Quantum Antenna Hypothesis

M. Pitkänen,

June 19, 2019
Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Recent postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland.

Contents

Abstract

So called MEs (MEs or topological light rays) are non-vacuum extremals of both Kähler action and the EYM action serving as effective action of the theory. These extremals have cylindrical geometry and are carriers of purely classical vacuum currents and Einstein tensor, which are both light like. These vacuum currents generate coherent states of photons and gravitons with frequencies coming as multiples of the basic frequency determined by the length of the microtubule. They can also carry Bose-Einstein condensates of massless particles. It is proposed that microtubules and other linear structures could act as quantum antennae so that coherent light would be for brain same as radiowaves for us. MEs associated with axonal microtubules or axons themselves could serve as waveguides for the photons of coherent light and realize the notion of neural window abstracted from the paradigm of holographic brain. Vacuum currents could be also behind the ability of the biosystems to form representations of the external world.

There is indeed evidence for the quantum antenna hypothesis: some monocellulars are known to possess primitive microtubular vision, biophotons of Popp could could be generated by MEs and the observations of Callahan support the view that odour perception of insects relies on maser-like emissions by the odour molecules. The coherent light emitted in sonoluminescence could be generated by light-like vacuum currents associated with regions with size given roughly by the diameter of microtubule when vapour-to-liquid phase transition occurs at the final stage of the bubble collapse. Also the observed direct transformation of kinetic energy of fluid motion to chemical energy could involve generation of MEs.

The light-like boundaries of MEs might not be allowed by boundary conditions: MEs could appear as pairs glued together along boundaries or as a similar pair of ME and magnetic flux tube. If the boundaries are however possible, they have the same miraculous conformal properties as the boundary of future lightcone and MEs also allow holography in the sense of quantum gravity and string models and there are good hopes to generalize the construction of the WCW geometry and quantum TGD to take into account the classical non-determinism of Kähler action. MEs provide a justification for the intuition that the supersymplectic and superconformal symmetries of the lightcone boundary $\delta M^4_+ \times CP_2$, which are cosmological symmetries, generalize to approximate macroscopic symmetries acting on the light-like boundaries of the spacetime sheets inside future lightcone and broken only by quantum gravity. Supersymplectic symmetries almost-commute with Poincare symmetries and the gigantic almost-degenerate supersymplectic multiplets defined by genuinely quantum gravitational state functionals in the "world of worlds" correspond in a well-defined sense to higher abstraction level expected to be crucial for understanding consciousness. MEs are also tailor-made for quantum holography and teleportation. Quantum holography conceptualization inspires much more detailed views about how biosystems process information and how this information becomes conscious.

1 Introduction

One of the basic problems faced by the quantum theories of consciousness is to understand how macroscopic quantum coherence in the brain is realized. Bose-Einstein condensates and coherent states are believed to be crucial in this respect but the great problem is how macroscopic quantum phases could be realized in the wetty, noisy and hot environment provided by brain. In TGD framework the notion of many-sheeted space-time provides a solution to this basic problem. Furthermore, the notion of self as a subsystem able to remain un-entangled is consistent with the fact that macroscopic quantum phases behave like quantum particles. The general views about macroscopic quantum phases predicted by TGD and about their role with regards to consciousness is described in previous chapters. This chapter is devoted to coherent and Bose-Einstein condensed photons which are crucial in the quantum models of brain consciousness relaying on microtubules and seem to be associated with linear structures also in TGD framework. These linear structures include not only microtubules but also axons, DNA and proteins and most of the considerations to follow are quite general and by no means restricted to microtubules.

1.1 Massless Extremals And Quantum Antenna Hypothesis

The purpose of this chapter is a more detailed formulation of the quantum antenna hypothesis stating that microtubules generate a macroscopic coherent state of photons. The so called massless extremals are a very general class of zero action non-vacuum extremals of both the Kähler

action and the effective action and differentiate clearly between TGD and standard gauge theories, in particular QED. Massless extremals describe the propagation of massless gauge fields in single preferred direction. The polarization for given values of transversal coordinates has a fixed direction. Linear superposition is not possible.

Topological field quantization assigns to each quantum notion its classical counterpart and a very attractive identification of the massless extremals is as the classical counterparts of massless classical quanta such as photons and gravitons. Even the classical counterparts of the virtual particles make sense: in particular, negative energy photons represented by annihilation part of the free photon field seem to have geometric representation as negative energy massless extremals.

Massless extremals (ME) of the effective action can indeed generate coherent states of photons and gravitons.

1. ME:s are characterised by light like vacuum Kähler current J_K. In general but not always this implies light-like em current J_{em} and the standard coupling to the quantized photon field generates a coherent state of photons.

2. The geometry of the 3-surface in question is most naturally cylindrical and microtubules (as also DNA, proteins, etc..) indeed possess this kind of geometry. There are sharp resonances at frequencies $\omega = n2\pi/L$, where L is the length of the cylindrical 3-surface (say a space-time sheet associated with a microtubule). The BE condensates for the resonance frequency photons provide means of communication for the neuron society and could orchestrate microtubules to form a single macroscopic quantum system. One could also consider the possibility that nerve pulse patters are coded to vacuum currents and in turn coded to patterns of coherent photons. In fact, the model of memetic code leads to the identification of nerve pulse/no nerve pulse as Boolean statement true/false. The coding of the nerve pulse patterns to the patterns of vacuum currents of axonal microtubules could occur naturally. The vacuum currents associated with the radial neuronal microtubules could communicate nerve pulse patterns to cell nucleus and the effects of the anesthetics on neuronal microtubules could mean the cutting of this communication line.

A necessary condition for the macroscopic quantum coherence is the phase locking of the vacuum currents associated with different microtubules. Join along boundaries bonds connecting the massless extremals to a larger space-time sheet serving as a common pacemaker could make possible the phase locking.

1.2 Evidence

This picture suggests that microtubules could act as senders and receivers of a coherent light and that visual consciousness should be closely related with the microtubules in accordance with the general philosophy already described. There is indeed some experimental support for identifying the coherent states of photons as associated with vision. It is known that some monocellulars possess elementary vision based on the microtubules [I4]. The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. Insects are known to perceive certain chemical compounds (such as pheromones) by the maser like emission of infrared light by these chemical compounds [I9]. Also human nose contains so called vomeronasal organ which seems to give rise to an additional unconscious sense of odors with social and sexual meaning. Interesting hypothesis is that also this vision is based on infrared vision.

There is quite unexpected connection with the phenomenon of sonoluminescence suggesting that liquids contain structures of size of order microtubule diameter and that the highly synchronized light flash emitted in the sonoluminescence results from the condensation of water vapor to liquid involving generation of $k = 149$ space-time sheets from $k = 151$ space-time sheets by p-changing phase transition and subsequent creation of light-like vacuum currents at almost empty $k = 151$ space-time sheets leading to the emission of the flash of coherent light.

An additional support for the quantum antenna hypothesis comes from the quite recently observed anomalous dissociation of water molecules to hydrogen and oxygen in room temperature in presence of catalyst and stirring of the liquid. Usually the reaction is driven by thermal photons at temperature of order 3300 K. A possible explanation is that the Z^0 magnetic flux tubes created

by the rotating nuclear Z^0 charge are accompanied by space-time sheets carrying light like vacuum currents generating coherent photons, which in turn drive the dissociation reaction.

Biefeld-Brown effect is one of the oldest poorly understood anomalous effects [H1, H2, H3]. What happens is that charged capacitor gains center of mass momentum in the direction orthogonal to the plane of the capacitor plates. Antigravity effect caused by the redistribution of gravitational and/or Z^0 fluxes of the capacitor between various space-time sheets could explain some aspects of the effect. The generation of negative energy space-time sheet with net momentum associated with classical em fields could be also involved with the effect. So called "massless extremals" are optimal candidates for this purpose. This mechanism might be applied by bio-systems to generate coherent motions.

1.3 Quantum Antenna Hypothesis And Brain Consciousness

The identification of macroscopic quantum phases possibly serving as quantum correlates of some qualia does not yet help much in understanding brain consciousness. Brain as a neuron society, brain as a music instrument or even entire orchestra and the notion of neural window are metaphors which have served as guidelines in the attempts to guess the general architecture of brain consciousness and might help also the reader to better understand the considerations to follow.

1.3.1 Brain as a neuron society metaphor

The brain as a society of conscious neurons metaphor has surprisingly nontrivial consequences. In particular, a plausible and testable hypothesis for the physical correlates of the sensory qualia becomes possible.

1. Brain as a society of conscious neurons metaphor suggests that our sensory qualia must have a reduction to the neuronal level. For instance, this could mean that our sensory experiences correspond to the sensory experiences associated with the large coherently firing neuron gap junction connected neuron groups in brain.

2. Conscious neurons must be able to communicate their conscious experiences to their fellow neurons. The simplest manner to achieve this is to regenerate the original sensory experience to be communicated by sending a message which creates the stimulus resembling the stimulus giving rise to the original sensory experience.

An attractive idea is that the massless extremals (MEs) associated with the microtubules and other linear structures are for the neuron society what radio receivers and stations are for us. Perhaps the idea about the information society at neuronal level does not look so far fetched if one recalls that a communication based on the genetic code takes place already at DNA-protein level. Furthermore, if Nature has invented a communication by means of a coherent light, it probably has invented also the use of several bandwidths by using several microtubule lengths so that very sophisticated communication systems could exists in brain.

Brain as a society of neurons hypothesis has close relationship to other hypothesis with very similar content. Global workspace hypothesis [J3] states essentially that mass media type communication available for large numbers of neurons plays crucial role in the functioning of conscious brain: coherent light is ideal for this purpose. Also brain as hologram idea [J9, J8]. which is abstracted to neuronal window idea in TGD framework, states that some kind of mass media type communication occurs.

1.3.2 The notion of neural window

The idea of neural window suggests that secondary sensory organs see either the classical em field or the coherent light generated by the mind-like space-time sheets representing the objects of the perceptive field, which can be associated with the primary sensory organ or with the secondary sensory organs in thalamus and cortex. This secondary vision, which could make possible imagination in or all sensory modalities, would be made possible by the coherent photons suffered Bose-Einstein condensation on space-time sheets associated with microtubules or with axons (several space-time

sheets might be involved) and serving as wave guides. Massless extremals allow to translate the notion of neural window to the notion of quantum hologram.

1.3.3 Music metaphor

Music metaphor which states that each neuron gives rise to characteristic sensory experience like string of piano gives rise to single note, gives strong constraint on the neuronal window idea. The massless extremal associated with axon corresponds to definite axon dependent frequency. In fact, in the proposed model for the quantum correlates of the sensory qualia [K8] sensory qualia are characterized by some frequency of BE condensed photons besides a pattern of cyclotron frequencies.

A related catching metaphor is to regard groups of parallel axonal microtubules as an orchestra producing light instead of sound with various frequencies. The interior containing the light-like em current would be the instrument and the note produced by single tubule would be a superposition of the frequencies $n\omega_0$, $\omega_0 = 2\pi/L$. The Fourier spectrum of the massless extremal would define the characteristics of the instrument. Of course, in long time scales microtubule could vary its length and achieve more impressive performances than single note samba. A good candidate for the player is the microtubule surface controlling the amplitude of the quantum photon field emitted by the interior by modulating the light-like current in the interior.

1.3.4 Brain as an associative net

The previous metaphors are consistent with the basic view about brain is as associative net such that conscious associations at neural level correspond to conscious experiences of presynaptic neurons associated with the experience of the postsynaptic neuron. The experiences of given neuron is always the same and only its intensity varies so that brain is indeed like a music instrument or orchestra. The intensity of experience is coded by the pattern of nerve pulses. The hypothesis about memetic code states following things. Nerve pulse/no nerve pulse corresponds to true/false Boolean statement; the codons of the memetic code consist of 126 bits and have total duration of order .1 seconds, the duration of our cognitive sub-self; single bit corresponds to a duration of order one millisecond, the duration of nerve pulse; codons are represented by temporal sequences of cognitive neutrino pairs to which nerve pulse sequences are coded; cognitive neutrino pairs are in turn coded to conscious experiences in many-to-one manner by a unique code analogous to that coding mRNA sequences to polypeptides.

1.4 Relationship Of TGD Approach With Microtubular Approach

The role of the microtubules (for a nice introduction see [J5]) is believed to be also important for brain consciousness. In TGD framework however microtubules are only one, rather low-lying, although certainly important, level of the self-hierarchy and microtubular consciousness is not expected to correspond to our consciousness directly. In fact, the identification of our sub-selves (mental images) as "ELF selves" having as their geometrical correlates topological field quanta of em field with size of Earth, supported by various experimental data about the effects of ELF (extremely low frequency) em fields on brain and correlating our sub-selves with certain EEG frequencies, could not be philosophically farther from the reductionistic identification of microtubules as seat of our consciousness proposed by Penrose and Hameroff [J11].

Fröhlich condensates [I5] and microtubular Bose-Einstein condensates of photons have been proposed as the relevant macroscopic quantum phases in the microtubular theory of consciousness. Also in TGD framework macroscopic quantum phases are crucial and serve as quantum correlates of sensory qualia. The basic problem of these theories is how to preserve macroscopic quantum coherence over a time interval of order .1 seconds characterizing our consciousness. In In TGD framework the wake-up time of the microtubular selves (time which they are able to stay p-adically unentangled) of about 10^{-16} seconds typically, is not a problem since microtubular selves are not our immediate sub-selves.

The notion of many-sheeted space-time allows TGD counterparts of both Fröhlich condensates and microtubular photon BE condensates as condensates associated not only with microtubules.

1. Wormhole contacts are unavoidable element of the many-sheeted space-time concept. Wormhole contacts behave in many respects like charged particles and are described by a complex order parameter and it makes sense to speak about wormhole super conductivity. The connection with Fröhlich's condensate comes as follows. Electric fields penetrate from one space-time sheet to another via wormhole contacts carrying quantized fluxes. Thus the normal component of electric field is essentially the density of wormhole charge given by the modulus squared for the order parameter of the wormhole BE condensate. Vacuum polarization of the space-time sheet amounts to the generation of wormhole BE condensates of opposite gauge flux on the two sides of the polarized space-time sheet. In a well defined sense wormhole contact order parameter is square root of the order parameter of Fröhlich condensate.

2. Living matter behaves as liquid crystal and the electret nature of liquid crystals is crucial for many-sheeted ionic flow equilibrium since the weak but coherent electric fields make possible ohmic currents at atomic space-time sheets transforming to supra currents at superconducting space-time sheets.

3. Vacuum gauge fields with non-vanishing gauge currents are a generic phenomenon in TGD and not possible in standard theories. These c-number currents automatically generate quantum coherent states of photons and gravitons via their coupling to the corresponding quantized boson fields. Massless extremals are ideal in this respect since the generation of coherent photons by the light-like vacuum current occurs resonant like manner. Very importantly, massless extremals allow BE condensates of photons in the direction of the light-like vacuum current. This means that massless extremals can serve both as receiving and sending quantum antennae.

1.5 MEs And Information Molecules

The notion of information molecule is central for the understanding of biological control. There are however several difficult questions related to the notion of information molecule. TGD inspired view about biocontrol and coordination suggests a general answer to these questions and leads to a general model of biological control based on both MEs and information molecules with massless extremals (MEs) serving as actual information carriers initiating self-organization processes whereas information molecules are in the role analogous to that of computer password.

1.6 MEs And Quantum Holography

One can generalize the original solution ansatz for MEs by introducing what might be called local light cone coordinates for M^4_+. Boundary conditions for MEs are satisfied if the boundaries of MEs are light-like 3-surfaces, and thus have the same miraculous conformal properties as the boundary of the future light cone. In fact, the light-likeness of the boundaries of M^4 like space-time sheets provide a universal manner to satisfy boundary conditions for field equations.

The superconformal and super-symplectic symmetries can be used to generalize the construction of the configuration space geometry to take into account the classical non-determinism of Kähler action. Quantum holography in the sense of the quantum information theory allows to interpret MEs both as receiving and sending quantum antennae as well as dynamical holograms with light-like vacuum currents defining the counterpart of the diffraction grating, and making possible the teleportation of quantum em fields. The superconformal and super-symplectic symmetries, which commute with Poincare symmetries apart from quantum gravitational effects, makes the boundaries of MEs natural seats of super-symplectic representations, and since these states are genuine quantum gravitational states defined by statefunctionals in the "world of classical worlds", they are expected to be crucial for understanding higher level consciousness.

MEs induce supra currents in superconducting magnetic circuits by magnetic induction mechanism, serve as Josephson junctions between magnetic flux tubes, and induce magnetic quantum phase transitions. MEs can generate reference waves or their phase conjugates (time reversals) acting on lower level MEs serving as dynamical holograms. The induced coherent light pattern would act as a control command or its time reversed version. Conjugate reference waves could provide an extremely simple basic mechanism of healing by time reversal allowing the living matter to fight against second law. MEs could read DNA strand to the light-like vacuum current by drifting along

it and thus code DNA strand/conjugate strand to a hologram or its phase conjugate in turn acting as a control command or its time reversal. Thus living matter could be regarded as a symbiosis in which MEs control superconducting magnetic flux tubes controlling ordinary matter at atomic space-time sheets via many-sheeted ionic flow equilibrium. DNA would represent the ROM of this system.

1.7 MEs And The Notion Of Conscious Hologram

The notion of conscious hologram is the last step in the development of ideas related to biholograms. The basic challenge is to generalize the notion of the ordinary hologram to that of a *conscious* hologram, about which bio-holograms would be examples. The notion of quantum gravitational hologram is defined at the level of geometric, purely physical existence whereas conscious holograms exist at the level of subjective existence defined by the sequence of quantum jumps and giving rise to the self hierarchy. Of course, these two notions of hologram must be closely related.

The notion of conscious hologram combines the saint and sinner aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition on the other hand.

In nutshell, the notion of conscious hologram follows from the topological field quantization. Classical fields and matter form a Feynman diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules,...), and virtual bosons are replaced by topological light rays ("massless extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to "real photons" are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by "virtual photon" MEs also analogous to laser beams. Hence also "self-holograms" with no laser beam from external world are possible (brain without sensory input).

The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as massless particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length. The particle like high frequency MEs induce "bridges" between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. Under certain conditions the leakage followed by dropping back to the larger space-time sheet can also give rise to a many-sheeted laser. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competion.

The 3-D vision associated with ordinary holograms generalizes to stereo consciousness resulting in the fusion of mental images associated with the points of conscious hologram [K2].

1.8 Negative Energy MEs And Bio-Control

Negative energy MEs correspond to space-time sheets with a reversed time orientation. These MEs serve as correlates for bound state entanglement. Low frequency negative energy MEs can contain inside them high frequency MEs propagating along them like negative energy particles. The possibility to quantum jump to a higher energy state by generating negative energy ME gives rise to the pay now-let others pay mechanism of metabolism. This quantum credit card mechanism makes the functioning of the living system extremely flexible. The fact that ELF MEs play an important role in living matter forces to consider the possibility of remote metabolism and the transfer of metabolic energy even in the length scale of Earth (7.8 Hz frequency corresponds to

Earth's circumference). The small energy dissipation related to "our" consciousness could perhaps help to solve "brain's energy crisis" [J2] raised by the puzzling observation that the human brain plus body as a whole does not use more energy than smaller brained mammals with a similar body size.

Negative energy MEs are optimal for the realization of intentions. First p-adic ME transformed to a negative energy ME is generated and serves as a geometric correlate of intention. Then quantum jumps of a real system to a higher energy state occurs and in this quantum jumps p-adic ME is transformed to a negative energy ME to take care of the conservation laws.

Right and left brain hemispheres could have different arrows of the geometric time at appropriate p-adic time scales. For instance, negative energy MEs would make possible quantum communications to the direction of the geometric past. The model of non-episodal memory call would involve quantum communication of the question to the geometric past (time-like entanglement and sharing of mental images), and a classical (dissipative) communication of the answer to the geometric future. Negative-positive energy dichotomy could be be realized in an extremely wide range of time scales and to explain, besides the basic mechanism of long term memory, also precisely targeted realization of intentions, sensory-motor dichotomy, and biocycles as dissipation-healing cycles.

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form. The hypothesis that Planck constants in CD (causal diamond defined as the intersection of the future and past directed light-cones of M^4) and CP_2 degrees of freedom are dynamical possessing quantized spectrum given as integer multiples of minimum value of Planck constant [K6, K5] adds further content to the notion of quantum criticality.

After several alternatives I ended with the conjecture that the value of $\hbar$ is in the general case given by $\hbar = n \times \hbar_0$. Integer n characterizes a sub-algebra of super-symplectic algebra or related algebra with conformal structure characterized by the property that conformal weights are n-multiples of those of the full algebra. The sub-algebra is isomorphic with the full algebra so that a fractal hierarchy of sub-algebras is obtained. One obtains an infinite hierarchy of conformal gauge symmetry breaking hierarchies defined by the sequences of integers n_i dividing n_{i+1}.

The identification in terms of hierarchies of inclusions of hyper-finite factors of type II_1 is natural. Also the interpretation in terms of finite measurement resolution makes sense. As n increases the sub-algebra acting as conformal gauge symmetries is reduced so that some gauge degrees of freedom are transformed to physical ones. The transitions increasing n occur spontaneously since criticality is reduced. A good metaphor for TGD Universe is as a hill at the top of a hill at the top.... In biology this interpretation is especially interesting since living systems can be seen as systems doing their best to stay at criticality using metabolic energy feed as a tool to achieve this. Ironically, the increase of $\hbar$ would mean increase of measurement resolution and evolution!

The only coupling constant of the theory is Kähler coupling constant $\alpha_K = g_K^2/4\pi\hbar$, which appears in the definition of the Kähler function K characterizing the geometry of the configuration space of 3-surfaces (the "world of classical worlds"). The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed value of $\alpha_K = g_K^2/4\pi\hbar$ should be analogous to critical temperature and determined by quantum criticality requirement. There are two possible interpretations for the hierarchy of Planck constants.

1. The actual value of $\hbar$ is always its standard value and value of $\alpha_K = g_K 2/4\pi\hbar$ is always its maximal value $\alpha_K(n = 1$ but there are n space-time sheets contributing the same value of Kähler action effectively scaling up the value of $\hbar_0$ to $n\hbar_0$ scaling down the value of $\alpha_K(1)$ to $\alpha_K(1)/n$. The n sheets would belong to n different conformal gauge equivalence classes of space-time surfaces connecting fixed 3-surfaces at opposite boundaries of CD. This interpretation is analogous to the introduction of the singular covering space of imbedding space.

   One can of course ask whether all values $0 < m \leq n$ for the number of "actualized" sheets are possible. A possible interpretation would be in terms of charge fractionization.

2. One could also speak of genuine hierarchy of Planck constants $\hbar = n\hbar_0$ predicting a genuine hierarchy of Kähler coupling strengths $\alpha_K(n) = \alpha_K(n = 1)/n$. In thermodynamical analogy zero temperature is an accumulation of critical temperatures behaving like $1/n$. Intriguingly,

in p-adic thermodynamics p-adic temperature is quantized for purely number theoretical reasons as $1/n$ multiples of the maximal p-adic temperature. Note that Kähler function is the analog of free energy. In this interpretation the n sheets are identified.

Phases with different values n behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality for the phase transition changing the value of n to its multiple or divisor. In large $\hbar(CD)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence.

Number theoretic complexity argument favors the hypothesis that the integers n corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, might be favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale.

Contrary to the original hypothesis inspired by the requirement that gravitational coupling is renormalization group invariant, α_K does not seem to depend on p-adic prime whereas gravitational constant is proportional to L_p^2. The situation is saved by the assumption that gravitons correspond to the largest non-super-astrophysical Mersenne prime M_{127} so that gravitational coupling is effectively RG invariant in p-adic coupling constant evolution [K17].

$\hbar(CD)$ appears in the commutation and anti-commutation relations of various superconformal algebras. Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of Planck constants coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

A further great idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

TGD thus predicts an infinite hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter and each other [K7] and the value of $\hbar$ is only one characterizer of these phases. These phases, especially so large $\hbar$ phase, seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics [K7, K13, K5]. This strengthens the motivations for finding whether dark matter might be involved with quantum critical superconductivity.

Cusp catastrophe serves as a metaphor for criticality. In the case of high T_c superconductivity temperature and doping are control variables and the tip of cusp is at maximum value of T_c. Critical region correspond to the cusp catastrophe. Quantum criticality suggests the generalization of the cusp to a fractal cusp. Inside the critical lines of cusp there are further cusps which corresponds to higher levels in the hierarchy of dark matters labeled by increasing values of $\hbar$ and they correspond to a hierarchy of subtle quantum coherent dark matter phases in increasing length scales. The proposed model for high T_c super-conductivity involves only single value of Planck constant but it might be that the full description involves very many values of them.

1.8.1 MEs and dark matter hierarchy

MEs can be regarded as space-time correlates for a hierarchy of particles characterized by different values of Planck constant and the de-coherence phase transition would naturally correspond to the decay of MEs to smaller space-time sheets. Single sheeted MEs correspond to fermions and their super partners and topologically condensed CP_2 type vacuum extremals representing particles

involve only single wormhole throat carrying the quantum numbers. Double sheeted MEs connected by wormhole contacts correspond to bosons and their super-partners with the throats of wormhole contacts carrying the quantum numbers. The two sheets have opposite arrow of time and signs of energies.

The ordinary laser light cannot be regarded as a large $\hbar$ phase, which de-coheres to ordinary photons before the interaction with ordinary matter. Very general consistency arguments lead to the working hypothesis that dark matter and dark MEs correspond to λ^k-fold ($k > 0$) coverings of CD (causal diamond) locally ($\hbar(k) = \lambda^k \hbar_0$, $\lambda = 2^{11}$) whereas ordinary laser light would correspond to $k = 0$.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [**?**].

2 Massless Extremals

The so called massless extremals are very general solution of field equations associated with the minimization of Kähler action parameterized by several arbitrary functions. The characteristic feature of the massless extremals is the presence of light-like currents generating coherent states of photons and gravitons. These features suggest that massless extremals might have important role in bio-systems.

2.1 Massless Extremals As General Solutions Of Field Equations

Let $k = (k^0, k^3, 0, 0)$ be a light like vector of M^4 and $u = u(m^1, m^2)$ arbitrary function of the Minkowski coordinates m^1 and m^2 in the plane orthogonal to the direction of the 3-vector $(k^3, 0, 0)$ associated with k. The surfaces defined by the map

$$s^k \quad = \quad f^k(k \cdot m, u) \ , \tag{2.1}$$

where f^k and u are arbitrary functions define massless extremals. They describe the propagation of massless fields in the direction of k: the fields are periodic with a period $\lambda = 2\pi/k$ so that only k and its integer multiples are possible wave vectors. The polarization associated with various induced gauge fields depends on the position in (m^1, m^2)-plane and is in the direction of the gradient of u. Field equations involve tensor contractions of the energy momentum tensor and gauge current but these are proportional to kk and k respectively and vanish by the light-likeness of k. Linear superposition holds true only in a restricted sense since both the propagation direction and the polarization direction in each $(m^1, m^2) = const$ plane is fixed.

What is remarkable that these solutions are not solutions of the ordinary Maxwell equations in vacuum: Kähler current density J_K is in general non-vanishing(!) and proportional to the light like four-momentum k. As a consequence, also a light-like electromagnetic current is in general (but not necessarily) present. The interpretation of the em current J as charged elementary particle current is impossible and the correct interpretation as a vacuum current associated with the induced gauge fields. The finite length of the microtubule plus the requirement that the total vacuum charge vanishes, implies that the Fourier decompositions of the massless fields contain only integer multiples of the basic four-momentum k. The direct detection of the light-like vacuum current inside a microtubule would provide strong support for TGD.

The physical importance of these extremals is suggested by the fact they are in certain sense elementary particle like objects: in fact, the original interpretation was as a model for the exterior space-time of a topologically condensed massless particle. The solution set is also very general involving several arbitrary functions. Although the minimization of the Kähler action favors the formation of Kähler electric fields, massless extremals might well appear as space-time sheets of the effective space-time. These space-time sheets should not contain ordinary charges since their presence implies a transition to the Maxwell phase described in an excellent approximation by the ordinary Maxwell electrodynamics.

Rather remarkably, massless extremals are also solutions of the field equations associated with the low energy effective action. This holds true in the absence of the topologically condensed matter, phenomenologically described using external currents. For instance, the term

$$(T^{\alpha\beta}_{\#} - \frac{1}{16\pi G}G^{\alpha\beta})D_\beta\partial_\alpha h^k \quad ,$$

where # refers to the topologically condensed matter, reduces to

$$\frac{1}{16\pi G}G^{\alpha\beta}D_\beta\partial_\alpha h^k \quad ,$$

and vanishes identically because Einstein tensor is light like so that contraction with the second fundamental form vanishes. The vanishing of these terms in presence of matter is not possible since the gauge currents and energy momentum tensor associated with the topologically condensed matter are not light-like. Thus massless extremals correspond to vacuum space-time sheets with respect to the ordinary matter. Massless extremals can however interact with the ordinary matter via # contacts.

The fact that vacuum em current and vacuum Einstein tensor do not in general vanish, implies that massless extremals serve as sources of coherent photons and gravitons. It is not very economical to maintain BE condensates all the time. In "dormant" states microtubules could correspond to ME: s with vanishing em fields but non-vanishing Z^0 fields or even vacuum extremals of the effective action with one-dimensional CP_2 projection and having vanishing classical gauge fields. Massless extremals can also reduce to vacuum extremals of the Kähler action in the case that the CP_2 projection is, in general two-dimensional, Legendre manifold of CP_2. Also in this case massless extremals are however non-vacuum extremals of the effective action.

2.2 About The Electro-Weak And Color Fields Associated With Massless Extremals

Space-time sheets carrying em fields carry usually also Z^0 and W fields and it is not possible to speak about em or Z^0 type MEs. It is however possible to speak about neutral and W MEs. The CP_2 projection of ME is 2-dimensional and in a special case it reduces to a geodesic sphere. There are two kinds of geodesic spheres in CP_2.

1. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

   $$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \quad .$$

   The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

2. For homologically trivial geodesic sphere a standard representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

The MEs corresponding to these two geodesic spheres could be called neutral and W MEs and they carry color fields for which the color group $SU(3)$ reduces to some of its $U(1)$ subgroups. Quite generally, the holonomy algebra of color group is Abelian since the induced color field is of the form $g^A_{\alpha\beta} \propto H^A J_{\alpha\beta}$, where H^A denotes color Hamiltonian.

Neutral MEs are excellent candidates for mediating EEG type communications from the biological body to the magnetic body whereas charge entanglement induced by W MEs would be ideal for the realization of motor actions of the magnetic body by generating first superposition of exotically ionized states of atomic nuclei entangling magnetic and biological body [K4]. State function reduction would lead to an exotically ionized state accompanied by dark plasma oscillation

pattern. By Faraday law this pattern would induce electric fields at the space-time sheets containing ordinary matter which in turn would generate ohmic currents leading to various physiological effects.

MEs are excellent candidates for the space-time correlates of laser beams. Dark matter hierarchy implies that also MEs can be classified by the level of the dark matter hierarchy involved. A very general argument leads to the conclusion that dark space-time sheets, in particular MEs, at the k^{th} level of the dark matter hierarchy correspond to space-time sheets defining λ^k-fold coverings of M^4 (recall that one has $\hbar(k) = \lambda^k \hbar_0$ and $\lambda \simeq 2^{11}$) [K15, K4]. $k = 0$ MEs would correspond to the ordinary laser light.

2.3 How Massless Extremals Generate Coherent States Of Photons?

ME: s can be in "dormant" or active state according to whether the em current associated with the ME is vanishing or not. In active state ME: s generate Bose Einstein condensate type state for ordinary photons. This means in TGD context the emission of (topological) vapor phase photons (CP_2 type extremals), which can condense on other condensate levels. ME: s generate gravitonic BE condensate and the possible biological role of this condensate will be discussed later.

Assuming that the coupling of quantized photon field to the massless extremal is given by regarding the massless extremal as a classical background field one obtains QED with a light like source J^α:

$$\begin{aligned} D_\beta F^{\alpha\beta} &= eJ^\alpha \ , \\ J^\alpha &= Jk^\alpha \ . \end{aligned} \tag{2.2}$$

The system is equivalent with an infinite number of harmonic oscillators each driven by a harmonic external force and a basic exercise in the quantum mechanics shows that the solutions of the field equations give the new oscillator operators as sums of free oscillator operators plus c-number term, which is essentially the Fourier component of the light like current in the direction of the polarization.

In the limit that ME has infinite duration and is a cylindrical structure of finite length L (that is microtubule) one has for $J \propto sin(k_z(t-z))$

$$\begin{aligned} a^\dagger(p) &\rightarrow a^\dagger(p) + g(p) \ , \\ g(p) &= \sum_n \delta(p^0, k_n^0) K(p, k_n) J(k_n^z, p_T) \ , \\ K(p,k) &= \epsilon(p) \cdot k \frac{1}{i(p_z - k_z)} (exp(ip_z L) - 1) \ , \\ k_n &= nk_0 = \frac{n2\pi}{L}(1,1,0,0) \ . \end{aligned} \tag{2.3}$$

Here p denotes the momentum of the photon and k the 4-momentum associated with the Fourier component of a light-like current. $\epsilon(p)$ denotes the polarization of the photon. $J(k_n^z, p_T)$ is essentially the 3-dimensional Fourier transform of the scalar function J. The infrared behavior of $J(k_z, p_T)$ as a function of the transversal momentum p_T can be deduced from the fact that the transverse dimension of the microtubule is small (about 25 nm) as compared to $1/p_T$ so that the Fourier component is in good approximation independent of p_T.

For the frequencies present in the Fourier decomposition of the massless extremal, the ordinary oscillator vacuum is transformed to a coherent state in the corresponding Fourier mode of the quantized photon field. The essential point is that the wave vectors of the radiation field and massless extremal are nonorthogonal. The radiation pattern resembles the ordinary antenna pattern associated with an oscillating current $J(t) = exp(i\omega t)$ in that the intensity of radiation vanishes at angles $\theta = \pi/2$ and $\theta = 0$. For $J \propto sin(k_z(z-t))$ $|K|^2$ has maxima for $\theta = 48.6$ degrees and 131.4 degrees. For an ordinary dipole with $J = sin(\omega t)$, $\omega = 2\pi/L$ the radiation pattern is concentrated at angles $\theta \geq 40$ degrees with maximum and 69.3 degrees and 110.7 degrees.

A more complicated situation corresponds to a group of several massless extremals (say microtubules). If massless extremals are parallel and have same length the previous expression generalizes with superposition of terms

$$g(p) \quad \rightarrow \quad \sum_n exp(i\phi_n)exp(ip_z z_n)exp(ip_T \cdot x_T)g_n(p) \quad . \tag{2.4}$$

The phase ϕ_n is the phase difference between n: th light like current with respect to some reference current. If the positions of microtubules and/or phases of the individual light like currents are suitably chosen then various terms interfere constructively and macroscopic quantum coherence is obtained at resonant frequencies. Suffice it so say that the needed timing is extremely accurate: less than 10^{-12} seconds! Since p_z is small rather larger transversal distances are allowed by the requirement of constructive interference. In a more general situation also the orientations of microtubules can vary in certain limits. Note that light-like energy momentum generates also gravitonic BE condensates at preferred frequencies.

2.4 Massless Extremal Is Accompanied By A Bose-Einstein Condensate Of Parallel Photons

The interaction Lagrangian describing the interaction of photon field with the light-like vacuum current does not couple to the photons collinear with the vacuum current (light-like wave vector has vanishing length squared). Therefore the ground states of the system are degenerate since one can add to any coherent state generated by the vacuum current any number of photons collinear with the vacuum current and topologically condensed inside the massless extremal. This means Bose-Einstein condensation in collinear degrees of freedom.

Collinear Bose-Einstein condensates of photons are crucial for the model of the quantum correlates of the sensory qualia. Sensory quale is characterized partially by the BE condensate of photons associated with the massless extremal parallel to the axon. The existence of the BE condensate makes possible induced emission. For instance, Josephson currents generate photons with frequencies which are multiples of the Josephson frequency. If the potential difference in Josephson junction equals to a multiple of the cyclotron frequency of some super conducting ion, the current flows resonantly in the sense that Josephson current serves as a harmonic perturbation generating quantum jumps and gives rise to a large dissipative current and also quantum jumps in either super conductor. Since the emission rate for photons by the current is proportional to N^2, where N is the number of photons already in the state, the presence of the BE condensate of photons with this frequency amplifies the emission rate. This kind of resonance mechanism is assumed in the model of sensory experience since it elegantly explains why given neuron corresponds to single quale. Since the potential difference over the Josephson junction can correspond to only single cyclotron frequency, the dominance of single quale is unavoidable even when all macroscopic quantum phases are present.

The existing BE condensate increases the probability of topological condensation of coherent photons generated by other massless extremals to the massless extremal. This mechanism could provide inter-neuronal communication mechanism and realize the metaphor about brain as a society of neutrons, the notion of neuronal window idea and also give a more precise content to the music metaphor. In particular, neurons far away from each other could communicate using wavelengths in a narrow wave length range by this mechanism.

The wave vectors of the photons are multiples of $k = \pi/L$. This means that the length of the massless extremal correlates with the maximal allowed wavelength. For ELF photons associated with EEG frequencies of order 10 Hz the length of massless extremal is of order Earth's circumference. This suggests that more general massless extremals with a topology of torus instead of linear topology could characterize the topological field quanta of ELF fields. It is however impossible to say, whether the field equations allow more general solutions resembling massless extremals.

2.5 MEs and apparent breaking of Uncertainty Principle

There is a popular article in Science alert (see `http://tinyurl.com/ybm9gcvu`) about finding that light can be squeezed to much smaller volume than the wave length in dimensions transversal to

the wave-length by using single-sheeted graphene. The original article by David Alcaraz Aronzo et al is published in Science [D2] (see `http://tinyurl.com/ya8u54ax`). A naive application of Uncertainty Principle suggests that this is impossible since this would mean a very large expectation value of momentum squared in transverse momentum degrees of freedom.

The finding is interesting from the point of view of classical limit of TGD. So called massless extremals (MEs) or topological light rays [K1, K16, K10] are extremely general solutions of field equations (practically independently of the details of the action principle: it is enough that it is general coordinate invariant). The counterparts of MEs are not possible in Maxwellian electrodynamics but TGD allows them because of the extreme non-linearity of the underlying geometric variational principle for which the topological pair of Maxwell's equations involving no currents is identically satisfied.

2.5.1 What MEs are?

MEs are 4- surfaces describing the propagation of massless topological field quanta of induced classical fields characterized by light-like propagation direction and polarization orthogonal to it. Classical 4-momentum is light-like. The propagation occurs with a maximal signal velocity, and there is no dispersion so that the pulse shape is preserved. If there are several pulses they must propagate in the same direction. The propagation of a laser beam in waveguide serves as an analogy. MEs are be ideal for targeted communications and MEs associaged with magnetic flux tubes and carrying dark photons assignable with wormohole contacts play a key role in TGD inspired quantum biology. A possible interpretation is as space-time correlates Bose-Einstein condensate of photons. Photons themselves would correspond to wormhole contacts (actually pairs of them) connecting ME to another space-time sheet, which could be magnetic flux tube or even ME.

MEs have finite size scale in directions orthogonal to the direction of propagation and MEs can be arbitrary thin. I do not see any reason why they could not be thinner than wavelength. The graphene seems to provide a situation in which classical modelling by MEs makes sense.

The QFT limit is obtained from many-sheeted space-time by replacing many-sheeted structure with a region of Minkowski space made slightly curved. Gauge potentials and gravitational fields are sums of the corresponding induced fields at space-time sheets so that the effects of these fields on a test particle sum up although fields themselves are at different space-time sheets. The linear superposition of Maxwell's theory is replaced with a set theoretic union of the space-time sheets in M_2^4. $The effects of the fields of space-time sheets on the test particle sum up just like in superposition of fields in Maxu$

For instance, this allows a situation in which one has two MEs describing propagation of signals in opposite directions as far effects on test particles are considered. This gives rise to standing waves not possible in TGD as single sheeted extremals. Lorentz transforms give analogs of em signals propagating with arbitrary velocity smaller than light velocity. Even field patterns for which the QFT limit corresponds to vanishing fields because the effects on test particles are trivial are possible: both sheets however carry non-vanishing fields with non-vanishing energy-momentum density.

2.5.2 Why the apparent breaking of Uncertainty Principle?

Why the apparent breaking of Uncertainty Principle is then possible in TGD? The point is that in TGD particles do not correspond to wavefunctions in a fixed space-time - this is true only at quantum field theory limit of TGD. Instead, they correspond to wave functions in what I call "world of classical worlds" (WCW). 3-space as "world" is in TGD replaced with 3-D surface defining the "world". In zero energy ontology (ZEO) one can identify space-time surfaces as preferred extremals of an action, which in a well-defined sense generalizes the Maxwell action for a point like charged particle. Thanks to holography the space-time surface is characterized by 2 3-surfaces at its opposite ends -initial and final 3-surfaces - located at the opposite boundaries of causal diamond (CD), whose M^4 projection is intersection of future and past directed light-cones and would look like diamond if it were 2-D. The world as 3-D surface or equivalently 4-D surface is the quantum dynamical object and space-time ceases to be a passive arena of dynamics. Uncertainty Principle holds true for wave functions in WCW rather than for induced fields at space-time surfaces. Therefore the apparent breaking of Uncertainty Principle is possible.

3 Microtubules As Quantum Antennae

3.1 Linear Structures As Quantum Antennae

The many-sheeted space-time concept of TGD indeed allows almost vacuum space-time sheets and these space-time sheets might be crucial for the understanding of the bio-systems. For instance, the weak interaction of these space-time sheets with the ordinary space-time sheets containing matter could provide representations of the external world in the physical properties of the almost vacuum space-time sheets. In particular, mind-like space-time sheets having finite time duration could generate coherent light and coherent light might make communication possible between mind-like space-time sheets and realize the idea of neuronal window discussed briefly in introduction [K3]. The mind-like space-time sheets associated with various linear structures are especially natural candidates for massless extremals serving as quantum antennae. Bio-systems are full of linear structures and the mind-like space-time sheets associated with microtubules, DNA and protein molecules are the most obvious candidates for quantum antennae.

3.2 Are Microtubules Accompanied By Massless Extremals?

The interior of the microtubule is by its cylindrical symmetry an ideal place for ME: s whereas the axonal cell membranes must correspond to "Maxwell phase", where ordinary Maxwell equations are satisfied in a good approximation but also a separate space-time sheet is possible candidate for a massless extremal. The function $u(x, y)$ appearing in the general solution is most naturally $u(x, y) = \sqrt{x^2 + y^2}$ for microtubules implying radial polarization. The explanation of the macroscopic quantum coherence in the brain would provide crucial support for the TGD based world picture since massless sources and vacuum currents are not possible in the ordinary QED.

There is analogy with the super radiance phenomenon [J6]: in this case however the photons radiated by the microtubule waveguide have momenta parallel to the microtubule so that the mechanism leading to the formation of the macroscopic BE condensate remains to be understood. The theories associating coherent photons with the microtubules typically assume that the coherent photons reside inside the microtubules: this leads to problems since Uncertainty Principle; the direct study of Maxwell equations also suggest that photons should have very large transversal momenta corresponding to the transversal dimension of the microtubule of order 10^{-8} meters. In TGD this difficulty is avoided since only the *sources* of the coherent photons are restricted into the interior of microtubules whereas the photons can exists in vapor phase and condense on various space-time sheets of the topological condensate.

The necessary condition for the formation of the coherent states in the presence of the matter is that ME condensate level does not contain ordinary gauge charges. If ME corresponds to a larger space-time sheet "below" the space-time sheet containing the ordered water, this requires that the gauge charges of the condensed matter do not flow to the interior of the ME space-time sheet. This is achieved if the condensed particles combine by flux tubes together to form a net like structure so that gauge fluxes can run along the flux tubes to the boundary of the ME region, where they can flow down to the ME condensate level. Ordered water is a good candidate for this join along boundaries/flux tube condensate. Microtubules are known to be surrounded by ordered water and also the interior contains ordered water. The axial electric polarization of the microtubular surface suggests that there is a longitudinal electric gauge flux at the condensate level of the ordered water running to/from the ME condensate level at the ends of the microtubule. The wave lengths appearing in the Fourier expansion of J are of form L/n, L being microtubule length.

In the active mode microtubule acts as a quantum antenna creating quantum coherent light unlike the ordinary antenna, which creates incoherent light. Also waveguide mode is possible for the topologically condensed photons but antenna mode is crucial for the generation of the macroscopic coherent states. The following argument suggests that he dielectric properties of the microtubule surface can change the antenna pattern somewhat. The dipoles of the microtubule are known to be parallel to the axis of the microtubule. The interaction energy of a dipole p with the radiation field is proportional to the quantity $p \cdot E = pEcos(\theta)$ so that the effect of the dielectric is largest, when the wave vector of the photon is orthogonal to the axis of the microtubule. As a consequence, the dipole pattern should concentrate in the forward direction.

The em current in the interior transforms ordinary QED vacuum to a coherent state in the

resonating Fourier modes of the photon field. In ME mode the resonance energies come as multiples of $E_0 = 2\pi/L$ and wavelength L/n, where L is the length of the microtubule whereas in VE mode the spectrum is continuous. Biophotons [I8] with energy of order one eV might be regarded as evidence for BE states associated with the shortest microtubules (such as centriole and basal bodies). The average length of the neuronal microtubules is about 10^{-5} m and corresponding IR radiation is more energetic than thermal IR radiation with a wavelength of order 10^{-4} m.

In the ME mode the resonances at energies $E_n = nE_0$, $E_0 = 2\pi/L$, provide ideal communication channels. Microtubules with different lengths provide independent communication channels so that very effective communication in principle becomes possible. This process could orchestrate axonal microtubules as well as the microtubules belonging to different neurons to form a larger macroscopic quantum state. An optimal performance is obtained if the microtubules belonging to same group are parallel and their lengths are quantized with a common multiple. The microtubules of the neighboring neurons indeed tend to be parallel. Axonal microbutules are also parallel whereas the microtubules inside the ordinary cells are in radial configurations. The grey matter in brain has a columnar structure so that axonal microtubules tend to be in the direction of the columns: this should favor the formation of a quantum resonance between different microtubules. Furthermore, the model of [I1], described in Tuscon II, for the microtubule interactions predicts that the microtubules of even far away neurons are parallel. The average length of the neuronal microtubules is about 10^{-5} m and it is known that the response of 3T3 cells to weak IR radiation is maximum at this wavelength. Neurons could be able to tune their microtubules to the desired infrared stations by controlling their orientation and length. The upper bound about 10^{-4} meters for the length of the axonal microtubules can be understood: for the longer microtubules the thermal IR radiation becomes important and makes communication impossible. In long axons this problem is avoided by joining shorter microtubules in series via Microtubule Associated Proteins (MAPs).

Since the time scale for the change of the tubulin polarization is of order 10^{-10} seconds and the period of the IR radiation is of order 10^{-13} seconds, amplitude modulated IR transmissions are possible. The mechanism of the amplitude modulation could be simply a change of the microtubule interior gauge field from active to dormant ME mode. Amplitude becomes vanishing if this field becomes ordinary sourcefree em field or Z^0 field. IR transmissions could be based on some kind of binary code resembling genetic code. There is indeed concrete proposal of Koruga for this code motivated by the geometric structure of the microtubule surface. [I2] , [J5]. One possibility is that the propagating modes of dipole and conformational oscillations perform elementary AM modulations. These modes could correspond to elementary language expressions at the level of the microtubules.

Microtubules can also absorb photons coming from an external source at resonance energies. If Bose-Einstein condensate of N photons in some mode is present, the absorption probability is amplified roughly by the factor N^2 as shown in appendix. This suggests that microtubules containing BE condensate of photons in some mode are able to "see" in some elementary sense. Of course, receiving antenna containing the BE condensate need not be microtubule. Centrioles (T shaped pair of microtubules inside animal cells) could provide cell with infrared eye and there is experimental evidence for this in the case of monocellular organisms [I4]. Also the radial microtubules could have elementary sense of vision. Note that all eukaryotic cells have radial structure of microtubules in their cytosceleton.

3.3 How Macroscopic Quantum Coherence Is Generated?

The big problem is the creation of constructive interference between the coherent states associated with different microtubules. The problem looks exceedingly difficult: microtubules should be able to tune up the frequency and phase associated with light like current inside microtubule with those of other microtubules contributing to the coherent state. Frequency tuning, or equivalently length tuning, involves time scales smaller than 10^{-13} seconds in case of infrared light associated with longest microtubules. The simplest solution to come into mind is that there exist some pacemaker keeping the microtubules in rhythm. One can imagine several mechanisms important for the tuning, each involving the special properties of the TGD space-time crucially.

3.3.1 Topological field quantization

TGD space-time surface decomposes into regions characterized by vacuum quantum numbers, which are frequencies and integers related to the time and angle dependences of the phase angles associated with the two complex CP_2 coordinates. Typically one has $\Phi = \omega t + Fourier\ expansion$ so that space-time surface vibrates with frequency ω. This vibration is an ideal candidate for a pacemaker for the physical systems inside a given space-time region. In fact, the vacuum quantum numbers characterize partially also the order parameter of a super conductor. Vacuum frequencies could also be special frequencies for the Maxwell fields.

The increased understanding about topological field quanta as classical and quantum coherence regions of em field is consistent with and generalizes this view. When topological field quanta are joined by join along boundaries bond generated in quantum jump they fuse to form a larger region of classical and quantum coherence. This suggests a general mechanism for how various axons/microtubules can generate phase coherent em fields. What is needed is that there is larger space-time sheet connected by flux tubes to the massless extremals associated with various axons/microtubules. This larger space-time sheet is most naturally the geometrical counterpart of higher level self so that consciousness is what creates synchrony rather than vice versa!

A further important aspect in the generation of synchrony is self-organization. The subsystems of self quantum self-organize and end up to asymptotic self-organization patterns selected by dissipation. These patterns are simple and typically involve spatially repeating patterns and synchronous oscillations (Benard flow is simple example of this). It is consciousness which implies synchrony and coherence whereas in standard approaches to quantum consciousness synchrony and coherence are believed to be prerequisites for consciousness.

3.3.2 Phase locking for the system of Josephson junctions

Japanese physicist Yoshiki Kuramato from the University of Kioto has shown that the solutions of the differential equations describing Josephson junctions tend to a state in which there is single collective oscillation frequency. A.T. Winfree from the University of Arizona has shown that a phase transition to single collective oscillation frequency analogous to the freezing of liquid occurs in this kind of system.

The solutions of the differential equations describing Josephson junctions model quantum self-organization and synchronization can be interpreted as an instance of the selection of asymptotic self-organization patterns selected by dissipation and occurring always in quantum self-organization. Of course, the quantum jumps can occur only provided the system of Josephson junction belongs to a system having self so that consciousness is again prerequisite for synchrony rather than vice versa! In any case, the fact that entire brain is hierarchy of space-time sheets such that the space-time sheets at various levels are connected by Josephson junctions makes this result rather encouraging.

3.3.3 Gap junctions and MAPs

As noticed, the formation of the join along bonds is the basic prerequisite for the formation of the macroscopic quantum systems. The so called gap junctions can be regarded as flux tubes between the cell membranes (understood as 3-surfaces in TGD picture) of the neighboring cells. They could have a key role in synchronous firing of neuron groups. Gap junctions could also force the vacuum quantum numbers of the neighboring cell membranes to be identical as well as provide the bridges for the propagation of the Maxwell type fields between neighboring cells. It is known that the coherently firing neuron groups in brain possibly responsible for the generation of sensory experience are gap junction connected. It is not however obvious whether gap junctions have anything to do with the synchronizing of the vacuum currents: the difference between the time scales involved is indeed huge. Also Microtubule Associated Proteins could act as join along boundaries bonds/flux tubes guaranteeing quantum coherence between microtubules inside same cell.

3.4 Are Nerve Pulse Patterns Coded Into Vacuum Currents And Coherent Light?

It has turned out that TGD based model for memetic code leads to the same interpretation of nerve pulse patterns as suggested by neuroscience. Nerve pulse/no nerve pulse corresponds to true/false Boolean statement or 1/0 value of binary digit. Fundamental coding of nerve pulse patterns is the coding into temporal sequences of cognitive neutrino pairs associated with cell membrane such that the spin of the cognitive antineurino codes for true/false (1/0). Of course, bits could code also for binary digits in the binary expansion and code for the intensity of the primitive sensory experience associated with the neuron. It is natural to ask whether nerve pulse patters could be also coded to some other representations. Light-like currents are indeed optimal in this respect.

The dependence of the light-like current on the longitudinal coordinate of massless extremal is arbitrary and therefore light-like current provides ideal tool of classical communication of information with light velocity as well as coding of this information to coherent light received by other massless extremals. The first bio-application to come into mind is that the instantaneous nerve pulse patterns propagating along the axon could be coded into the pattern of the vacuum current. The velocity of propagation for the nerve pulse pattern is extremely small as compared to light velocity but this is not a problem if the coding takes place in the region where nerve pulses are generated. What happens is that same temporal pattern of pulses propagates with different velocities. This coding in turn implies coding of nerve pulses to coherent states of photons and in principle the communication of nerve pulse pattern to other neurons.

The relationship between memetic and genetic code is that between two hierarchy levels of a computer program. This suggests that nerve pulse patterns representing memetic codons could serve as transcription factors at gene level. This requires the communication of nerve pulse patters to nucleus. Even more, communication mechanism must treat different presynaptic inputs as different inputs. Modulation of the vacuum current could make possible communication of the nerve pulse patterns to the cell nucleus along the massless extremals associated with the radial microtubules which in case of neurons have direct contact with the cell membrane. The fact, that some anesthetics seem to affect microtubules and that some brain diseases involve changes of microtubules could also be explained as a breaking of the cell membrane-nucleus communication link. That this kind of communication link might exist is suggested by the fact that ELF em fields have direct efect on genetic expression [J7].

4 Masless Extremals And Information Molecules

The notion of information molecule is central for the understanding of biological control. There are however several rarely asked questions related to the notion of information molecule: in particular, the phenomenon of pleiotropy is not easy to understand on basis of pure chemistry [I6]. TGD inspired view about biocontrol and coordination suggests a general answer to these questions and leads to a general model of biological control based on both MEs and information molecules with massless extremals (MEs) serving as actual information carriers and information molecules having a a role analogous to that of computer passwords.

4.1 Questions About Information Molecules

Central nervous system (CNS), endocrine system and immune system are three basic systems involved with bio-control and -communication. The work of Candace Pert and other neuroscientists has led to a general notion of information molecule described in popular manner by Candace Pert [J4]. Neural transmitters and modulators associated with CNS are only special cases of information molecules. Also neuropeptides and various hormones are involved. It has become clear that emotions are closely related with the activity of information molecules and that both brain, endocrine system and immune system communicate intensively with each other. One could regard even brain as a big gland. Of course, one could also consider various glands and organs as mini-brains.

The interactions of the information molecules involve the formation of receptor-information molecule complex either at cell surface or in the cell plasma inside cell. Receptor-information

molecule complex inside cell can move to genome and induce gene transcription. In case that the complex is formed at the surface of cell, second messenger action is involved. One can also speak about N: th messenger action. There are many poorly understood aspects related to the mechanisms of information molecule action [I6].

1. There are only few second messenger pathways and relatively few receptors but large number of different functions. This phenomenon is known as pleiotropy or multi-functionality. For instance, given second messenger causes different effects depending on the hormone that activated it (the phenomenon is somewhat analogous to the phenomenon in which message can be understood in several manners depending on the state of receiver). At purely chemical level the problem is how second messenger knows what hormone activated it? In steroid action the complex formed by information molecule and receptor in turn activates some gene. Now the question is: How the activated RNA polymerase knows which gene has to be activated? Pleiotropy appears also at level of hormones. Same hormone can have multiple effects and the border between hormone, neuropeptide or even neurotransmitter is unclear. For instance, hormone which by definition transmits long distance communications, can have effects in nearby cells and thus acts like a neuropeptide. How hormone knows what function it must perform? Also drugs and treatments can have different effects and side effects.

2. There is also functional redundancy: the same function is performed by several second messenger molecules. For instance, glucagon, growth hormone, adrenaline and corticosteroids elevate glucose levels. This suggests that there is deeper level of communication involved and that second messenger molecules are more like computer passwords than subprogram calls. Now the question is: What these subprogram calls do correspond physically?

3. Biological functions can be initiated also in non-chemical manner. The phenomena of healing by touch and the effects of meditation and biofeedback are examples of biological self-organization processes are initiated in non-chemical manner. Even other treatments like massage, acupuncture or meditation can decrease or inhibit pain. These observations suggest that chemical level is not the deepest level involved with biological functions and the question is: What is this deeper control level?

Simple lock and key mechanism cannot provide answer to the questions raised above. Rather, computer password might provide better metaphor for the second messenger action whereas receptor-information molecule complex would effectively generate subprogram call perhaps carried by the second messenger molecule or possibly broadcasted. It seems that information molecules act more like signs or symbols rather than being purely chemical agents. These symbols are interpreted by cell level intelligences and the interpretation depends on context.

4.2 A Model Of Biological Self-Organization Based On Quantum Antenna Hypothesis

The view that self hierarchy is present already at molecular level and realized in terms of MEs provides rather straightforward interpretation of pleiotropy and redundancy. The phenomenon of pleiotropy suggests there is non-chemical communication between receptor-peptide complex and cell nucleus. The most natural TGD inspired candidate for the communication is wake-up of genome sub-self by general wake-up mechanism in which classical em field associated with ME induces quantum jumps leading to quantum phase transition which could correspond to the transcription process. The almost-determinism of the transcription process would be due to the Darwinian selection caused by dissipative effects.

These considerations suggest that information molecule-receptor complex could generate ME carrying classical gauge fields and vacuum current. Vacuum current is excellent candidate for coding the information and can lead to a generation of coherent light.

1. The first possibility is broadcasting. The ME associated with information molecule receptor-complex acts as active quantum antenna and activated structure, say genome, serves as a passive quantum antenna receiving the coherent light. Classical fields and/or coherent light would induce quantum jumps serving as seeds of quantum phase transitions leading to a wake-up of conscious and self-organizing sub-self inside receiver.

2. Alternatively, second messenger molecule could carry the information carrying ME with itself as a genuine message inducing the self-organization process in, say, genome.

A natural hypothesis is that the states of the exotic Super Virasoro representations define the macroscopic quantum phases in question: the reason is that these representations are present in all length scales. The information molecule-receptor pair corresponds to a definite frequency, or more generally, combination of frequencies, coding the corresponding function. For instance, genes might be coded to harmonics of Super Virasoro frequencies associated with various p-adic length scales. All information molecule-receptor combinations initiate some function determined by these frequencies and pleiotropy emerges as a basic prediction of the model. Second messenger pathway is like a password to computer, universal key, together with the frequency or even entire ME specifying the function in question: this initiates the desired self-organization process waking-up proper sub-self.

These ideas suggest the following general framework for understanding biological self-organization.

1. Biological programs consist of self-organization patterns generated by classical gauge fields associated with MEs at specific resonance frequencies inducing quantum jumps leading to quantum phase transitions. These resonance frequencies serve as names of the genetic sub-programs. Messenger molecules in turn serve in the role of computer passwords.

2. Self-organization processes are associated with MEs and generated by special frequencies, which could be harmonics of the fundamental frequencies associated with various exotic Super Virasoro representations. For instance, combinations of harmonics of various Super Virasoro transition frequencies could define "name of gene". The fact that these frequencies are constants of Nature means that the model is immediately testable. Of course, also other transition frequencies, in particular, magnetic and Z^0 magnetic transition frequencies, could be important.

3. The ability of a biological system to act effectively like a deterministic computer is due to the Darwinian selection of the asymptotic patterns of self-organization caused by dissipation in systems which are fed by energy.

4. The four-dimensionality of this self-organization process is also important element. The frequency of ME defines time scale $T = 1/f$ which defines the duration of biological chronon. With this interval of geometric time entire 4-dimensional space-time surface changes in self-organization process.

5 Evidence For Quantum Antenna Hypothesis

In the following some evidence for quantum MEs and quantum antenna hypothesis is discussed. It must be emphasized that there is also other evidence discussed in other chapters of the book (for instance, see the chapters [K8, K11, K12].

5.1 TGD Inspired Model For Sonoluminescence

Sonoluminescence [D1] is a peculiar phenomenon, which might provide an application for the hydrodynamical hierarchy. The radiation pressure of a resonant sound field in a liquid can trap a small gas bubble at a velocity node. At a sufficiently high sound intensity the pulsations of the bubble are large enough to prevent its contents from dissolving in the surrounding liquid. For an air bubble in water, a still further increase in intensity causes the phenomenon of sonoluminecence above certain threshold for the sound intensity. What happens is that the minimum and maximum radii of the bubble decrease at the threshold and picosecond flash of broad band light extending well into ultraviolet is emitted. Rather remarkably, the emitted frequencies are emitted simultaneously during very short time shorter than 50 picoseconds, which suggests that the mechanism involves formation of coherent states of photons. The transition is very sensitive to external parameters such as temperature and sound field amplitude. In the following only the rough hydrodynamical characteristics of the phenomenon are considered from the point of view of p-adic length scale hypothesis. Also an attempt to understand the mechanism behind quantum coherence in terms of light-like vacuum currents associated with massless extremals is made.

5.1.1 Sonoluminescence and hydrodynamic hierarchy

A plausible explanation for the sonoluminescence is in terms of the heating caused by shock waves launched from the boundary of the adiabatically contracting bubble [D1]. The temperature jump across a strong shock is proportional to the square of Mach number and increases with decreasing bubble radius. After the reflection from the mimimum radius $R_s(min)$ the outgoing shock moves into the gas previously heated by the incoming shock and the increase of the temperature after focusing is approximately given by $T/T_0 = M^4$, where M is Mach number at focusing and $T_0 \sim 300\ K$ is the temperature of the ambient liquid. The observed spectrum of sonoluminescence is explained as a brehmstrahlung radiation emitted by plasma at minimum temperature $T \sim 10^5\ K$.

The model reproduces nicely the time development of the bubble and sonoluminescence spectrum and explains sensitivity to the external parameters [D1]. The problem is to understand how the length scales are generated and explain the jump-wise transition to sonoluminescence and the decrease of the bubble readius at sonoluminescence: ordinary hydrodynamics predicts continuous increase of the bubble radius. The length scales are the ambient radius R_0 (radius of the bubble, when gas is in pressure of 1 atm) and the minimum radius $R_s(min)$ of the shock wave determining the temperature reached in shock wave heating. Zero radius is certainly not reached since since shock front is susceptible to instabilities.

Since p-adic length scale hypothesis introduces a hierarchy of hydrodynamics with each hydrodynamics characterised by a p-adic cutoff length scale there are good hopes of achieving a better understanding of these length scales in TGD. The change in bubble size in turn could be understood as a change in the "primary" condensation level of the bubble.

1. The bubble of air is characterized by its primary condensation level k. The minimum size of the bubble at level k must be larger than the p-adic length scale $L(k)$. This suggests that the transition to photoluminescence corresponds to the change in the primary condensation level of the air bubble. In the absence of photoluminescence the level can be assumed to be $k = 163$ with $L(163) \sim .76\ \mu m$ in accordance with the fact that the minimum bubble radius is above $L(163)$. After the transition the primary condensation level of the air bubble is $k = 157$ with $L(157) \sim .07\ \mu m$. In the transition the minimum radius of the bubble decreases below $L(163)$ but should not decrease below $L(157)$: this hypothesis is consistent with the experimental data [D1].

2. The particles of hydrodynamics at level k have minimum size $L(k_{prev})$. For $k = 163$ one has $k_{prev} = 157$ and for $k = 157$ $k_{prev} = 151$ with $L(151) \sim 11.8\ nm$. It is natural to assume that the minimum size of the particle at level k gives also the minimum radius for the spherical shock wave since hydrodynamic approximation fails below this length scale. This means that the minimum radius of the shock wave decreases from $R_s(min, 163) = L(157)$ to $R_s(min, 157) = L(151)$ in the transition to sonoluminescence. The resulting minimum radius is 11 nm and much smaller than the radius .1 $\mu\ m$ needed to explain the observed radiation if it is emitted by plasma.

A quantitative estimate goes along lines described in [D1].

1. The radius of the spherical shock is given by

$$R_s \quad = \quad At^{\alpha} \ , \tag{5.1}$$

where t is the time to the moment of focusing and α depends on the equation of state (for water one has $\alpha \sim .7$).

2. The collapse rate of the adiabatically compressing bubble obeys

$$\frac{dR}{dt} \quad = \quad c_0(\frac{2}{3\gamma}\frac{\rho_0}{\rho}(\frac{R_m}{R_0})^3)^{1/2} \ , \tag{5.2}$$

where c_0 is the sound velocity in gas, γ is the heat capacity ratio and ρ_0/ρ is the ratio of densities of the ambient gas and the liquid.

3. Assuming that the shock is moving with velocity c_0 of sound in gas, when the radius of the bubble is equal to the ambient radius R_0 one obtains from previous equations for the Mach number M and for the radius of the shock wave

$$\begin{aligned} M &= \frac{\frac{dR_s}{dt}}{c_0} = (t_0/t)^{\alpha-1} \ , \\ R_s &= R_0(t/t_0)^{\alpha} \ , \\ t_0 &= \frac{\alpha R_0}{c_0} \ . \end{aligned} \tag{5.3}$$

where t_0 is the time that elapses between the moment, when the bubble radius is R_0 and the instant, when the shock would focus to zero radius in the ideal case. For $R_0 = L(167)$ (order of magnitude is this) and for $R_s(min) = L(151)$ one obtains $R_0/R_s(min) = 256$ and $M \simeq 10.8$ at the minimum shock radius.

4. The increase of the temperature immediately after the focusing is approximately given by

$$\frac{T}{T_0} \simeq M^4 = (\frac{R_0}{R_s})^{\frac{4(1-\alpha)}{\alpha}} \simeq 1.3 \cdot 10^4 \ . \tag{5.4}$$

For $T_0 = 300\ K$ this gives $T \simeq 4 \cdot 10^6\ K$: the temperature is far below the temperature needed for fusion.

In principle the further increase of the temperature can lead to further transitions. The next transition would correspond to the transition $k = 157 \to k = 151$ with the minimum size of particle changing as $L(k_{prev}) \to L(149)$. The next transition corresponds to the transition to $k = 149$ and $L(k_{prev}) \to L(141)$. The values of the temperatures reached depend on the ratio of the ambient size R_0 of the bubble and the minimum radius of the shock wave. The fact that R_0 is expected to be of the order of $L(k_{next})$ suggests that the temperatures achieved are not sufficiently high for nuclear fusion to take place.

5.1.2 The model of sonoluminescence by Buzzacchi, del Giudice and Preparata

The coherence of the light generated in sonoluminescence looks rather mysterious from the view point of standard physics. There is very interesting paper of Buzzacchi, del Giudice and Preparata about sonoluminescence with title "*Sonoluminescence Unveiled?* " [D1]. The study of this paper revealed that the physical picture behind microtubule as quantum antenna hypothesis leads to a model for sonoluminescence and that sonoluminescence could be interpreted as a direct evidence for light-like vacuum currents generating coherent photons in TGD. Needless to say, vacuum currents are a purely TGD based phenomenon and implied by the induced gauge field concept deriving from the hypothesis that space-time is 4-dimensional surface in certain 8-dimensional space.

The assumptions of the work of Buzzacchi, del Giudice and Preparata [D1] are following.

1. The energy of the coherent radiation created in sonoluminescence results from the latent heat 0.26 eV per molecule for gas to liquid phase transition occurring at the final stage of the bubble collapse. In [D1] the latent heat is used to deduce the width Γ of the energy spectrum of photons.

2. When shock wave is formed during the collapse of bubble (collapse velocity becomes supersonic), a front of layers with distance that between water molecules is formed. The average distance of molecules in tangential direction are much larger but gets smaller during the collapse of bubble. One can say that there is vapor layer looking like water in radial direction but in transversal directions the layer is much less dense. When the radius of the buble reaches certain critical value (so that density is about 1/3 of the density of liquid phase), condensation in the transversal directions to liquid occurs. Note that this means that there is preferred direction suggesting cylindrical symmetry for the condensing regions.

3. The phase transition is assumed to occur in coherent regions with size of order $\lambda \simeq 500$ Angstroms, which is not far from the diameter of microtubules. In these regions there is a coherent plane wave electromagnetic field with frequency $\omega = 2\pi/\lambda$ and the decay of this field produces the highly synchronized light flash of duration of less than 10^{-11} seconds.

4. The physical origin of the coherent regions is somewhat mysterious in standard physics but authors propose that QED is enough to explain the mystery. Authors identify the source of coherent light as resulting from the transitions between two different molecular energy states with energy difference $\Delta E \simeq 12$ eV. One could criticize this assumption as ad hoc. In any case, classical current must be defined as expectation value, which vanishes unless the two energy eigen states get mixed by interactions.

5.1.3 TGD inspired model for sonoluminescence

Consider now the TGD based modification of this model based on the same assumptions 1), 2), 3) about the origin of the coherent light as related to the liquid-gas phase transition but with different identification for the mechanism producing the coherent light. The model is based on the idea that bubble collapse might involve the sequential formation of several new space-time sheets with p-adic primes $p \simeq 2^k$, $k = 163, 157, 151, 149$ characterizing their typical sizes. The importance of the many-sheeted space-time concept was realized already in the previous rough model of the phenomenon just suggesting the identification of the basic scales of the problem in terms of the p-adic length scale hypothesis but involved no model for the generation of coherent light.

a) Light like vacuum currents generate coherent light

What is known is that the light flash emitted is *coherent* light. All frequencies are emitted simultaneously. The temporal widths of various frequencies do not depend on the nature of the gas. Thus the spectrum is certainly not genuine black body spectrum and the production mechanism must involve macroscopic quantum coherence. In TGD there indeed exists a unique mechanism leading to the generation of coherent light and is based on so called "massless extremals" carrying light-like *vacuum currents* generating coherent light in a resonant like manner. Clearly, this mechanism predicts no dependence of the spectrum on the chemical nature of the gas in bubble. Of course, the gas can affect the spectrum by absorbing some frequencies and this indeed seems to occur. It is also known that the presence of noble gases is favorable for sonoluminescence: this is perhaps understandable from the fact that presence of noble gases (no absorption) reduces the effect of other gases by reducing their densities. In TGD inspired theory of bio-systems as macroscopic quantum systems massless extremals correspond to almost empty space-time sheets associated with microtubules and possibly also other linear bio-structures and create coherent photons (perhaps bio-photons of Popp [I8]).

b) Vapor-liquid phase transition in regions of microtubular size occurs

Following [D1], it will be assumed shockwave formation leads to the formation of vapor layers with the mutual distance $a \simeq 3.2$ Angstroms equal to the average distance between liquid molecules and that condensation to liquid occurs when the transversal distance between the molecules of the layer becomes smaller than some critical distance $a < a_T < a_0$, where $a_0 \simeq 3.2 \times 10^{-7}$ meters is the transversal distance of the molecules when shockwave is generated. In the model of [D1] $a_T \simeq \sqrt{3}a$ holds true: in TGD based model p-adic argument gives $a_T = 2a$. In TGD framework the formation of liquid phase is assumed to mean the formation of new cylindrical space-time sheets of size of order 500 Angstroms, when the transversal distance between H_20 molecules becomes critical (3 times the distance in liquid phase). At these space-time sheets water molecules are condensed into liquid phase. The length scale 500 Angstroms is suggested by [D1] and in TGD framework the justification for this length scale is that it corresponds to the diameter of microtubules: these cylindrical structures could serve as templates for the formation of microtubules). Rather flat cylinders with radius equal to height are in question: of course, one can consider also cubic geometry.

c) p-Adic length scale hypothesis

p-Adic length scale hypothesis makes this picture more quantitative. Before the phase transition vapor phase is join along boundaries/flux tube condensate of $k = 151$ space-time sheets glued

to $k = 157$ sheets. Note that $L(151) \simeq 10^{-8}$ meters corresponds to the thickness of the cell membrane: now however the sheets are larger having size of order 500 Angstroms. Gas-to liquid phase transition is identified as a phase transition changing the value of the p-adic prime p: most naturally $k = 151 \rightarrow k = 149$. This implies $a_T = 2a_0$ rather than $\sqrt{3}a_0$ as in the model of [D1]. Therefore the critical density is $\rho^* = \rho(liquid)/4$ instead of $\rho(liquid)/3$ of [D1]. Using the relationship

$$a_T(t) = a_0 \frac{R(t)}{R_0} \quad , \tag{5.5}$$

where $R_0 \simeq 4.5\mu m$ is the radius of the bubble when contraction velocity becomes supersonic one obtains for the transversal distance a_T^* at criticality:

$$a_T^* \simeq 2a = a_0 R^*/R_0$$

giving $R^* \simeq .9\ \mu m$ to be compared with $R^* \simeq .8\ \mu m$ of [D1].

One can estimate the thickness of the condensing shell from the requirement that the number of molecules in the shell with inner and outer radii R^* and R_0 at time t_0 is same as the number of molecules in the thin liquid shell at time when condensation to liquid has occurred. This gives for the thickness T of the liquid shell

$$T \simeq \frac{R_0^2}{R^{*2}} \frac{a^3}{a_0^3} (1 - \frac{R^{*3}}{R_0^3}) R_0 \quad , \tag{5.6}$$

giving $T \simeq 10^{-7}$ meters which is *two* (!) times the size of the coherence domain as suggested by the transversal size of microtubules.

d) Topological details of the phase transition process

Consider next the topological details of the process. The transversal size of $k = 151$ sheets is (most naturally) halved in the phase transition and the flux tubes connecting $k = 151$ sheets to each other are probably split. According to the basic rules of p-adic TGD, space-time sheets with different p-adic prime p can have only wormhole contacts as stable contacts. This means that, for a p-changing phase transition to take place, the bonds connecting $k = 151$ sheets belonging to different sides of the shock front must be split, probably immediately after the formation of the shock wave. The inward flow of the newly formed $k = 149$ sheets slows down whereas the flow of $k = 151$ sheets behind them continues: the molecules condensed on them cannot however follow the flow since they collide with the liquid phase. Therefore these sheets become thus almost vacuum space-time sheets and the $k = 149$ sheets containing liquid phase topologically condense on them. At this stage the vacuum currents are generated on these almost empty $k = 151$ sheets.

e) Generation of coherent light

In the last stage of the process vacuum currents are generated on the almost empty $k = 151$ sheets and they generate the coherent light giving rise to the flash. The experience with microtubules as quantum antennae hypothesis suggests that massless extremals carrying classical light-like vacuum currents flowing in radial direction are in question. The vacuum current, possible *only* in TGD context, generates coherent photons and the flux of coherent photons from the system creates the coherent flash of photons. The frequency spectrum for the current associated with the massless extremals comes in multiples of the basic frequency π/L, L being the length of the cylinder, which is roughly equal to the thickness of H_2O layer condensing to liquid (this length is expected to have some distribution). The dependence of the vacuum current on transversal and longitudinal coordinate, which is not specified by the field equations for the vacuum extremals, in principle determines the energy spectrum. The model for the sonoluminescence should be able to predict the form of the vacuum current but this requires a model for the coupling between the parameters of the vacuum current and ordinary matter.

The model of [D1] suggests that only the lowest frequency $\omega_0 = 2\pi/L$ is effectively present. The spectrum of [D1] is of form

$$\begin{aligned}\frac{1}{V}\frac{dE}{d\omega} &= \frac{3\omega_0^3}{16\pi^3}|c_1|^2|F(\omega)|^2\frac{\omega^2}{(\omega-\omega_0)^2+\Gamma^2/4} \ , \\ |c_1|^2 &\simeq 1.8 \ , \\ F(\omega) &= exp(-1.4\frac{\omega^2}{\omega_0^2}) \ . \end{aligned} \tag{5.7}$$

It is of considerable interest to verify that a spectrum, which is product of a form factor and resonance factor, results also now. The presence of the form factor $F(\omega)$ reflects the dependence of the vacuum current on transversal coordinate, which for cylindrical geometry is radial coordinate. The dependence on the transversal coordinate is left completely open by the field equations and the unknown coupling of the vacuum current with matter should determine it. The resonance factor has a purely kinematical origin: the energy spectrum for photons has form $1/(\omega-\omega_0)^2$ resulting from the fact that matrix element for photon emission involves the overlap integral $\int exp[i(\omega-\omega_0)t]dt$ over a finite time-interval. One must take dissipation into account so that the real spectrum is proportional to $1/\left[(\omega-\omega_0)^2+\Gamma^2/4\right]$. The resonance width is of order $\Gamma \simeq 18$ eV and in [D1] it is determined by the requirement that total energy output equal to the latent heat .28 eV per molecule.

The order of magnitude for the duration of the flash can be estimated from the radial contraction velocity $dR/dt(t_0) \simeq 1.5 \times 10^3 m/s = 10^{-5}c/2$ of the bubble at the moment t_0 when the phase transition begins (according to [D1]) and from the length $l \leq 500$ Angstroms, which the empty $k = 151$ sheets must travel before $k = 149$ sheets can condense on them. This gives the estimate $t(flash) \simeq 3\times 10^{-11}$ seconds which is less than the experimental upper bound $t(flash) < 5\times 10^{-11}$ seconds,

To summarize: sonoluminescence could provide a direct verification for the concept of massless extremal and light-like vacuum currents. Gas-liquid phase transitions could quite generally involve the formation of massless extremals. Perhaps massless extremals of microtubular size are always present in liquid phase but carry very weak vacuum currents and bio-systems are perhaps able to amplify them. One could perhaps understand all phase transitions as formation of new space-time sheets involving p-changing phase transition.

5.2 Stirred And Shaken

Japanese chemist Kazamuri Dozen and his colleagues have observed mysterious splitting of water into hydrogen and oxygen at room temperature using a simple catalyst (copper oxide in powder form) and by stirring the liquid [I7, I7]. The quicker the container is stirred the more hydrogen and oxygen are produced. Usually the dissociation occurs at temperature of about 3000 C and is driven by light: the photon density of thermal radiation has maximum at $E \sim 4T$ giving the estimate $E \sim 1.32$ eV: which gives an estimate for the energy of O–H bond possibly lowered by the presence of a catalyst. Notice that the photons in question correspond to visible light. Domen believes that direct transformation of the kinetic energy of the liquid motion to chemical energy must take place: standard wisdom allows only the transformation *kinetic energy* $\rightarrow$ *thermal energy* $\rightarrow$ *chemical energy*. There is no idea about the underlying mechanism. According to [I7, I7] already 1980 analogous direct transformation of acoustic energy to chemical energy was discovered and gave rise to the field of sonochemistry. An attractive possibility is that liquid motion somehow generates coherent light which in turn drives the reaction. Similar mechanism might be at work in sonochemistry. Since sonoluminescence involves the transformation of mechanical energy into coherent light, quantum antenna hypothesis is an obvious guide line in the attempt to identify the mechanism.

The simplest TGD based mechanism explaining the anomalous splitting of hydrogen is following.

1. Stirring creates linear cylindrical vortex like structures, which are accompanied by space-time sheets carrying light like vacuum currents. The splitting to oxygen and hydrogen is driven by the coherent light emitted by the vacuum currents associated with cylindrical structures of length L. The energies for the photons of the coherent light come as multiples of $E_0 = \pi/L$

(or of $E_1 = 2\pi/L$ if periodic boundary conditions are assumed). For $E = E_0 \sim 1.32$ eV this gives the estimate $L \sim .47 \cdot 10^{-6}$ meters. This length scale is not too far from the p-adic length scale $L(163) \sim .64 \cdot 10^{-6}$ meters assuming that $L(151)$ corresponds to cell membrane thickness $L(151) \simeq 10^{-8}$ meters.

2. The rotational motion creates classical Z^0 magnetic fields realized as Z^0 magnetic flux tubes and a natural expectation is that these flux tubes are accompanied by cylindrical space-time sheets carrying light like vacuum currents. Since quarks feed their Z^0 gauge fluxes to the space-time sheets having typically twice the cell size, the naive expectation for the length of the cylindrical structures in question would be of order $L(169) \sim 5 \cdot 10^{-6}$ meters, which is however almost by one order of magnitude too large. This of course does not exclude the possibility that Z^0 magnetic flux tubes are in question. The generation of Z^0 magnetic flux tubes was suggested already many years ago to explain the observed loss of the super fluidity at much smaller critical rotational velocity than predicted by standard physics [K9].

3. A possible function of the catalyst powder is to lower the O–H bonding energy, so that it is nearer to the energy of the photons of the coherent light.

What is interesting from the point of view of consciousness theorizing is that in gel-phase vigorous streaming of intracellular liquid occurs. Furthermore, the coherent photons causing dissociation would correspond to visible light. Therefore one can wonder whether the generation of light-like vacuum current emitting coherent bio-photons [I8] could be one function of the streaming. A possible test for this hypothesis is to look for an additional sink of metabolic energy inside cell.

5.3 Evidence For Quantum Antenna Hypothesis In Living Systems

It is known that some monocellulars possess elementary vision based on the microtubules [I4]. The emergence of the multicellulars during the Cambrian explosion was preceded by the appearance of the microtubules. If the emergence of the microtubules meant the emergence of the visual consciousness in the length scale of the cell, then the formation of the multicellulars as cell societies can be understood as a natural consequence. The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. The coherent light in question could be identifiable as bio-photons of Popp [I8].

A further piece of evidence comes from the work of Callahan about the sense of smell of insects [I9]. Many insects, such as moths and ants, are known to be attracted by light, say candles and electric lamps and Callahan took as his challenge to understand what is involved. Callahan discovered that insect's olfaction is not based on chemistry but to a maser like emission of infrared light generated by various molecules such as pheromones, scent molecules and many other biomolecules. Thus insects would see rather than chemically perceive the sources of the infrared light. The sensillae of the insects serve as receiving antennas and amplify the incoming infrared radiation. Callahan also observed that the oscillation of insect antennae induce maser like emission from scent/etc. molecules by creating an oscillating emf. Thus sensory experiencing seems to involve active participation from the part of insect. The results of Callahan suggest that coherent light could be important also in our neuronal sensory experiencing.

Quite remarkably, pheromones are known to mediate sexual and social signals also in case of many mammals. For instance, certain chemical messages from female mouse can make male mouse to mate immediately while certain chemical messages from other males make him aggressive. Many mammals, for instance rodents, are known to possess vomeronasal organs, small cigar like sacks containing neurons and having length of order few millimeters [J1], giving rise to an accessory olfactory system, which is known to have much more primitive structure and to work in different way than the ordinary olfactory system. It is also known that this systems bypasses cerebral cortex in rodents. There is evidence that even humans have the ability to sniff certain chemicals mediating social and sexual signals without being aware of it and there is already now an entire perfume industry based on this evidence. The chemicals giving rise to sexual attraction are probably pheromones. The fact that pheromones mediate sexual signals in case of both insects and mammals, is hardly an accident and suggests that the sensory mechanism must be the same and be based on the infrared emissions by pheromones. If the response is at neuronal level and if the cortex is not involved, one could understand why these messages are not experienced consciously. One

could test this hypothesis by finding whether coherent infrared radiation at frequencies emitted by pheromones can affect the behavior of higher mammals including humans.

There is a further peculiar co-incidence: the cascade of transduction events occurring in the absorption of photon in retina is repeated in a remarkably similar way in olfactory receptor cells, which respond to odors whereas the receptor cells that respond to sound use a very different system [J1]. Could this mean that also the experience of odor primarily involves the detection of (also) infrared light so that humans would not basically differ from insects or that olfactory system has evolved from the receptor neurons originally sensing infrared light? This would conform with the idea that the Kähler field generated in ear corresponds to classical Z^0 field, which does not generate coherent photons but couples with neutrinos. One must however notice that the resemblances between visual and linguistic imagery suggest that some part of ear generates cognitive representation based on coherent light and experienced by the secondary sensory organs in the thalamus.

In CASYS'2000 conference Peter Marcer reviewed the work done by him in collaboration with Russian group [I3] providing experimental evidence for the hypothesis that DNA acts as receiving and sending quantum antenna. What was observed that irradiation of DNA with visible laser light induced emission of coherent light with both visible and radio frequencies. The emitted radiation was also modulated in time scale of about .01 seconds. The modulation could be due to propagation of soliton sequences propagating along Josephson junction formed by the strands of DNA or due to non-propagating spatially constant Josephson current: both cases are mathematically equivalent with gravitational pendulum

5.4 Biefeld-Brown Effect

Biefeld-Brown effect was invented as early as 1926 and is one of the oldest poorly understood electromagnetic anomalies [H1, H2, H3]. The basic experiments are following.

1. Capacitor is balanced on beam balance and then charged. If the positive pole of the capacitor points upwards, the condenser moves up. If it points down the condenser moves down.

2. Capacitor is placed in free suspension such that the normal orthogonal to the plane of capacitor plates is horizontal and then charged. Capacitor is found to exhibit a horizontal thrust in the direction of the positive plate.

   Thus it seems that when capacitor is provided with large charge, a force acting on capacitor in direction normal to the plane of the capacitor is observed. The motion takes place to the direction of the positively charged plate. The larger the surface area A of the capacitor, the shorter the distance d between the plates, the larger the mass M between the capacitor plates, the higher the relative dielectric constant ϵ of the dielectric, the larger the voltage V used, the larger is the size the effect. This behavior can be understood if the size of the effect is proportional to the total electric energy $E_e = \epsilon \frac{AV^2}{d}$ between capacitor plates. It is difficult to understand this effect in standard physics framework.

Consider first experiment 1) in which the normal of the capacitor plane is in vertical direction. This experiment could be understood in the general conceptual framework described in the chapter [K14]. Capacitor generates some net gravitational flux. This flux is in general fed to several space-time sheets, although most of it goes to the "standard" sheet at which the gravitational field of Earth resides. One could understand the result of the experiment a) in terms of a redistribution of these gravitational fluxes. When the positive plate points upwards/downwards the flux $\phi_{gr}(Earth)$ fed to the "standard" space-time sheet is reduced/increased. Therefore the effective weight of the capacitor decreases/increases. The dependence of $\phi_{gr}(Earth)$ on the relative orientation of the gravitational field and electric field is not surprising from TGD point of view since classical gravitational and electric fields are very closely related in TGD framework. If classical Z^0 electric force contributes to the effective gravitational force significantly, then similar mechanism in case of Z^0 electric flux could contribute significantly to the change of the effective weight of the capacitor.

It seems that this mechanism cannot explain the result of the second experiment in which capacitor moves to horizontal direction. Rather it seems that two effects must be involved. there must be some mechanism giving for the capacitor momentum in the direction of the electric field.

The TGD based general mechanism of energy production relying on the generation of space-time sheets with negative time orientation and carrying negative energies could explain this aspect of Biefeld-Brown effect.

1. Suppose that the charging of capacitor involves generation of space-time sheet with negative time orientation. The energy density associated with classical fields at this space-time sheet is negative. Energy conservation requires that capacitor receives compensating energy which in case of Biefeld-Brown effect is partially realized as kinetic energy associated with center of mass motion.

2. The classical gauge fields associated with the negative energy space-time sheet can carry also momentum and compensating momentum must be developed at the space-time sheet of the capacitor. Therefore condenser is forced to move. The momentum density of em field is proportional to the cross product $E \times B$ of the electric and magnetic fields. This momentum density gives rise to a net field momentum in the direction orthogonal to the plane of condenser plates if E and B are in directions parallel to the plates. This resembles somewhat the situation encountered in the case of Hall effect.

A working hypothesis worth of studying is that the negative energy space-time sheet associated with the capacitor corresponds to a massless extremal with E and B fields propagating from positive to negative plate (field momentum is in this direction).

1. Momentum conservation implies that the space-time sheet of the capacitor generates opposite momentum so that capacitor must move in the direction normal to the plane of the plates. What remains to be understood why the direction of motion is towards the positively charged plate. The light-likeness of 4-momentum gain together with the presence of Fourier components with single direction of wave vector means that momentum gain per energy gain is maximal. Therefore generation of negative energy "massless extremals" is optimal mechanism of propulsion. Massless extremals can have also net angular momentum since polarized Fourier components carry spin. Therefore capacitor can gain internal angular momentum in some form.

2. Assuming that the entire momentum of the classical field on negative energy space-time sheet is compensated by the momentum gain of capacitor, one obtains for the total energy gain

$$E_t = M\beta \ ,$$

where M is total mass of the capacitor and β is its velocity (the units $\hbar = 1$, $c = 1$ are used). This means quite large energy gain. For instance, for $M = .01$ kg and $\beta = 10^{-12}$, one has $E_t \sim 10^2$ Joule. The energy ΔE, which is not realized as kinetic energy, is given by

$$\Delta E = M\beta(1 - \frac{\beta}{2}) \ .$$

Obviously, only a small fraction of the energy is realized as kinetic energy of the capacitor.

The ratio of the energy to thermal energy is given by

$$\frac{E_t}{E_{th}} \sim A\frac{m_p\beta}{T} \ ,$$

where A denotes atomic number. This ratio is much smaller than one for $\beta \ll T/Am_p$. In room temperature this gives $\beta \ll 10^{-11}/A$. An estimate for the magnitude of the electric field is obtained from $E_t = P$. Expressing everything in terms of integrals of energy and momentum densities, one obtains $EB \sim \rho\beta$. Since $E = B$ holds true for massless extremals, one has $B \sim \sqrt{\rho\beta}$. In condensed matter densities one has $\rho \sim Am_p/a^3$, where a is Bohr radius. This gives $B \sim \sqrt{10^5 A\beta}/a^2$. B is roughly about one $\sqrt{A}$ Tesla for $\beta \sim 10^{-12}$. Very strong electric and magnetic fields are clearly involved.

The proposed mechanism might also make possible to understand how living systems are able to generate coherent motions.

1. The ability of bio-systems (70 per cent of water!) to generate coherent motions is complete mystery from the point of view of standard physics describing bio-system as a soup of randomly moving atoms and molecules. The generation of massless extremals provides an optimal mechanism for coherent motion. Negative energies are not absolutely essential for generating coherent motions. However, if massless extremals have positive energies, the efficiency of energy usage is however very low, approximately $\beta/2$, where β is the velocity generated: something like 10^{-8} if velocity is of order one meter per second. It could quite well be that massless extremal is created only for the period of time that motion lasts: this in accordance with the idea that classical counterparts of virtual particles are in question. Since the surplus energy generated on the material space-time sheet is partially dissipated during this time interval, this mechanism requires that metabolism feeds energy to the system to compensate this loss. Thus there is no contradiction with the general wisdom about the necessity of metabolic energy feed.

2. Brown observed that capacitors had definite effects on plants and animals. This is not surprising if TGD picture about bio-systems is correct. Coherent light is generated and this coherent light can affect the communications of neuronal society.

3. If bio-systems can generate negative energy massless extremals, a very efficient generation of metabolic energy from vacuum becomes possible. There is a lot of anecdotal evidence about the ability of yogis and mystics to survive without eating [J10]. The explanation often proposed by yogis themselves [J10] is that the energy of light replaces the usual sources of the metabolic energy. Standard science sceptics of course "know" and ridicule all this but, against the background of new physics predicted by TGD, I cannot avoid asking myself whether there might be some seed of truth behind these claims.

6 Appendix: A Model For The Topological Condensation Of Coherent Vapor Phase Photons

In ordinary QED classical gauge fields can have only ordinary charged particles as their sources. In TGD genuine vacuum currents are possible. The coupling of the quantum field to the classical em field with a non-vanishing vacuum source implies the generation of a coherent state of photons such that each Fourier component present in the classical gauge current gives rise to an eigen state of the corresponding photonic annihilation operator. In case of light-like vacuum currents allowed by TGD, the coherent state is generated in resonant-like manner so that light-like vacuum current acts as an ideal quantum antenna.

If one introduces a second space-time sheet, which contains BE condensate of photons for some modes of the photon field, a stimulated topological condensation of both coherent vapor phase photons and transfer of coherent condensed photons from other space-time sheets to this space-time sheet occurs. This effect makes possible the action of the second space-time sheet as an optimal receiving antenna. In the following calculation the consideration is restricted to the stimulated condensation of vapor phase photons.

In biological context microtubules could server both as senders and receivers of coherent photons. According to the proposed identification of coherent photons as the quantum correlate of vision, the microtubules contain BE condensate of photons in some some modes would have the ability to see in some primitive manner.

6.1 The Action

The simplest model for the situation is based on Maxwell action for electromagnetic field regarded as an induced field obtained from superposition of the classical emf in CP_2 degrees of freedom and second quantized free emf in $M^4_+ \times CP_2$ having only M^4 components and depending on M^4_+ coordinates only and having decomposition into vapor phase and condensate parts ($\hbar = 1$ and $c = 1$ will defined the units used in the following).

$$\begin{aligned} F_{\mu\nu} &= F_{\mu\nu}(cl) + F_{\mu\nu}(qu) \ , \\ F_{\mu\nu}(cl) &= F_{kl}(cl)\partial_\mu s^k \partial_\nu s^l \ , \\ F_{\mu\nu}(qu) &= F_{kl}(qu)\partial_\mu m^k \partial_\nu m^l \ , \\ F_{kl}(qu) &= \partial_l A_k(qu) - \partial_k A_l(qu) \ , \\ A_k(qu) &= A_k(qu,v) + A_k(qu,c) \ . \end{aligned} \tag{6.1}$$

$F_{kl}(qu)$ satisfies empty space Maxwell equations. m^k and s^k refer to M^4_+ and CP_2 coordinates and v and c refer to vapor phase and condensate.

Maxwell action density can be transformed to a sum of a total divergence reducing to mere boundary term, to be neglected, plus free part and two interaction terms in the following manner:

$$\begin{aligned} \frac{L}{\sqrt{g}} &= \sum_i L(free,i) + L_1(int) + L_2(int) \ , \\ L(free,i) &= \frac{1}{4} F_{\mu\nu}(qu,i) F^{\mu\nu}(qu,i) \ , \ i = c,v \ . \\ L_1(int) &= \frac{1}{2} j^\mu(cl) \sum_i A_\mu(qu,i) \ , \\ L_2(int) &= \frac{1}{2} \sum_i J^\mu(qu,i) A_{mu}(cl) \ , \\ J^\mu(qu,i) &= F^\mu_k(i) M^{k\nu}_\nu + F_k{}^\nu(i) M^{k\mu}_\nu \ , \ i = c,v \\ M^k_{\alpha\beta} &= D_\beta \partial_\alpha m^k \ . \end{aligned} \tag{6.2}$$

$L(free,i)$ denotes the free action for the classical emf and vapor phase and condensed quantum emfs and defines photon propagators. Standard propagator is obtained, when Minkowski coordinates are used for space-time surface.

$L_1(int)$ corresponds to the action of the vapor phase and condensed quantum emf with the vacuum current and leads to generation of coherent state of photons both in vapor phase and condensate.

$L_2(int)$ is non-vanishing only, when the M^4_+ part of the second fundamental form $M^k_{\alpha\beta}$ for 4-surface is non-vanishing: in this case the em current associated with $A_{mu}(qu)$ is non-vanishing despite the fact that it vanishes for $A_k(qu)$! This term describes the external curvature of the 4-surface as opposed to the internal curvature described by the curvature tensor. In general case, the external curvature can be large even when the gravitational field vanishes. It must be however emphasized that this term is proportional to the metric of CP_2 and, in case of the massless extremals, this term is significant only if the dependence of CP_2 coordinates on the transversal coordinates of M^4_+ is strong: this in turn requires huge value for the light-like Einstein tensor. This term will be neglected in the sequel.

The representation

$$\begin{aligned} &A_+(k,\lambda) = \sqrt{\tfrac{2\pi}{\omega_k}} a^\dagger(k,\lambda) \ , \\ &\left[a(k_1,\lambda_1), a^\dagger(k_2,\lambda_2)\right] = \delta^3(k_1-k_2)\delta_{\lambda_1,\lambda_2} \ , \end{aligned} \tag{6.3}$$

for which the density of states factor for photon states is $dN = d^3k$, will be used in the sequel.

6.2 Coherent State Is Generated In Resonant-Like Manner For Light-Like Vacuum Currents

The presence of the vacuum current leads to the generation of coherent state of photons both in vapor phase and condensate. Coherent states states are eigen states of the photonic annihilation operators and in the estimates for the rate of topological condensation, one in a good approximation one can replace $A_\mu(qu,i)$, $i = cond, vap$, with the classical photon field $A_\mu(coh,i)$ having classical

vacuum current as its source and serving as order parameters for the coherent state. The Fourier component of a vector potential describing the eigenvalue of the annihilation operator part of the photon field is for given momentum k and polarization direction λ given by

$$\begin{aligned} A^\mu(coh, v|\lambda, k) &= \sum_n c(k, k_n) \frac{\lambda_\mu J^\mu(k_n)\lambda^\mu}{k_n^2} \ , \\ exp(-ik\cdot m) &= \sum_n c(k, k_n) exp(-ik_n \cdot m) \ . \end{aligned} \tag{6.4}$$

$c(k, k_n)$ is the Fourier component of the plane wave $exp(-ik\cdot m)$ expressed using discrete plane wave basis for the space-time sheet containing the vacuum current. m denotes Minkowski coordinates.

If the classical vacuum current is associated with a "massless extremal", em current is light-like and this implies resonance for those frequencies for which photon wave vector corresponds to the wave vectors appearing in the vacuum current. The resonance is smoothed out by the finite spatial size of the space-time sheet containing the light-like vacuum current. At the limit of an infinitely large spatial size for the space-time sheet, one obtains infinitely large amplitude since one has $k_n^2 = k^2 = 0$ at this limit.

6.3 Stimulated Topological Condensation

The presence of the coherent state of photons implies the possibility of the topological condensation of photons. If the device contains $N(k, \lambda)$ photons in the state (k, λ), stimulated topological condensation, completely analogous to the stimulated emission, occurs and the condensation rate is proportional to $(N(k, \lambda) + 1)^2$.

Assume that there exists a coherent state generated by quantum antenna of possibly astrophysical dimension and associate label "1" with this space-time sheet. Assume also a second space-time sheet and associate with it label "2". In the lowest order the matrix element for the topological condensation of single photon can be obtained as the matrix element of the creation operator part of the interaction term of the action

$$\begin{aligned} &iS_+ = \tfrac{i}{2} \int_{V_2} dV_2 j_\perp^\mu(coh, 1) A_{\mu,+}(cond, 2) \\ &= \tfrac{i}{2} \sum_{\lambda_2} \int d^3k_2 X(k_2, \lambda_2) a^\dagger(k_2, \lambda_2) \ , \\ &X(k_2, \lambda_2) = \sqrt{\tfrac{2\pi}{\omega_{k_2}}} \sum_{\lambda_1} \int d^3k_1 Y(k_1, \lambda_1, k_2, \lambda_2) \ , \\ &Y(k_1, \lambda_1, k_2, \lambda_2) = j(coh, 1|k_1, \lambda_1) c(k_1, k_2) e_{\lambda_1} \cdot e_{\lambda_2} \ , \\ &c(k_1, k_2) = \int_{V_2} dV_2 exp\left[i(k_1 - k_2)\cdot m\right] \ , \end{aligned} \tag{6.5}$$

between the initial and final states. $j^\mu(coh, 1)$ is just the transversal part of the classical vacuum current creating the coherent state. The latter expression is obtained by using Fourier expansions for j and A_+ (, which denotes the creation operator part of the free photon field projected to the space-time surface representing the device: Minkowski coordinates are used for both source regions and device).

In case that the region V_1 is box of length L in the direction of the vacuum current, the explicit calculation, writing the light-like vacuum current as $j^\mu = Jp^\mu$, $p^0 = p^z = 1$, leads to the following expression for the Fourier component $j(coh, 1|k_1, \lambda_1)$:

$$\begin{aligned} &j(coh, 1|k, \omega_k, \lambda) = j^\mu(coh, 1|k, \omega_k) e_\mu^\lambda \ , \\ &= \textstyle\sum_n \frac{exp(ik_z L) - 1}{ik_z} J(\omega_n, k_T) p \cdot e^\lambda \delta(k^0 - \omega_n) \ , \\ &\omega_n = \tfrac{n\pi}{L} \ . \end{aligned} \tag{6.6}$$

Delta-function expresses the fact that only discrete frequencies are allowed for the vacuum current and one can write the condensation amplitude as a sum $iS_+ = i\sum_n iS_{+,n}$ over the allowed

frequencies ω_n. k_T refers to the transversal part of the wave vector orthogonal to the light-like vacuum current.

From this expression one can deduce the probability for the topological condensation of photon (k, λ) to a state containing $N(k, \lambda)$ photons as

$$|S(k,\lambda)|^2 \quad = \quad |\sum_n S_{+,n}|^2 (N(k,\lambda)+1)^2 \ , \tag{6.7}$$

Clearly, $(N(k, \lambda) + 1)^2$ factor corresponds to the induced condensation. By a standard trick one can eliminate the square of the delta-function by replacing the condensation probability with condensation rate $R(k, \lambda)$ obtained by dividing condensation probability with $T \to \infty$ eliminating one delta function. Furthermore, one can calculate the transition rate to a set of final states by multiplying the expression thus obtained with the density of states factor $dN = d^3k$, which after the elimination of the second delta function effectively reduces to $\omega_n^2 d\Omega$. In this manner one obtains for the differential condensation rate a a rather neat expression in terms of the vacuum current

$$\begin{array}{l} \frac{dR(k,\lambda,n)}{d\Omega} = \frac{\pi}{2}\omega_n L^2 |M(k,\lambda|^2 (N(k,\lambda)+1)^2 \ , \\ M(k,\lambda) = i \sum_{\lambda_1} \int d^3k_1 J(\omega_n, k_T^1) c(k^1, k) X(k_1, \lambda_1) \ , \\ X(k_1,\lambda_1) = \frac{exp(ik_z^1 L)-1}{ik_z^1 L} p \cdot e_{\lambda_1} e_{\lambda_1} \cdot e_\lambda \ . \end{array} \tag{6.8}$$

From this expression it is clear that resonance indeed occurs and at the limit $L \to \infty$ the rate for condensation diverges as L^2. In this expression the overlap integral $c(k_1, k_2)$ carries information about the geometry of the space-time sheet associated with the "device" whereas $J(\omega_n, k_T)$ characterizes the vacuum current and the remaining factor X is a purely "kinematic" factor.

REFERENCES

Theoretical Physics

Condensed Matter Physics

[D1] Barber BR et al. *Phys Rev*, 72(9):1380, 1994.

[D2] Iranzo DA et al. Probing the ultimate plasmon confinement limits with a van der Waals heterostructure. *Science.* Available at: `http://science.sciencemag.org/content/360/6386/291`, 360(6386):291–295, 2018.

Fringe Physics

[H1] Thomas Townsend Brown. Available at: `http://www.virtualtheater.com/ttbrown-01.html`.

[H2] Burridge G. In *Townsend Brown and his antigravity discs*, 1994.

[H3] Rose M. "The Flying Saucer". The Application of the Biefield-Brown Effect to the Solution of the Problems of Space Navigation. Available at: `http://www.soteria.com/brown/docs/rose.htm`, 1952.

Biology

[I1] Kaivarainen A. Abstract of conference: Toward a science of consciousness-iii, 1998, no: 1078, tucson, usa, 1998.

[I2] Koruga D. Micro-tubule screw symmetry: packing of spheres as a latent bioinformation code. *Ann Ny Acad Sci*, 466, 1974.

[I3] Gariaev P et al. *The DNA-wave biocomputer*, volume 10. CHAOS, 2001.

[I4] Albrecht-Buehler G. Surface extensions of 3T3 cells towards distant infrared sources. *J Cell Biology*, 114:493–502, 1991.

[I5] Fröhlich H. The extraordinary dielectric properties of biological materials and the action of enzymes. *Nature*, 72(1968):641–649, 1975.

[I6] Matter-Walstra K. Unasked questions. Available at: `http://www.datacomm.ch/kmatter/unaskq.htm`, 1999.

[I7] Buchanan M. Shape is all. *New Scientist*, 2157, 1998.

[I8] Rattemayer M Nagl W, Popp F-A. Evidence of Photon Emission from DNA in Living Systems. *Naturwissenschaften*, 68(5):577, 1981.

[I9] Callahan PS. Moth and Candle: the Candle Flame as a Sexual Mimic of the Coded Infrared Wavelengths from a Moth Sex Scent. *Appl Opt*, 16(12), 1977.

Neuroscience and Consciousness

[J1] A Secret Sense in The Human Nose? Available at: `http://www.hhmi.org/senses/`.

[J2] Gibbons A. Solving the Brain 's Energy Crisis. *Science*, 280, May 1998.

[J3] Baars BJ. Understanding Subjectivity: Global Workspace Theory and the Resurrection of the Observing Self. *J Conscious Stud*, 3(3):211–16, 1996.

[J4] Pert CB. *Molecules of Emotion*. Simon & Schuster Inc., 1997.

[J5] Nanopoulos DV. Theory of Brain function, Quantum Mechanics, and Superstrings. Available at: `http://arxiv.org/abs/hep-ph/9505374`, 1995.

[J6] Jibu M et al. Quantum optical coherence in cytosceletal microtubules: implications for brain function. *Biosystems*, 32, 1994.

[J7] Hitt J. This is Your Brain on God. *Wired* . Available at: `http://www.wired.com/wired/archive/7.11/persinger_pr.html`, 1999.

[J8] Pribram KH. The Neurophysiology of Remembering. *Sci Am*, January 1969.

[J9] Pietch P. Shuffle Brain : the The Quest for Hologramic Mind. Available at: `http://www.indiana.edu/~pietsch/shufflebrain-book00.html`, 1972.

[J10] Yogananda P. *Autobiography of Yogi*. Self-Realization Fellowship, 1993.

[J11] Penrose R. *Shadows of the Mind*. Vintage, 1994.

Books related to TGD

[K1] Pitkänen M. Basic Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: `http://www.tgdtheory.fi/tgdhtml/tgdgclass.html#class`, 2006.

[K2] Pitkänen M. Bio-Systems as Conscious Holograms. In *Bio-Systems as Conscious Holograms*. Online book. Available at: `http://www.tgdtheory.fi/tgdhtml/holography.html#hologram`, 2006.

[K3] Pitkänen M. Conscious Information and Intelligence. In *TGD Inspired Theory of Consciousness*. Online book. Available at: `http://www.tgdtheory.fi/tgdhtml/tgdconsc.html#intsysc`, 2006.

[K4] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#eegdark, 2006.

[K5] Pitkänen M. Dark Nuclear Physics and Condensed Matter. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/neuplanck.html#exonuclear, 2006.

[K6] Pitkänen M. Does TGD Predict the Spectrum of Planck Constants? In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/neuplanck.html#Planck, 2006.

[K7] Pitkänen M. General Ideas about Many-Sheeted Space-Time: Part I. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#topcond, 2006.

[K8] Pitkänen M. General Theory of Qualia. In *Bio-Systems as Conscious Holograms*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/holography.html#qualia, 2006.

[K9] Pitkänen M. Macroscopic Quantum Phenomena and CP_2 Geometry. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#super, 2006.

[K10] Pitkänen M. Quantum Antenna Hypothesis. In *Quantum Hardware of Living Matter*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/bioware.html#tubuc, 2006.

[K11] Pitkänen M. Quantum Model for Nerve Pulse. In *TGD and EEG*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#pulse, 2006.

[K12] Pitkänen M. Quantum Model of EEG. In *TGD and EEG*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#eegII, 2006.

[K13] Pitkänen M. TGD and Nuclear Physics. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/neuplanck.html#padnucl, 2006.

[K14] Pitkänen M. The Notion of Free Energy and Many-Sheeted Space-Time Concept. In *TGD and Fringe Physics*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/freenergy.html#freenergy, 2006.

[K15] Pitkänen M. Was von Neumann Right After All? In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/padphys.html#vNeumann, 2006.

[K16] Pitkänen M. About Preferred Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#prext, 2015.

[K17] Pitkänen M. TGD View about Coupling Constant Evolution. In *Towards M-Matrix*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdquantum.html#ccevolution, 2018.