Article

Extensive Quantum Biology, Applications of Nonlinear Biology and Nonlinear Mechanism of Memory

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ABSTRACT

Based on the extensive quantum theory in which the formulations are the same with the quantum mechanics and only quantum constant *h* is different. We propose the extensive quantum biology. Then the fractal, chaos and soliton in nonlinear biology and neurobiology are discussed, in which soliton may keep the integrality and veracity of information in neural transfer. Finally, the nonlinear mechanism of memory is researched.

Key Words: biology, quantum theory, nonlinearity, neurobiology, fractal, chaos, soliton, memory

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1. Introduction

Nowadays the hotspots of biology are molecular biology, cell biology and neural biology, and quantum and complicated biology. Haken (1996; 2002) proposed and investigated the principles of brain functioning and the brain dynamics (synchronization and activity patterns in pulse-coupled neural nets with delays and noise).

Conte *et al.,* (2011) researched the dynamics of living matter in the fields of the basic foundations of quantum mechanics by Clifford algebra, and applied to the analysis of perceptive and cognitive functions in humans, and obtained experimental results that are of basic significance in the fields of neuroscience and of psychology. Tarlaci (2011) ask a problem: Until today, we still do not know what glue binds together neural activity to sub-cellular molecular mechanisms or the phenomenon which we call mind to our organic brain. What kind of an equation could this quantum physical/mechanical equation be, which would join mind/consciousness using the knowledge which we have or may have in the future? If such a linking equation were to be found, it would surely give rise to a new age in physics, the queen of existence and science.

Based on the inseparability and correlativity of the biological systems, we proposed the nonlinear whole biology and four basic hypotheses. It may unify reductionism and holism, structuralism and functionalism. Further, the loop quantum theory as new method is applied to biology, and obtained the model of protein folding and lungs (Chang, 2001; 2008).

2. The extensive quantum theory

We found that the average distances (the Titius-Bode law) between the Sun and planets may be a new form (Chang, 1993; 2002):

$$r_n = an^2, \quad (1)$$

where a is a constant and n is an integer. If let $a_1 = 0.042$, the values n=3,4,5,6 will be referring to the terrestrial planets, n=7,8 to asteroids. For $a_2 = 1.2, n$ =2,3,4,5,6, this form describes the Jovian planets. Using a similar method of the Bohr atom model, the theory can be developed, and obtained the quantum constants of the solar system

$$H = (aGM_{\odot})^{1/2} = 1.15203218 \times 10^{10} a^{1/2}\, m/sec. \quad (2)$$

Here

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$$H_1 = 9.1317\times10^{14} m^2/\sec, H_2 = 4.8811\times10^{15} m^2/\sec. \quad (3)$$

Based on the fluid dynamical equation and the continuity equation of diffuse interstellar matter in the celestial evolution, we derived the astronomical Schrödinger equation

$$iH\frac{\partial\psi}{\partial t} = -\frac{1}{2}H^2\nabla^2\psi + (U-Q)\psi, \quad (4)$$

where Q is a quantum potential, and the distance rule is a statistical result of planet evolution (Chang, 1993; 2002).

The quantized Hall effects have exhibited macroscopic quantized phenomena (von Klitzing, 1986). Using the above method, it can be constructed similarly that the astronomical quantum theory has the same formation with the present quantum theory. Of course, some questions in nature are not solved, for example, whether or not there is a star whose densities of energy and momentum may be expressed by $\varepsilon = Hv, P/m = H/\lambda$, whether or not the similar uncertainty principle holds. But various soliton waves, which are waves and are also like-particles, exist widely from small particle to gigantic universe (Scott *et al.,* 1973). It implies that the wave-particle duality is a cosmic universal property, perhaps. Based on the cosmic duality (Chang, 2002; 2010), we can develop the cosmic quantum theory. Furthermore, based on the fluid dynamical equation, which corresponds to wide existence of the diffuse matter in the universe, or on statistics and stochastics possessed generally in the cosmic evolution (Wisdom, 1987), the Schrödinger equation and the cosmic quantum theory may be derived. Moreover, the form of the Schrödinger equation of free particle may be derived by a diffusion equation that corresponds to the big bang universe.

Further, we proposed the extensive quantum theory, in which the formulations are the same with the quantum mechanics, and only quantum constant h is different (Chang, 1993; 2002). From this and the middle value between the similar solar system and atom model, we obtained exactly the anthropic principle (Chang, 2002). Such the Universe shows perfection and harmony. It proved a viewpoint in "*Disturbing the Universe*" written by a well-known physicist Freeman Dyson (1979):

> "As we look out into the universe and identify the many accidents of physics and astronomy that have worked together to our benefit, it almost seems as if the Universe must in some sense have known that we were coming."

There is a known relationship between quantum field theory and statistical physics (Kogut, 1979; 1980), and statistics is also universal. The two aspects are combined each other, so the extensive quantum theory (Chang, 1992; 2002) can be produced. There are possibly some quantum systems whose formulations are similar to each other, but whose quantum constants are different. The symmetrical constructions of these quantum systems exist widely in the nature. It is a system whose mathematical forms and fundamental properties are invariant when the scaling (quantum constant) is transformed. It is similar to the extensive relativity (Chang, 1989), in which the formulations are the same with the relativity, and only various invariant velocities are instead of light velocity c (a scaling transformation). This type of extensive theory that possesses the scaling invariance should correspond to a certain renormalization group, and should have some fundamental characters of fractals.

3. The extensive quantum biology and various quantum constants

Based on the general Schrödinger equation, various models and different forms of quantum mechanics can be applied to biology and nature. From the statistical model and this form in quantum mechanics, the general Liouville equation can be introduced in biology. Perhaps, the statistical and stochastic chaotic liquid can evolve to the ordered quantized symmetrical cell system. The known science has shown that if fluctuations of a classical system with infinite degree of freedom are treated, a noncommutative operator will be introduced naturally, and a certain wave equation, which does not contain the Planck constant, will appear necessarily. In the biological evolutionary process the gaseous mineral with the infinite degree of freedom possess various fluctuations, and it may produce the quantized biology.

The ratio between the average distance of the earth to sun and the Bohr atomic radius is about 2.8270×10^{21}, it is a scale stridden across space. Assume that the extensive quantum theory is suitable for man, cell and macromolecule inside this scale, so the quantum constant of man is

$\hbar_1 = H_1 m_1 = (HM_0\hbar)^{1/2} = 4.3764\times10^5 kgm^2/\sec = \hbar\times$ (*large number*). (5)

A middle value between the solar mass and proton mass is *57.678kg*, which is about the mass of man, so $H_1 = 7.5876\times10^3 m^2/\sec$. In this case the space size is *2.8136m,* which is a middle value between both distances of the Earth-to-Sun and the Bohr radius (Chang, 2002). Matthews proved that the maximum height of man is about *3m* by a theory similar to Press' (Matthews, 1995). It agrees approximately with various characteristic values of man, and corresponds to the uncertainty relation $\Delta(mv)\Delta x \approx \hbar_1$ of man probably.

Further, there is nucleus around which cytoplasm and chondriosome, etc., exist in a cell. If the quantum constant of cell is $\hbar_2, \hbar_1/\hbar_2 = \hbar_2/\hbar,$ so

$$\hbar_2 = (\hbar_1\hbar)^{1/2} = 6.7933\times10^{-8} gcm^2/\sec = \hbar\times(large\ number)^{1/2} \quad (6)$$

The space size is

$(2.8136\times5.2918\times10^{-7})^{1/2} = 1.2202\times10^{-3} cm$,

it corresponds to the scale of cell, while the size of usual cell is about $(35-0.05)\times10^{-3} cm$. In this theory the masses are

$$(m_{man}m_p)^{1/2} = 3.1060\times10^{-10} g, (m_{small}m_e)^{1/2} = 4.6103\times10^{-13} g. \quad (7)$$

Since cells are varied, the above values seem to correspond to the masses of some cell nucleus or chondriosome, etc. Usual cell nucleus are smaller along with ripening, conversely, they are larger. It is analogous to the total volume of a star from larger to smaller in the evolutionary process of the star. A geometric average is taken between the Bohr radius and above scale, and then space size will be $(1.2202\times5.2918\times10^{-12})^{1/2} = 2.5411\times10^{-6} cm$, masses will be

$2.2793\times10^{-17} g$ and $2.0493\times10^{-20} g$. (8)

While length of myosin molecule is about $4.9\times10^{-6} cm$, molecular masses of macromolecule for protein and nucleic acid, etc., are $10^3 - 10^7$, *i.e.*, $10^{-21} - 10^{-17} g$. For instance, the molecular masses are about 10^6 for rRNA, and are 2×10^4 for tRNA. The quantum constant of a macromolecule is

$$\hbar_3 = (\hbar_2\hbar)^{1/2} = 8.4642\times10^{-18} gcm^2/\sec.$$

At present, it has been found that DNA of some cell nucleus has the satellite belt besides main belt. Short small satellite DNA, even middle satellite DNA, have been found in the genes of human insulin and α -globin (Freifelder, 1987). Perhaps, a new quantum biology, which has different quantum constants, is suitable for those quantum biological phenomena, and will be able to apply to the biological macromolecule, cell and their interactions. Their applications should mainly be the general principles and methods of the quantum mechanics. In these cases the quantum constants in the Schrödinger equation should be different.

Actual quantum biology is based on a level on electron-molecule, and studies electronic structure of the biomolecule. It is mainly the nonlinear Schrödinger equation. Here the constant is still $\hbar$. We propose that the quantum biology should be an extensive quantum theory (Chang, 1993; 2002; 2006), in which various quantum constants may be different, and should be discrete values with big transition. Theoretically, Dirac equations and Schrödinger equation can describe completely the quantum biology, but this must add some proper biological conditions. Such we may apply various theories of quantum mechanics, and whose equation will be very known and simple (Tarlaci, 2011). This combines the nonlinear whole biology (Chang, 2001; 2008), and then from molecules may derive various cells, tissues, apparatus, a biological individuality, colony, ecosystem and total biosphere. Jordan, Schrödinger, *et al.,* thought that the biological variation is a quantum process. While the variations may be various levels, and correspond possibly to various quantum jumps with different quantum constants. The biological combination rule should be related with general Bose-Einstein (BE) or Fermi-Dirac (FD) statistics.

We consider that the quantum biology should not show a concrete quantum constant h, and should be an indeterminate H. Sometimes a ratio in theory neglects already a possible change of the constant h. Moreover, at present the research of an evolution from microcosm to macrocosm has going on. Many biological phenomena should be macroscopic quantum effects. Perhaps the different

constants show a certain aspect of different essence in various systems. But they are not some absolute continuous values. Otherwise theory will be not quantized. In the extensive quantum biology the smallest live element of different levels is namely a quantum. If these elements are broken down, life of this level will not exist. Therefore, gene, cell, man and any live individual are different live quantum of various levels. Based on the experimental results, Sitko and Gizhko (1991) reviewed the concepts, which enable to conclude that living matter is one of the steps of the Weisskopf quantum ladder. In *"The Fifth Miracle"* (1999), mathematical physicist Paul Davies stated: "If life follows from primordial soup with causal dependability, the laws of nature encode a hidden subtext, a cosmic imperative."

A Special Issue of *NeuroQuantology* devoted to the genetic code and related topics (2011; 9; 4). The origin and the structure of the genetic code of Earth's living organisms is still a big challenge for science, with many unanswered questions as for example its "degeneracy". It includes: The investigation of Miloje Rakočević shows that the genetic code is indeed a coherent system; some new results of Branko Dragovich on the p-adic structure of the genetic code, etc. Négadi (2011) used several simple arithmetic functions to investigate the physico-mathematical structure of the genetic code, whose "quantum-like" approach describes nicely the encasing and the inter-relationships of many results, and constitute a basis for biological coding/computing.

Further, it should combine string and superstring theories. At least their mathematical forms and physical meanings may be applied, for example, for biological space. Such it may develop the extensive superstring and the extensive loop gravity theory by using a method extended c or/and h, and are applied to biology.

4. Fractal, chaos and soliton in nonlinear biology and neurobiology

The gravity loop quantum theory in essence is that the matter determines the structure of space. The method may be applied to describe the link, kink and knot theory, etc. Based on the loop quantum theory we discussed the fractal combining a Gambini's quantity (Chang, 2008). The spinor and twistor correspond to the protein folding and crimp. It is consistent with the basic idea of the general relativity (Chang, 2001; 2008).

The fractal in biology may be dependent on gene, DNA and their structural formations. They are continuously embedded by some self-similarity, and form various organism. A self-similarity may construct the same new cells, synapses and so on. The blood, breathing and neural systems possess the fractal characters and the fractal dimensions.

There is the chaos dynamics in biology and physiology. It includes the excited or stimulated state of neuron and whose Hodgkin-Huxley equation (Aihara *et al.*, 1984), and the heart beats rhythmically and whose Bonhoeffer-Van der Pol equation (Fitzhugh, 1969), and the exudation of hormone, and the dynamical disease and epidemic, and the complex structure of living systems (Cramer, 1988). Hartline equation in the inhibitory neural network may add the nonlinear terms, and then chaos will appear.

Schrödinger equation in quantum biology induces time rhythm and periodicity. The neural pulse obeys "all-or-none law", which is integrated "all" pulse, or "none" pulse, and never exist in fractional pulse. It is a typical quantized phenomenon, and is already an extensive quantum theory (Chang, 1993; 2002). Therefore, the nerve conduction may apply the nonlinear quantum biology and the soliton model. The soliton and the catastrophe theory may describe the cognition model. The transmission of neuron action potential hardly decays to bottom along axon. This must correspond to the soliton in mathematics. It keeps the integrality and veracity of information in biological transfer, in particular, for heredity.

The soliton and exciton of energy transfer in biological macromolecules are the typical nonlinear phenomena. Davydov (1982) investigated the soliton model of the vibrational energy transported along the biological macromolecules. The known neural conduction may use Davydov soliton and its extension. For example, the nonlinear Klein-Gordon equation is:

$$\frac{\partial^2\phi}{\partial t^2}-\frac{1}{2}\omega_1^2 r_0^2\frac{\partial^2\phi}{\partial x^2}+(\omega_0^2-\omega_1^2)\phi-c|\phi|^2\phi=0\,. \qquad (9)$$

Let $\frac{1}{2}\omega_1^2 r_0^2$ =A and $\omega_0^2-\omega_1^2$ =B, then a solution is

$$\phi=[\frac{4}{c}(B+k^2-\omega^2)]^{1/2}\sec h\{\sqrt{\frac{B+k^2-\omega^2}{p^2-\omega^2}}(\frac{\bar{p}x}{\sqrt{A}}-vt)\}\exp[i(\frac{kx}{\sqrt{A}}-\omega t)] \quad (10)$$

Such $|\phi|^2$ is a soliton. The nonlinear Schrödinger equation is:

$$i\hbar\frac{\partial\phi}{\partial t}=(\hbar\omega_0-\frac{\hbar\omega_1^2}{2\omega_0})\phi-\frac{\hbar\omega_1^2}{4\omega_0}r_0^2\frac{\partial^2\phi}{\partial x^2}+a|\phi|^2\phi=0 . \quad (11)$$

Its solution is

$$\phi(x,t)=\phi_0\sec h[2\phi_0^2(x-x_0-vt)]\exp\{i[\frac{\hbar v}{2Jr_0^2}(x-x_0)-\frac{Et}{\hbar}]\} \quad (12)$$

For the Davydov model of a one-dimensional protein, Lomdahl and Kerr (1985) added the fluctuation and dispersion terms, and the lifetime of Davydov soliton is only the order ns. Cottingham and Schweitzer (1989) calculated that the lifetime of a Davydov soliton at finite temperature is still 1ns for the α-helical protein molecule using a first-order perturbation theory. This is too short to be useful in biological processes. Using the quantum Monte Carlo technique, Wang *et al.,* (1989) investigated the one-dimensional Davydov model in the α helix, and found that an Davydov soliton at 310K is instable. The width of Davydov soliton is direct ratio

$$(1-\frac{T}{T_0}), \text{ here } T_0=\frac{\pi}{2}\frac{\hbar}{k_B}\sqrt{\frac{\beta}{M}} . \quad (13)$$

When T= T_0 , this soliton will become an infinite expanded state, i.e., is instability. For the double helix model, T_0 is about 100-120K. Perhaps, T= T_0 for T=310K. If we apply the extensive quantum theory (Chang, 1993; 2002; 2006), such h becomes H, and then T_0 and so on will change.

Generally, the fractal, chaos and soliton will appear in the nonlinear biology, in particular, for the neurobiology in which there are much nonlinear interactions.

5. A nonlinear mechanism of memory

It is well-known that different memories lie in different regions of brain, and correspond to various structures, for example, the declarative memory corresponds to the medial temporal cortex, diencephalon and prefrontal cortex.

Hebb (1949) hypothesis is: learning rests on a strengthening of the synapses that connect those neurons that are again and again simultaneously active, and similarly on a decrease of synaptic strengths if one or both neurons are inactive at the same time. Kandel studied and elucidated the connection between the learning of behavioral patterns and changes at the neural level. In 1963 Squire *et al.,* (1987) discovered that the formation of a long-term memory depend on the synthesis of new protein. Kandel *et al.,* (1982) investigated molecular biology of learning.

In the nonlinear neurophysiology Aihara *et al.,* (1984) studied the electric potential of neurilemma. It and the general biomembrane should correspond to the barrier penetration in quantum mechanics.

Haken (1996) proposed a relation between learning process and change of synapse strength:

$$\dot{q}=\sum_{k=1}^{M}\lambda_k(v_k^+q)v_k-B\sum_{k,k'=1}^{M}(v_{k'}^+q)^2(v_k^+q)v_k-C(q^+q)q . \quad (14)$$

Many experiments shown that the synthesis of proteins for the long-term memory is necessary (Agranoff *et al.,* 1965). For example, stimulation produces cAMP, then cAMP activates cAMP-dependent protein kinase (DeZazzo *et al.,* 1995), and this cell change is synaptic facilitation (Stevens et al., 1994). It is a possible mechanism, but is not only (Levitan *et al.,* 1997).

Squire and Kandel (1999) investigated the molecular mechanism from a short-term memory to a long-term memory. Now it is known, the memory is a result of synapse formation. The phosphorylation of protein produces a change of transfer effect of synapsins, and from this forms memory. The long-term memory first only relates to the formation of synapsin, and new transgene and synthesis of protein is simultaneously started up. Further, it translates to produce a structural change, and forms the long-term memory (Tulving, 1990; Bailey *et al.,* 1993; Bliss *et al.,* 1993; Marford *et al.,* 1996). Kesner and Martinesz (2007) edited neurobiology of learning and memory.

Jibu and Yasue researched the quantum field theory of Nambu-Goldstone bosons as the one and only reliable quantum theory of fundamental macroscopic dynamics realized in the brain. This theory was originated by Ricciardi and Umezawa in a general framework of the spontaneous symmetry breaking formalism, and then developed into a

quantum field theoretical framework of brain functioning called quantum brain dynamics and that of general biological cell functioning called quantum neurodynamics. Umezawa proposed a general theory of quanta of long-range coherent waves within and between brain cells, and showed an outstanding mechanism of memory storage and retrieval in terms of Nambu-Goldstone bosons characteristic to the spontaneous symmetry breaking formalism (Tarlaci, 2005).

Klapproth (2009) investigated memory mixing. Başar *et al.,* (2009) tried to describe the concept of great philosopher Henri Bergson, related to episodic memory, intuition and duration, and describe shortly the relation of "Quantum Theory" to Bergson's philosophy, and discussed the importance of Bergson's concepts to "Quantum Methodology" and modern science. Ross *et al.,* (2009) build on recent progress in understanding how the initial neural networks are built in the fetal brain. Short term memory results from Glia cells forming speculative links directly and solely as a result of neural activity generated by life experiences. These temporary 'glia bridges' create long term memory by stimulating the growth of axons, dendrites and synapses, and provide the pathways enabling permanent neural structures to be constructed. This fundamental algorithm for how the brain generates new links is the underlying process of memory maintenance, learning and creativity.

Based on these progresses, we search a possible nonlinear mechanism of memory: The propagations of neuronal impulses are nonlinear, whose solitons possess invariant shape, so information is invariant, and memory is the same. Further, the corresponding new astrocytes and synapses are formed. Various solitons, impulses and synapses are all some extensive quantization phenomena. They may correspond to the extensive quantum theory (Chang, 1993; 2002; 2006). The synaptic activity-dependent structural plasticity is possibly the basis of the long-term memory.

Hippocampus for the long-term potentiation are perhaps necessary. Their transmission shape of the perforant path is a like-soliton (Bliss *et al.,* 1973; Nicoll *et al.,* 1988). A hypothesis on role of Ca-ion in long-term potentiation (Lisman *et al.,* 1988; Malenka *et al.,* 1989) and CA1 pyramidal neuron along the Schaffer collateral pathway for long-term depression of hippocampus (Bear *et al.,* 1994) are also some like-solitons.

From this mechanism we may obtain some phenomenological rules:

1) The long-term memory corresponds to the formation of new synapse and structure. While the short-term memory cannot form new synapse and structure.

2) The repeat memory corresponds to continuous pulses of the same solitons, so that form new synapse and structure.

3) For some people, the formations of new synapse and structure are easy, so their memories are well. Contrarily, their memories are bad.

4) The cells and synapses have a certain elasticity, their recovery is namely to forget.

5) Memory may be some connected methods, in particular, for association. It is namely the neural network and its model.

6) The glial cells in brain include similar astrocyte and oligodendrocyte (Levitan *et al.,* 1997).

Their number may increase. If the astrocyte was related to memory, perhaps, the fibrous astrocyte corresponds to fixed memory, and protoplasmic astrocyte corresponds to be able to increase memory. According to this hypothesis, for the former old is more, and the latter young one is more. Penner and Barnes investigated the neurobiological correlations and memory changes with age, which is related with normal brain aging (Kesner *et al.,* 2007).

In a word, the neural science, the cognizance science and the nonlinear whole biology, the extensive quantum theory should be combined each other.

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