The computation power of living systems is maintained by decoherence-free internal quantum states

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Abstract: The internal quantum state (IQS) is a kind of a pilot-wave (in the Bohmian sense) attached to a macroscopic system and representing its potential field continuously reduced during its exhibition to the external world. This state is maintained as decoherence-free by applying error-correction commands to it and by screening from thermal interactions. Its effective temperature is kept down below the millikelvin range thus being screened even from the background microwave radiation. The quantum Zeno effect enables coherent superpositions and entanglement to persist for macroscopic time intervals. The IQS thus avoids the Boltzmann statistics and approaches a state when the Bose-Einstein statistics is applicable. The IQS of a living system can be viewed as a subtle individual subatomic structure reduced to a complex pattern of vibrating strings and exhibiting itself via a visible classical body-like system. Light quanta inside IQS are trapped like matter is trapped by a black hole in space. The IQS can be considered as a unified field meeting place of gravitational, electromagnetic, weak and strong nuclear forces. The phenomenon of emission of weak coherent light is an indirect evidence of coherent long-living internal quantum states in living systems. This emission is a kind of a similar phenomenon as the Hawking's radiation from black holes and it may serve for unification of the processes taking place in different subsystems of a biological system (synchronization of individual coherent states within the whole system). The external exhibition of the IQS can be expressed as a mapping from complex to real numbers where the certain rules are generated, e.g. the power law and other recursive formulae. In the simplest case when two superposed states are reduced, it has a limit of price of action equal to the Planck's constant. The reduction is non-computable and resembles the act of volition. The result is Gödel number appearing above superposed states and memorizing the act of reduction. It is used by living system as an information unit in emerging computation process.

Keywords: coherence; computation; internal quantum state; monad; quantum measurement

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1 Introducing numbers

According to Pythagoras, the basis of the world is number. But how the numbers appear? Really some energy or action (the fire, *Pyr*, in terms of Heraclitus) (which could be quantified, i.e. numberized itself) has to be applied to introduce numbers into real world. I.e. a number is needed to introduce the number. A number is used to establish the set of numbers similarly as the Cretean establishes the set of Creteans-liars in the Epimenides paradox. Thus the semiotic paradox (having the same structure as the Epimenides paradox) is applied in the introduction of mathematics to real physical world [1]. The fixation of this paradox in the physical world involves some minimum quantified price of action to introduce a number, i.e. a kind of the value that is non-computably embedded to link mathematical operations to the parameters of the existing physical world.

As it was mentioned by Liberman [2], mathematics and physics have no simple connection. Physics implies that the world is intrinsically deterministic (externally viewed), while mathematics implies an internalist view that it can be controlled if we know an equation. The presence of a physical law described by the mathematical formula means that the process could be controlled if we compute it. But there is a physical limitation of computation: any calculation action has a price. Addition of one takes energy, and this energy cannot be zero. This means that the control is limited: if the price of action is high, the process cannot be controlled. Determinism is a state appearing after applying the control. I.e. physics describes the world after mathematics is applied to it, i.e. physics in some sense is an applied mathematics. Really, the fundamental constants of physics are the primary parameters for the embedding of computation into real world.

If we divide space, ideally we can do this infinitely. However, the real space cannot be like this: movement in such space is impossible, which is proven by Zeno paradoxes. For the division of space we should apply a certain amount of energy, which cannot be infinitely small in a given real world. This means that the smallest amount of energy being introduced to separate two points, i.e. to establish a division, which can introduce a number (e.g. add one), has a certain value specific for the existing world. This determines the smallest space and time intervals defined (in our world) through the Planck's constant. Below the Planck scale, "the conventional notions of space and of distance between points melt away, leaving us in a vastly different conceptual landscape" [3, p.379]. On scales larger than the Planck's length "our conventional notion of space does re-emerge" [3]. This means that in real physical world there should be a materialized analogy to the infinitesimal [4], to quantify it and "resolve" (or "hold") the Zeno paradox. It is determined by physical impossibility to divide space or time below certain values, which contradicts to pure mathematical models. This idea of minimum measurement is quantum mechanical. It establishes a non-computable definition of the value that is needed to introduce the value (number) in the real world. Zeno paradox is solved via the physical impossibility of infinite division of the space-time. We need a minimum quantity (indivisible "one") that introduces a quantity in the real world. This also shows that the Zeno paradox (the movement paradox) is a consequence of the semiotic paradox (generally of the Epimenides paradox) [1].

The minimum unit of the reality should correspond to the transition from potentiality to actuality. This is explicitly developed in Plato's dialogue Parmenides through the notion of the "exaipnes", i.e. of some non-computable event that introduces computation into real world [1, 5]. Really, Diogenes was not fully wrong by solving the kinematic paradox by walking: the physical (but not mental) impossibility of the infinite division of space in a given universe fixes the paradox and creates the set of physical laws via introduction of minimum price of action for calculation.

The elementary process (minimum action) can be defined as a Whitehead-type creative event of non-computable reduction of potentiality leading to formation of a state [6] described as a set of real numbers. It relates to other events via a relational space-time interaction. A unit that realizes such a process can be defined as the monad following Leibniz [4]. It is a unit that embeds mathematics into the real world via introducing the time that separates contradictory statements in space. Embedding is contradictory, but there should be a non-contradictory solution for separation of contradictory statements in time. That implies a possibility of holding the paradox within the Universe. The properties of time (one-dimensionness and irreversibility) are those that keep the paradox “alive” in the real world. Fixation of contradictory statements is possible by means of intrinsic logic of a given logical unit (topos) [7]. When we introduce time, which separates contradictory statements, we sink from the mathematical into the physical world and face infinite regression avoiding simultaneous existence of opposite definitions [8].

2 Leibnizean world

Leibniz [4] portrayed the Universe as an infinite set of fundamental units (monads), each having a psychological being, from primitive (as expressed in modern science in uncertainty in quantum reduction at subatomic levels) to the sophisticated (as in living beings having free will). A monad realizes non-computable choice, i.e. makes a decision. The space, according Leibniz, is a pattern of coexistences and the whole world is a universal harmony (mutual complementarity) of monads. Each monad has its own time consisting of the set of points of view (reflections) of the monad on itself, while the space is a set of points of view on the whole. In other words, the space is a set satisfying the principle of the universal harmony of monads, and there should be certain parameters uniting time and space, satisfying the principles of coexistence of monads, i.e. of observability of the world. Such a representation of the world derives its objectivity from the relativity of a single picture represented by a monad’s point of view. This relativity means uncertainty in the formal representation of the view of the single monad. Evolution serves as an engine to overcome such uncertainty, the process open into infinity and without frames.

One special case of the pre-established harmony accounts for the apparent interaction of mind and body in a human being as nothing more than the perfect parallelism of their functions. In fact, the human mind is just the dominant member of a local cluster of monads, which collectively constitute the associated human body (Monadology §63) [4]. Individual substances stand in spatial relation to each other, but relations of this sort are reducible in logic to the non-relational features of windowless monads. In exactly the same way, temporal relations can be logically analyzed as the timeless properties of individual monads. “An invisible harmony is better than a visible one” (Heraclitus, fragment 54) [9]. Realization of computation could be possible only at certain fundamental symmetries serving as preconditions. These symmetries correspond to fundamental physical laws.

In modern physics, the pre-established harmony corresponds to the formulation of the anthropic principle. Mathematically expressed physical parameters may strictly correspond to observability of the world by embodied living organisms having internal digital structure with the alphabet and grammar, which generates a unique solution for the appearance of free will and consciousness [10]. The existing values of fundamental constants and dimensionality of space-time may represent the only solution for the existence of shielded coherent states corresponding to living states and consciousness. But we probably cannot prove this only solution mathematically; we can only get sets of empirical data that this solution fits to the observability of real world. In other words, we can prove the validity of fundamental constants as Diogenes proved the existence of movement, by walking.

3 Measurement and its price

Any event can be described as a reduction of potentiality represented as a mapping from complex to real numbers. In the simplest case when two superposed states are reduced, it has a limit of price of action equal to the Planck's constant [2]. Since it is non-computable, the reduction resembles the volition act. The result is a number appearing above superposed states. The minimum time of the reduction is the Planck's time, while the minimum length is the Planck's length. These values correspond to a putative black hole with the Planck's density, which inflates into a Universe.

The presented picture can be described following Penrose [11, 12] and his twistor theory in a way that there is no preexisting geometry for space, no fixed reference points: everything is dynamic and relational. The fundamental things in the world are processes ("volitions"). The things exist only by virtue of the meetings of the intersections of processes (quantum measurements). The quantum measurement is a basic non-computational physical process. The fundamental constants appear as a correspondence of measurement (embedding mathematics) to the consistency of the actual world. They divide the world in two parts: one being recursive (in which physical laws are operating), and the other is non-recursive (where algorithmic operations are impossible) [13]. It appears that below the Planck's time, there is no measurable amount of time and below the Planck's length there is no measurable amount of space. This corresponds to modern views that the black holes (defined as gravastars in this approach) can collapse down to the Plank length but not to a zero scale [14] and this establishes the limits of the third law of thermodynamics in approaching the zero-temperature final state of the black hole [15].

The wave functions that involve superpositions of spatially separated wavepackets should also have superpositions of the gravitational fields associated with the distinct mass distributions of the wavepackets [12]. The gravitational field states involved in superposition require different space-times among which a point-wise identification is not possible due to covariance. Under these conditions, it is not possible to define a unique time-translation operator and the very concept of stationary state. This leads to uncertainty of energy, which makes such spatially superposed states inherently unstable.

A particle exhibits the quantum behavior according to the Schrödinger equation only over a length scale, which depends on the mass of the particle [16]. Beyond this scale, the behavior is dominated by gravitational effects which do not permit spatial superpositions and may lead to classical-like behavior. The Planck's mass (which value is high being of the order of 10^{-5} g) corresponds to the energy at which the gravitational force between particles becomes stronger than the electroweak or the strong forces [16]. In terms of quantum mechanics, real times of measurement form concrete patterns of interactions leading to realization of coherent events and formation of spatial structures.

4 Internal quantum states

In living systems, there should be mechanisms that preserve coherence over a time of the order of a second. A reaction region enveloped in an enzyme molecule will be partly screened from the van der Waals-mediated thermal interactions from the rest of the cell. Similarly, the histone wrapping of DNA might serve to shield coding protons from decoherence [17]. Organisms exploit thermodynamic gradients by acting as heat engines to drastically reduce the effective temperature of certain macromolecular complexes. The effective temperature of the coherent state of the actomyosine complex was calculated (from emitted quanta) as near 10^{-3} K [18]. In the processes associated with mind, the effective temperature can be much lower.

The coherent state with very low temperature is delocalized. Coherent states involving Bose-Einstein condensation (the most ordered form of condensed phase possible when a macroscopic number of particles occupies the same single-particle state) actually bridge the gap between micro and macroscales, realizing the “prehension” [6] of single points into total entities [19]. The screened regions forming decoherence-free subspaces can also be shielded by error-correction [20]. When a system couples very strongly to its environment through certain degrees of freedom, it can effectively freeze other degrees of freedom by a sort of quantum Zeno effect, enabling coherent superpositions and even entanglement to persist [21]. The situation is that unexpectedly long decoherence times exist in biological systems allowing maintenance of internal quantum states.

The problem is if calculated values of millikelvin range in biological macromolecules can drop down to the scale of tens or hundreds nanokelvin necessary to maintain Bose-Einstein condensate, i.e. to avoid the Boltzmann statistics inherent to macromolecular systems. Probably both screening from thermal interactions and error-correction can drop internal temperatures down to such low temperatures [10, 17]. The effective temperature of the actomyosin complex was calculated according to the time of its conformational relaxation and the amount of quanta emitted. But the ATP-linked actomyosin processes support more subtle coherent phenomena of maintaining living system entity, which could be much colder. Really there should be processes in living systems (particularly in long-size microtubules of nervous system) [22, 23] that correspond to emitting much less quanta and hence to supercold effective temperatures orders of magnitude below that calculated by Matsuno and Paton [18]. The protein-based circuits in bacteria are based on structures strikingly similar to the microtubule protein, tubulin [24].

What happens when temperature drops down to such low values? We approach the state described by Bose-Einstein statistics and likely present in the regions of the Universe shielded from the temperature of microwave radiation of the Big Bang, which currently is 2.7 K. Such shielded states exist in black holes or gravastars [14]. Gravastars are quark stars, analogously as neutron stars exist and represent a gravitational version of the Bose-Einstein condensate. These states can be also modeled in supercold fluids [25-27]. Light inside such a fluid can become trapped into the inescapable grip of the vortex much like matter is trapped by a black hole in space [28-30]. The point of no return is the event horizon. Sound waves are trapped in these areas of moving fluids like light in black holes. According to [31], this state traps phonons (particles of sound) in much the same way that a black hole traps photons and there is a sonic analog of black hole. This black hole-like state is the virtual state having no distinct localization in the space-time. The gravitational Bose-Einstein condensate is all composed of an identical wave function [32]. It consists of particles created in pairs out of the vacuum near the edge of black hole. This is the place where four fundamental forces come together.

The IQS can be considered as a meeting place of gravitational, electromagnetic and weak and strong nuclear forces (unified field). The low-energy Bohm quantum qualia pilot wave (or quantum potential or IQS) [33] is supplemented by direct back-action of the material Fröhlich [34] modes of the macromolecules on its attached pilot wave. According to Sarfatti [35], the distinction between dead and living matter is that for dead matter the quantum wave function acts on the matter but is not acted upon by the matter. What defines life is the action of sufficiently organized matter back on its own wave function (internal non-demolition measurement)[35]. Gödel numbers are needed to this kind of control.

Fröhlich [34] explained biological activity as a result of the collective vibrations of electric dipoles in biomacromolecules. As we can add from the quantum mechanical point of view, to these vibrations an IQS (quantum "Bohm pilot-wave") is attached. It governs Fröhlich-like vibrations via Hamilton-Jacobi force [35] with the minimum price of action of the value of Planck's constant. The operation of quantum reduction of wave function realized in biosystems by macromolecular devices is a background of the infinite recursion, thus the actual irreversibility and time flow. The relevant particles are electrons whose spatial displacement controls the conformations of the protein molecules. The idea of the living system doing a quantum computation requires that there be no collapse or decoherence whilst the computation is in progress [36,37].

The initial evidence of coherent long-living quantum states in living systems is a phenomenon of emission of weak coherent light discovered by Gurwitsch [38] in early XX century [39]. It is worth to note that the emission of quanta during actomyosin contraction allowed calculation of effective temperature of its internal coherent state [18]. Recently a strong evidence of ultraweak photon emission was demonstrated [40]. This emission is a kind of the same phenomenon as Hawking's radiation from the black holes [41] and it may serve for unification of the processes taking part in different subsystems of biological system (synchronization of individual coherent states), i.e. serve as a kind of informational field as originally proposed by Gurwitsch [38]. The internal quantum state of a living system is a subtle individual subatomic structure and really can be reduced to a complex pattern of vibrating strings, which exhibits itself via a visible classical body-like system.

5 Theoretical biology as applied metamathematics

In biological world, real numbering appears as Gödel numbering and the digital computation is a result of such embedding of Gödel numbers [1, 10]. Gödel numbering appears only in complex formal systems. We have mentioned that the structure of the potential field of the internal quantum state is self-contradictory. Actualization ends up this self-contradiction realizing one possibility from many. But the measurement itself remains self-contradictory before we do not consider it as occurring with finite velocity [42-44]. Otherwise it will contain contradictory statements at the same moment of time.

Describing a system in which internal detection proceeds with a finite velocity is always destined to end up with a form of self-contradiction [44]. Hierarchical structures will arise through interference between local and global description. Decoherence of a continuously measured system is completely determined by the measurement readout, i.e., by the information recorded in its environment. Information plays a dynamic role in quantum mechanics, determining the back influence of the measuring medium onto the measured system. Finite velocity in continuous measurement provides that decoherence may be described as a continuous (prolonged in time) measurement.

Gunji's model [42,44] implies the notion of relativity of any resolution of the paradox. In a dynamical system a certain transition rule is used recursively along time. In order to resolve the paradox, we identify the form of a fixed point with a domain equation and obtain a reflective domain, however we simultaneously show that any resolution is relative. Solving and obtaining a reflexive domain is used as a new transition rule. Finite velocity of observation propagation thus collapses into fractal structure. In Gunji's approach, the notion of relativity of any resolution of the paradox is implicit. In order to resolve this paradox, a system identifies the form of a fixed point with a domain equation and obtains a reflective domain. This process perpetually proceeds along time, and then the system perpetually proceeds while any solution is destined to be relative [44].

Newly generated structure is put into correspondence not to the previously existing reality, but to the changed reality non-recursively modified after the inclusion of this structure in it. The developing (evolving) system realizes the reflection to the area, which is not defined before. It should be compatible with the maximal number of existing things. Transformation therefore is analogous to the creation of new formulae (Gödel numbers), which were absent in the initial formalized calculus. An active combinatorial process of self-modification of information, being an internalized language game, allows a system to generate wider possibilities for creating Gödel numbers. A new solution appearing during the evolution of a formal system cannot be obtained in a recursive combinatorial way. Therefore evolution cannot be predicted with certainty, it can only be prognosticated with more or less exactness.

The phenomenon of actualization corresponds to a reflection from the infinite set of potentialities into a finite set of actualized elements in the frames of the self-referential process [8, 10, 45]. For its description only spatial relations are insufficient: the irreversible time flow separates the references to the whole (the set of potentialities) representing a biosystem and to its finite actualized model. The choice of a definite set of quantum reduction parameters is determined by its consistency and optimality in the whole system. The increase in complexity occurs simply as a result of perpetual solution of the semantic/ measurement paradox [46]. The evolution, viewed as an internalist continuous measurement in the system "living organism plus environment", becomes its own cause, a universal property of our world.

6 Internal quantum states and the problem of self

Liberman [2, 47, 48] suggested that the internal self refers not to molecular but to quantum structures. Intranuclear distances ($<10^{-25}$ cm) are characterized by the properties of "local freedom" when the interactive forces are decreased. Colored quarks move at such small distances independently but they cannot separate from each other: their interaction force does not decrease with the distance. E.g. the visual perceptive system consists of the color *3D* display separated from "me" who is looking on it. The hypothesis of Liberman is that at these distances there is no need for the separation between "me" and "monitor", they both can be a polarization of the vacuum which is caused by the pictures of distribution in space of the quarks (or even strings) responsible for our senses. Liberman [2] mentions in this connection a possibility of interpretation of music via electromagnetic field distributing in the system which is close to the absolute zero in normal conditions. We come to the concept that the consciousness phenomena are possible as shielded from decoherence in the Bose-Einstein condensate state [49].

Inside the regulatory system its internal volition-based behavior occurs that an external observer describes via the probability (wave) function. The cause of such a behavior always represents non-computable decision of the controlling system (monad) preceding a control. When we formalize living system, we transform it into a program for a macroscopic computer without the internal point of view and the freedom of will. Internal measurements occur by internally attached observer (Bohm´s pilot-wave) and they are non-computable. They may be computed from the time future, i.e. from the perfection of the final cause. A quantum superposition (actual separation of mass from itself in Penrose's concept) is equivalent to simultaneous space-time curvatures in opposite directions, causing bubbles or separations in fundamental reality [11, 12]. They are unstable and become reduced after a critical degree of separation equal to the Planck's mass. In the uncertainty principle $E = \hbar/T$, E is the energy of the superposed mass, $\hbar$ is the Planck's constant, and T is the coherence time until reduction. The size (and energy) of a superposed system is inversely related to the time T until self-collapse. The result of collapse may be estimated from the time future as being compatible to a larger number of existing events than an alternative result, in correspondence with the unpublished (in his life time) logic of Leibniz [50].

The problem of internal self and consciousness is how a device evolves that detects the rest of the world [51]. We assume that the consciousness and social human being appear when the meaning of a whole is encoded in the semiotic system as a Gödel number [1]. A human being thus can model a picture of the reality as something external but in which he is embedded. Measuring this reality means that both measuring object and the measured reality are perpetually changing. This determines the social development of the mankind whilst the embedding actual infinity means the beginning of social evolution [1].

The molecular-based body of organism with Gödel numbers encoded in the genome is linked to an attached internal quantum state. Until the organism is alive, it keeps connection to this state. The anthropic principle is a direct consequence of such structure of the world. Human minds can see the truth or falsity of the statements (Gödel sentences) that are non-computable. They can intuitively solve certain machine-unsolvable problems (such as Kurt Gödel's problem of recognizing the consistency of arbitrary sets of axioms or Alan Turing's halting problem for Turing machines). The consequences of such incomputability are the Saussurean arbitrariness (contingency) of sign, the idea of Chomsky [52] of indefiniteness in generative mechanisms as a requirement for the explanation of semiotic creativity and the notion of Kolmogorov [53] about the randomness defined as sequential incompressibility.

We observe the outside world from the black hole-like coherent state and our perceptions (of color, sound etc.) are quantum phenomena linked to macroscopic processes such as wavelengths, sound waves etc. At the quantum (Bose-Einstein) level, there will be no division on subject and object and our perceptions arise as polarizations of the Bose-Einstein state generating the observed pictures [2]. The human thought and any decision-like activity of living beings can be described as a non-computable process of generation of Gödel numbers [44, 45, 54]. The system as a whole (this may be highly organized brain or simply an evolving system "organism plus environment") decides whether the statement (Gödel number) is true. Such mathematical process (generation of Gödel numbers) has an analogy in the background physical reality (actualized world). This analogy is the quantum mechanical reduction, occurring as an internal measurement.

7 References

[1] Igamberdiev, A.U. Semiosis and reflectivity in life and consciousness. *Semiotica* **1999,** *123,* 231-246.

[2] Liberman, E.A. Molecular quantum computers. *Biofizika* **1989**, *34*, 913-925.

[3] Greene, B. *The Elegant Universe.* Vintage Books; N.Y, 2000.

[4] Leibniz, G.W. *Opera Omnia (Vols 1-6).* Dutens L, ed.; Geneva, 1768.

[5] Igamberdiev, A.U. Semiokinesis – Semiotic autopoiesis of the Universe. *Semiotica* **2001,** *135,* 1-23.

[6] Whitehead, A.N. *Process and Reality.* Macmillan, London, 1929.

[7] Goldblatt, R. *Topoi, the Categorial Anaysis of Logic*. North Holland; Amsterdam, 1979.

[8] Igamberdiev, A.U. Time, reflectivity and information processing in living systems. A sketch for the unified information paradigm in biology. *BioSystems* **1998,** *46,* 95-101.

[9] Heraclitus. *Fragments*, trans. by T.M. Robinson. University of Toronto Press, Toronto, 1987.

[10] Igamberdiev, A.U. Quantum computation, non-demolition measurements, and reflective control in living systems. *BioSystems* **2004,** *77,* 47-56.

[11] Penrose, R. Angular momentum: an approach to combinatorial space-time. In: *Quantum Theory and Beyond* (Bastin, E.A., ed.). Cambridge University Press; Cambridge, 1971, pp. 151-180.

[12] Penrose, R. On gravity's role in quantum state reduction. *General Relativity and Gravity* **1996,** *28,* 581-600.

[13] Conrad, M., Liberman, E.A. Molecular computing as a link between biological and physical theory. *Journal of Theoretical Biology* **1982,** *98,* 239-252.

[14] Mazur, P.O., Mottola, E. Gravitational vacuum condensate stars. *Proceedings of the National Academy of Sciences, USA* **2004,** *101,* 9545-9550.

[15] Liberati, S., Rothman, T., Sonego, S. Extremal black holes and the limits of the third law. *International Journal of Modern Physics D* **2001,** *10,* 33-39.

[16] Kumar, D., Soni, V. Single particle Schrödinger equation with gravitational self-interaction. *Physical Letters A* **2000,** *271,* 157-166.

[17] Davies, P.C.W. Does quantum mechanics play a non-trivial role in life? *BioSystems* **2004,** 78, 69-79.

[18] Matsuno, K., Paton, R. Is there a biology of quantum information? *BioSystems* **2000,** *55,* 39-46.

[19] Igamberdiev, A.U. Foundations of metabolic organization. Coherence as a basis of computational properties in metabolic networks. *BioSystems* **1999,** *50*, 1-16.

[20] Nielsen, M.A., Chuang, I.L. Programmable quantum gate arrays. *Physical Review Letters* **1997,** *79,* 321-324.

[21] Kay, A., Pachos, J.K. Quantum computation in optical lattices via global laser addressing. *New Journal of Physics* **2004,** *6,* 126.

[22] Hameroff, S.R. 'Funda-Mentality': is the conscious mind subtly linked to a basic level of the universe? *Trends in Cognitive Science* **1998,** *2,* 119-124.

[23] Hameroff, S.R., Penrose, R. (1996) Conscious events as orchestrated space-time selections. *Journal of Consciousness Studies* **1996,** *3,* 36-53.

[24] Löwe, J., Amos, L.A. Crystal structure of the bacterial cell-division protein FtsZ. *Nature* **1998,** *391,* 203-206.

[25] Garay, L.J. Black holes in Bose-Einstein condensates. *International Journal of Theoretical Physics* **2002,** *41,* 2073-2090

[26] Fischer, U.R. Quasiparticle universes in Bose-Einstein condensates. *Modern Physics Letters A* **2004,** *19,* 1789-1812.

[27] Fedichev, P.O., Fischer, U.R. (2004) Observer dependence for the phonon content of the sound field living on the effective curved space-time background of a Bose-Einstein condensate. *Physical Review D* **2004,** *69,* 064021.

[28] Leonhardt, U., Kiss T., Ohberg, P. A laboratory analogue of the event horizon using slow light in an atomic medium. *Nature* **2002,** *415,* 406-409.

[29] Leonhardt, U., Kiss T., Ohberg, P. Theory of elementary excitations in unstable Bose-Einstein condensates and the instability of sonic horizons. *Physical Review A* **2003,** *67,* 033602.

[30] Juzeliunas, G., Ohberg, P. Slow light in degenerate Fermi gases. *Physical Review Letters* **2004,** 93, 033602.

[31] Barcelo, C., Liberati, S., Visser, M. Towards the observation of Hawking radiation in Bose-Einstein condensates. *International Journal of Modern Physics A* **2003,** *1,* 3735-3745.

[32] Silverman, M.P., Mallett, R.L. Coherent degenerate dark matter: a galactic superfluid? Classical and Quantum Gravity **2001,** *18,* L103-L108.

[33] Bohm, D., Hiley, B.J. *The Undivided Universe*. Routledge, London, 1993.

[34] Fröhlich, H. Evidence for coherent excitations in biological systems. *International Journal of Quantum Chemistry* **1983,** *23,* 1589-1595.

[35] Sarfatti, J. The End of Quantum Theory. http://www.qedcorp.com/pcr/mmq.html

[36] Mensky, M.B. Continuous quantum measurements and the action uncertainty principle. *Foundations of Physics* **1992,** *22,* 1173-1193.

[37] Mensky, M.B. Decoherence in continuous measurements: from model to phenomenology. *Foundations of Physics* **1997,** *27,*1637-1654.

[38] Gurwitsch, A.G. Versuch einer synthetischen Biologie. *Schaxels Abhanglungen der Theoretische Biologie* **1923,** *17,* 1-83.

[39] Gurwitsch, A.G., Gurwitsch, L.D. *Die Mitogenetische Strahlung*. Fischer; Jena, 1959.

[40] Popp, F.A., Chang, J.J., Herzog, A., Yan, Z., Yan, Y. Evidence of non-classical (squeezed) light in biological systems. *Physical Letters A* **2002,** *293,* 98-102.

[41] Barcelo, C., Liberati, S., Sonego, S., Visser, M. Causal structure of analogue spacetimes. *New Journal of Physics* **2004,** *6,* 186.

[42] Gunji, Y.P. Autonomic life as the proof of incompleteness and Lawvere's theorem of a fixed point. *Applied Mathematics and Computation* **1994,** *61,* 231-267.

[43] Gunji, Y.-P., Ito G. Orthomodular lattice obtained from addressing a fixed point. *Physica D* **1999**, *126*, 261-274.

[44] Gunji, Y.-P., Ito K., Kusunoki Y. Formal model of internal measurement: Alternate changing between recursive definition and domain equation. *Physica D* **1997**, *110*, 289-312.

[45] Igamberdiev, A.U. Quantum mechanical properties of biosystems: A framework for complexity, structural stability and transformations. *BioSystems* **1993,** *31,* 65-73.

[46] Matsuno, K. Quantum and biological computation. *BioSystems* **195,** *35,* 209-212.

[47] Liberman, E.A. Analog-digital molecular cell computer. *BioSystems* **1979**, *11*, 111-124.

[48] Liberman, E.A. Extremal molecular quantum regulator. *Biofizika* **1983**, *28*, 183-185.

[49] Marshall, I.N. Consciousness and Bose-Enstein condensates. *New Ideas in Psychology* **1989,** *7,* 3-83.

[50] Font, J.M., Jansana, R. Leibniz filters and the strong version of a protoalgebraic logic. *Archive for Mathematical Logic* **2001,** *40,* 437-465.

[51] Gunji, Y.P., Kamiura, M. Observational heterarchy enhancing active coupling. *Physica D – Nonlinear Phenomena* **2004,** *198,* 74-105.

[52] Chomsky, N. *Aspects of the Theory of Syntax.* MIT Press; Cambridge, MA, 1965.

[53] Kolmogorov, A.N. Three approaches to the quantitative definition of information. *Problems of Information Transmission* **1965,** *1,* 1-17.

[54] Hu, H., Wu, M. Spin-mediated consciousness theory: possible roles of neural membrane nuclear spin ensembles and paramagnetic oxygen. *Medical Hypotheses* **2004,** *63,* 633-646.