the cd, either up or down.

2. The reduction of the degree of polynomials used and the algebraic dimension of extension E reduce the complexity. The restriction of an extension of E to E reduces complexity and the hierarchies of extensions of E define complexity hierarchies.

3. Also the hierarchies of analytic maps of $(f_1, f_2) \to (g_1(f_1, 2_2), g_2(f_1, f_2))$ define iteration hierarchies analogous to those associated with fractals and approach to what looks like chaos. One can also "imagine" more complex systems at the level of representation by extending E or performing these iterations.

10.4 The version of the learning model for quantum versions of classical computers

One can formulate this picture also in the speculative vision [L39] in which a classical computer becomes a living system as a hybrid of classical and quantum computers.

1. A quantum computation-like process would be associated with classical computation. The classical non-determinism could be maximal in the sense that each tick of the computer clock would involve loci of classical non-determinism making the outputs of the gates non-deterministic.

   Classical computation would correspond to the most probable Bohr orbit in the representation of the computation as a zero energy state. If localization in WCW is possible (position measurement in the discrete degrees of freedom of WCW due to non-determinism) this localization could occur at a single Bohr orbit.

2. The output of a gate would be a superposition of pairs of ordinary bits and $OH - O^-$ qubits. For the $OH - O^-$ qubits, the proton of OH would be transformed to a gravitationally dark proton at the gravitational magnetic body of the Earth or the Sun. This entanglement would be reduced in an SSFR which could, but need not, occur after each clock period.

3. This would give rise to a computational analog of the associative learning process in which the learning process assigns to the pairs $A_1 \to B_1$ computations $A \to B$. Note that classical non-determinism also makes possible the formation of association sequences.

10.5 Conscious associative learning as an analog of sensory perception and motor action

Holography, together with the TGD based view of sensory perception [L4], suggests that the conscious associative learning process has a lot of common with sensory perception in a 4-D sense.

In the TGD framework, motor action could be seen as a time reversal of sensory perception. Motor action could involve a pair of BSFRs inducing a quantum tunnelling from a configuration of muscles to a new configuration so that same basic mechanism but with a reversed arrow of geomeric time could be involved. Intention for the motor action should relate to the process of building a sensory perception as a sequence of SSFRs in a reversed time direction.

1. In ZEO, sensory perception at the classical level would not be 3-D surface, but a 4-D space-time surface, an almost deterministic classical time evolution representing association $A_1 \to B_1$. In the case of hearing this is rather obvious but for vision the time scale is so short that the percept looks like time= constant snapshot. Actually the geometric time duration assignable to the visual percept or order .1 seconds.

   The association $A \to B$, one might perhaps speak of cognitive representation, is realized at the magnetic body (MB) of the brain as a representation of $A_1 \to B_1$. $A \to B$ is generated in a stepwise learning process. The goal is to construct a standardized mental image consisting of familiar objects consisting of standard features.

   The difference between $A \to B$ and $A_1 \to B_1$, rather than only the difference between B and B_1, is minimized. The sequence of SSFRs keeps A fixed. A pair of BSFRs changes also A: this makes possible a trial and error process in which one starts from scratch, so to say.

2. Sensory organ serves as a kind of screen, both for the sensory input arriving from the external world and for the virtual sensory input from MB. The sensory input is analyzed by the brain to features in various scales and the features are sent to the magnetic body. At the MB, the features in various scales are compared to standard features and those minimizing the difference is selected.

3. The selected features determine the virtual sensory as a slight amplification of the contribution of the selected features. The step *sensory organ* $\to$ *brain* $\to$ *MB* $\to$... is repeated until the total sensory input at the sensory organ does not change anymore. The original percept

$A_1 \to B_1$ is affected in the process and eventually replaced with $A \to B$ at the level of the sensory organ. In this respect the process differs from the associative learning.

If the signals from the brain to MB and back are realized as dark photons (, which can decay to ordinary photons identifiable as biophotons), the process is so fast that the process can converge in a reasonable time.

4. The outcome is not realistic but essentially an artwork. It must be so since $A_1 \to B_1$ is very noisy so that both $A_1 \to B_1$ and $A \to B$, can be only guesses for what really happened. For instance, people who are physiologically blind and get back their vision, can see only diffuse light since they have not learned this process in childhood. This suggests that temporary time reversals as analogs of the time reversed diffusion play changing A play an essential role. Note BSFRs could mean a position measurement in the space of Bohr orbits selecting a single Bohr orbit and is analogous to time reversed diffusion.

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